This is to certify that the

dissertation entitled

SPATIAL EQUILIBRIUM ANALYSIS OF CONIFER TIMBER MARKETS IN SOUTHERN BRAZIL AND IN THE OTHER MERCOSUR COUNTRIES

presented by

MARCELO SERGIO SOUZA WIECHETECK

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Forestry

Karen Potter-Witter
Major professor

Date 05/11/2001

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.
MAY BE RECALLED with earlier due date if requested.

DATE DUE	DATE DUE	DATE DUE

SPATIAL EQUILIBRIUM ANALYSIS OF CONIFER TIMBER MARKETS IN SOUTHERN BRAZIL AND IN THE OTHER MERCOSUR COUNTRIES

By

Marcelo Sérgio Souza Wiecheteck

A DISSERTATION

Submitted to
Michigan State University
In partial fulfillment of the requirement
For the degree of

DOCTOR OF PHILOSOPHY

Department of Forestry

2001

ABSTRACT

SPATIAL EQUILIBRIUM ANALYSIS OF TIMBER MARKETS IN SOUTHERN BRAZIL AND IN THE OTHER MERCOSUR COUNTRIES

By

Marcelo Sergio Souza Wiecheteck

With an estimated 242 million people in 2000 and an aggregate GDP of US$ 1.7 trillion in 1999 (CIA, 2000), Mercosur has become an important economic bloc in the Southern Hemisphere. Its forest products market has gained growing importance from large investments in plantations and industrial facilities notably in Brazil, Chile and Argentina. In particular, the conifer sawlog and lumber markets face increasing demand, limited supply of plantation industrial roundwood, and trade liberalization.

The purpose of this study was to investigate the market equilibrium for conifer sawlogs and lumber in Mercosur, focusing on Southern Brazil. The mathematical framework was based on Samuelson (1952), extended by Takayama and Judge (1964a. 1964b and 1971). Multiple regression analysis and price endogenous linear programming system for economic modeling (PELPS III - Zhang, Buongiorno and Ince, 1993) were used to create a regional spatial equilibrium model. Price elasticities were mostly estimated through systems of simultaneous equations.

A spatial equilibrium model was developed, which simulates the optimal trade pattern, consumption, production, and capacity that satisfy the price and the supply/demand quantity relationship. The study demonstrated that the Southern Cone countries have increased their pattern of production, consumption and trade under more

economic efficiency. Limited production of pine sawlogs and lumber in Brazil and relative expansion of the lumber market in Chile and Argentina are indicated. In addition, limited trade within the bloc and significant trade with partners outside the bloc are also predicted. The sensitivity analyses indicated the possible changes in the outcomes as a result of changing one key variable at a time, including changes in the availability of pine sawlogs in Brazil, change in the growth of GDP in Brazil and change in the price elasticity of demand for sawnwood in both Brazil and Chile. The future pattern of production, consumption and trade of conifer lumber in Southern Brazil is likely to be highly influenced by the magnitude of changes in the availability of pine sawlogs from plantations. Southern Brazil could face a significant reduction in its pine lumber production and consequent exports, even becoming a net importer, if a drastic decrease in the availability of pine sawlogs occurs. Such a scenario, however, will be positively or negatively influenced by the interaction with other major macroeconomic variables and the expansion of the resource base, both in Brazil and in some of the other Mercosur countries. The model is useful as a policy instrument to analyze strategies for further forest sector development in individual countries.

DEDICATION

This dissertation is dedicated to my wife, Rosane Braga Wiecheteck, for her encouragement and support throughout this project. Her patience and love kept my perspective on life and helped me to accomplish this goal. I also dedicate this work to my mother and father, Nadazir and Arnoldo Wiecheteck, who taught me to pursue my dreams and have always been a source of inspiration.

ACKNOWLEDGEMENTS

This project is the result of the efforts of a great number of individuals at Michigan State University, in Brazil, and in a few other countries. First and foremost, I thank Dr. Karen Potter-Witter, my advisor and professor, for her continuous support, expertise, and for the opportunity I had to pursue my graduate program under her guidance. Her patience and generosity in terms of time and resources were invaluable and helped me throughout the study. My sincere thanks also to my other committee members, Dr. Scott Swinton and Dr. Larry Leefers, and Dr. Runsheng Yin for their helpful comments, encouragement, and positive criticism.

This work was funded by the scholarship received from the 'Conselho Nacional de Pesquisa Científica e Tecnológica' (CNPq/Brazil). I am also thankful for the graduate assistanship received from the Eastern Hardwood Utilization Program at the Department of Forestry of Michigan State University, which helped me while part of this project was carried out. I am deeply indebted for the support and contribution from these institutions.

Special thanks go to Dr. Luiz Roberto Graça, for his invaluable support, friendship, and help on providing part of the data needed for this project. I extend my sincere thanks to Dr. James Stevens, whose support contributed significantly to the result of this study. His encouragement, expertise, and guidance in the initial phase of the study were determinant for me to pursue this study. Also thanks to Dr. Joseph Buongiorno (UofW/Madison) and Dr. Peter Ince (USFS/FPL) for their invaluable advises and contributions. My gratitude to Patti Lebow (USFS-FPL) and James Turner (UofW) for their continuous technical help with the use of PELPS III. For many professionals in Brazil, Chile, Argentina, Paraguay, Uruguay, and in the USA, who provided me with data and useful information for this work, my most sincere appreciation, in particular to Marlus Wiecheteck, Jefferson Mendes, Luiz César Ribas, Sebastião Kengen (Brazil), Gonzalo Paredes (INFOR/Chile), Liliana Corinaldesi and Ricardo Larobla (SAGPyA/Argentina), Mr. Robert Flynn (USA), and professionals from CNPF/EMBRAPA, IBGE, STCP, IBAMA, ABIMCI, and CEDEFOR (Brazil), FAO-Latin America and INFOR (Chile), INDEC and SAGPyA (Argentina). Many others deserve my acknowledgements and thanks including Dr. Daniel E. Keathley, my dedicated friends Gem Castillo, Demetris Gatziolis, and Joe Zelesnik, and other friends, colleagues and staff members of the Department of Forestry at Michigan State University.

Finally, I would like to take the opportunity to say my special thanks to my wife (Rosane), my parents (Nadazir and Arnoldo), sister, brother, my family and friends that have always been there for me. You are the best!

Hopefully, the results of this study will contribute to the design of forest policies, programs, and projects that respond to the continuos advancement of the forest sector in Brazil and in the other Mercosur countries, under a sustainable and responsible manner.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

List of Abbreviations - National and International Agencies and Institutions

CODE	AGENCY (Local Name)	AGENCY (English Name)	COUNTRY
ABIMCI	Associação Brasileira de Indústria de Madeira Processada Mecanicamente	Brazilian Association for Mechanically Processed Timber	Brazil
ABPM	Associação Brasileira de Produtores de Madeira	Brazilian Association of Wood Producers	Brazil
ANFPC	Associação Nacional de Fabricantes de Papel e Celulose	National Association of Pulp and Paper Producers	Brazil
BRACELPA (ex-ANFPC)	Associação Brasileira de Celulose e Papel	Brazilian Pulp and Paper Association	Brazil
BNDES	Banco Nacional de Desenvolvimento	National Developement Bank	Brazil
BRDE	Banco Regional de Desenvolvimento do Extremo Sul	Southern Regional Development Bank	Brazil
CEDEFOR	Conselho de Desenvolvimento Sustentado Florestal do Mercosul	Forest Sustainable Development Council of Mercosur	Brazil - Mercosur
CIA	-	Central Intelligency Agency	USA
CNPF/ EMBRAPA	Centro Nacional de Pesquisa de Florestas/Empresa Nacional de Pesquisa Agropecuária	National Forest Research Center/Brazilian Agriculture and Pasture Agency	Brazil
DNER	Departamento Nacional de Estradas e Rodagem	National Road Department	Brazil
ECLAC	Comisión Económica para a América Latina y el Caribe	Economic Commission For Latin America and Caribbean	International
FAO	-	Food and Agriculture Organization	International
FF	Fundação Florestal	Forest Foundation	Brazil
FGV	Fundação Getúlio Vargas	Getúlio Vargas Foundation	Brazil
FPL/USFS	-	Forest Products Laboratory / US Forest Service	USA
IADB	Banco Inter-Americano	Inter-American Development Bank	International

... continued

List of Abbreviations - National and International Agencies and Institutions

CODE	AGENCY (Local Name)	AGENCY (English Name)	COUNTRY
IBAMA (ex-IBDF)	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis	Brazilian Institute of Environment and Renewable Natural Resources	Brazil
IBDF (currently IBAMA)	Instituto Brasileiro de Desenvolvimento Florestal	Brazilian Institute for Forest Development	Brazil
IBGE	Instituto Nacional de Geografia e Estatística	Brazilian Institute of Geography and Statistics	Brazil
INDEC	Instituto Nacional de Estadística y Censos	National Institute of Statistics and Censuses	Argentina
INFOR	Instituto Forestal de Chile	Forest Institute - Chile	Chile
INE	Instituto Nacional de Estadística	National Institute of Statistics	Chile
INE	Instituto Nacional de Estadística	National Institute of Statistics	Uruguay
IPEA	Instituto de Pesquisa Econômica Aplicada	Research Institute of Applied Economics	Brazil
MECON	Ministério de Economia	Ministry of Economy	Argentina
MGAP	Ministério de Ganaderia, Agricultura y Pesca	Ministry of Farming, Agriculture and Fisheries	Argentina
MMA	Ministério do Meio Ambiente	Ministry of Environment	Brazil
RISI	Resource Information Systems, Inc.	Resource Information Systems, Inc.	USA
RM	Revista da Madeira	'Revista da Madeira' Journal	Brazil
SAGPyA	Secretaria de Agricultura, Ganadería, Pesca y Alimentación	Secretariat of Agriculture, Livestock, Fisheries and Food	Argentina
SEAB	Secretaria do Estado e do Abastecimento	Bureau of State and Provisions (Paraná)	Brazil
SIFRECA	Sistema de Informações de Fretes para Cargas Agrícolas	'System for Information on Freight for Agricultural Cargo'	Brazil
STCF	STCF-Engenharia de Projetos Ltda	STCF-Engenharia de Projetos Ltda	Brazil
USFS	US Forest Service	US Forest Service	USA
WFI	World Forest Institute	World Forest Institute	USA
WTO	-	World Trade Organization	International

CHAPTER 1

INTRODUCTION

The forest products industry has become an important economic sector in Brazil and in some of the other Southern cone countries, including Chile, Argentina, and Uruguay. Among the important solidwood products markets are those for conifer sawlogs and lumber, which have experienced a fast growth in supply, demand and trade in recent years. This rapid expansion has been based on large-scale plantations with fast-growing pine species, established primarily in Southern Brazil and in Chile since the mid-1960s, and more recently in Argentina and Uruguay. As a result, the profile of the conifer-based industries has been re-shaped by shifting from the consumption of a native conifer (*Araucaria*) in the past to planted pines, developing a new market product, with significant social and economic impacts.

Recent economic, political, social, and environmental developments have become driving forces that may affect the future of the solidwood and sawmilling industries in various countries. A major event was the creation of Mercosur, the trade bloc agreement including Brazil, Argentina, Uruguay, and Paraguay as member countries, with Chile and Bolivia as associate members. With an estimated 240 million people in 2000 and an aggregate GDP of US$ 1.7 trillion in 1999 (CIA, 2000), Mercosur has become an important economic bloc in the Southern Hemisphere. It brings opportunities for trade creation, and industrial expansion and diversification. Its forest products market has gained growing importance from large investments in plantations and industrial facilities notably in Brazil, Chile and Argentina. In particular, the conifer sawlog and lumber markets face increasing demand, limited supply of plantation industrial roundwood, and trade liberalization.

In Brazil, the forest industry emerged when tax incentives were made available for reforestation from 1966-86, resulting in the reforestation of over 5 million ha with *Pinus* and *Eucalyptus* (Suchek, 1991). Such species are highly integrated into the industrial process, primarily in the South and Southeast regions, where a significant proportion of the country's forest plantations and forest-based industries are located. Since the end of the fiscal incentive program, however, and with few economic incentives for new plantations (e.g.: BRDE, 1995; MMA, 2000) the annual planting rate has declined significantly. Both the South and Southeast Brazil will likely face a deficit of roundwood starting in the first decade of the twenty-first century (Azeredo, 1993; Wiecheteck and Stevens, 1997; Leite[1], 1998, cited by Kengen and Graça, 1998). On the other hand, countries like Chile, and, in a smaller scale, Argentina and Uruguay, have steadily expanded their forest base. Some studies indicate that the possible deficit of roundwood in Southern Brazil could be reduced through investments in new plantations (Dos Santos, 1996) or through an effective re-planting program (Ramos, 1993). Both studies, however, did not consider the classical price-quantity relationship, the inter-dependencies of the forest based-industries, the stages of the transformation process, the influence of demand and supply shift variables, the relationship with the other Mercosur countries, the opportunity for intensifying intra and inter-Brazilian trade, nor the spatial distribution of the plantations. Ramos (1993) suggested that the allocation pattern should allow wood transportation under economically viable conditions. In 2000, the Brazilian

[1] Leite, N.B. 1998 Pesquisa Florestal lá na Frente [Forest Research Ahead]. Speech at CNPF/Embrapa, August 11, 1998

government launched a forest policy program aimed at sustainable development, and among other measures, creating incentives for plantations of 600,000 ha per year by 2010 (MMA, 2000). However, the lengthy sawlog rotation for pines, of as low as 15 years, makes this policy effective primarily for the middle- to long-run, with little impact in the short-run.

Other important aspects are environmental issues, the increasing costs of transportation from more remote supply regions, and changes in the domestic economic policies effecting both domestic and international trade.

1.1 Statement of the Problem

With limited forest resources and capital, and an expected shortage of roundwood in some industrial sectors and regions, combined with forest and industrial expansion in some countries, it is important to determine the optimal use of the resources and the pattern of production, consumption and trade of forest products, as well as the geographic and timing pattern for establishing new plantations. The idea of importing forest products rather than producing regionally is another alternative, taking advantage of more globalized markets and the relatively stable economy of the Mercosur countries in recent years. Therefore, the market forces, the government policies and regulations, the forest industry profile in each country, and the social-economic trends are important variables to be considered in a study related to the supply, demand and trade of forest products.

The relevance of this study relies on the economic and social importance of the species and commodities under investigation and in the lack of previous studies focusing on the classical quantity-price relationship for the forest products market in the Mercosur.

Considering the existing gap in knowledge, this research investigates the market equilibrium for prices and quantities and trade flows for supply and demand of sawlogs and sawnwood in Brazil and in the other Mercosur countries. The study is based on the theory of spatial equilibrium of supply and demand among separate markets. A spatial equilibrium model that represents the relationship among demand and supply of conifer sawlogs and lumber and transportation is developed using the formulation proposed by Samuelson (1952), extended by Takayama and Judge (1964a and 1964b), and adapted by Zhang, Buongiorno and Ince (1993).

1.2. Objectives of the Study

The general objectives of this study are:

(a) to investigate qualitatively and quantitatively the forest resources and solidwood industry in Mercosur, with focus on the Southern Brazilian market for conifer sawlogs and sawnwood;

(b) to evaluate the relationship between demand, supply and prices of sawlogs and sawnwood in the countries under investigation;

(c) to determine the optimal trade pattern, and the economic allocation of forest plantations and industrial capacity and production that satisfy the price and the supply/demand quantity relationship.

1.3. Study Outline and Organization of the Dissertation

To accomplish the objectives described above, the dissertation is divided in three major chapters, which address different related research questions using specific principles and tools.

Chapter 2 provides an overview of the dynamics of the plantation forests and the solidwood industry in Brazil and in the other Mercosur countries pointing out the relative importance of each country and the trends, challenges and opportunities faced by their sawtimber and lumber industries. While focusing on the Southern Brazilian market for conifer sawlogs and lumber, the chapter also includes recent developments in Chile, Argentina and Uruguay (the bloc's other major forested countries). Qualitative and quantitative approaches are combined to provide an overall picture of the regional forest sector and the conifer sawlogs and lumber markets introduces the variables and data used in the remaining chapters. A historical perspective of the development of the forest sector in Brazil is presented, which to a certain extent coincides with the development of the forest business in Southern Brazil. In discussing the importance of forestry in Brazil and in the Southern region, statistics about the magnitude and location of the existing forests and the forest-based industries, major products, exports and imports and social aspects are presented.

Overall, Chapter 2 analyses the plantation forest industry in Brazil, by describing the historical developments of the sawmilling sectors, the conifer sawlog and lumber markets, the forest products trade, the Mercosur integration, and the opportunities and limitations of each country. Trends in domestic consumption, production and prices of conifer sawlogs and lumber in Brazil, Chile and Argentina, with brief references to the other Mercosur countries (Uruguay, Paraguay, and Bolivia) are also presented. Particularly for Brazil, Chapter 2 provides a new synthesis of the Brazilian forest sector supported by literature and trend analysis. The analysis is intended to provide a better understanding of the setting and the major actors/elements in the study.

While Chapter 2 focused on an overall description of the forest sector in each of the Mercosur countries, Chapter 3 explores the simultaneous price-quantity relationship between supply and demand for each forest product (sawlogs and sawnwood) and region under investigation, as well as their relationship with other supply and demand shift variables. The main objective is to provide estimates of the price elasticities of supply and demand for each product and country to be used in the spatial equilibrium analysis of Chapter 4. Such elasticities have not been investigated before in other research, which makes this an important chapter by revealing the range of possible elasticities. A review of the literature is presented, focusing on the major economic and market forces that affect the demand for and supply of forest products, the approach and results from other econometric studies related to solidwood products, and a review of the limited studies for other solidwood products carried out in Brazil. While discussing the forces affecting supply and demand for a given commodity, the fact that lumber is a derived demand from the transformation of sawlogs is considered, bringing to attention the major demand and supply shifter variables. The theorethical foundation and framework of the study, as well as the simultaneous equation estimation procedure used in the chapter is discussed. Given data limitations and the characteristics of specific countries, the econometric analysis was carried out for Brazil, Chile and Argentina, with the other Mercosur countries (Uruguay, Paraguay, and Bolivia) combined in a separate analysis with Argentina. Results for each country are compared with findings from other studies. Price and GDP elasticities of demand and supply to be used in the spatial equilibrium analysis of Chapter 4 were estimated in Chapter 3. The major findings of the analysis are discussed, including recommentadions for further studies.

Chapter 4 combines data and information from the previous chapters, as well as additional data for each country and region, in order to create a functional price-quantity spatial equilibrium model of supply of and demand for conifer sawlogs and sawnwood. The model is a partial equlilibrium model, where the domestic demand and supply markets in Brazil, Chile, Argentina and the other Mercosur countries are combined with the markets for imports from and exports to the ASIA-S countries and the rest of the world. The main goal is to determine the optimum level of production, consumption, and equilibrium price in each region and the interregional equilibrium trade flows of commodities between pairs of regions. The problem involves the estimation of a set of prices that equate supply and demand among regions. In the literature review of Chapter 4, an overview of forest sector models and applications to different forest sectors are presented and followed by a comparison of different sector and market equilibrium models. In the review of the market equilibrium models, Samuelson's (1952) conceptual framework of spatial equilibrium among separated markets is presented and a description of PELPS III, the price-endogenous linear programming system used in the study, is detailed. The empirical method is formulated in terms of the stages of production, the boundaries of the study and the economic actors and major elements involved. Results of the base scenario (for the base year 1995 with a 15 year-horizon) and from the sensitivity analysis are presented for each individual country. The study is also discussed with reference to its major contributions, strengths and limitations. Major conclusions are formulated and recommendations for further studies are suggested.

Chapter 5 is a conclusive chapter that outlines the major conclusions from the previous chapters, also addressing policy-related issues and recommendations for future research.

CHAPTER 2

THE PINE SOLIDWOOD SECTOR IN BRAZIL AND IN THE OTHER MERCOSUR COUNTRIES

Introduction

This chapter presents an overview of the solidwood sector in Brazil and in the other Mercosur[2] countries (Figure 2.1), with focus on the pine markets in Southern Brazil. Qualitative and quantitative approaches were combined to provide an overall picture of the forest sector and the market of conifer sawlogs and lumber in the region.

Plantation forestry, particularly with the emergence of pines, has become an integral part of the forest landscape of Southern Brazil and some of the other Mercosur countries (such as Chile, Argentina, and Uruguay) due largely to past government incentives, land use policies, and public and private investments. Plantations have also added significantly to the development of the regional forest-based industries in the past decades.

In Brazil, pines have become an important part of the forest industry, being primarily used by the pulp and paper and the lumber industries. However, the current lack of incentives for forest investments, the profile of the forest-based industries, and the overall economic situation of the country in the recent past have raised the question of whether or not the existing forests and forest companies will be able to fulfill the growing demand for pine sawlogs and sawnwood.

[2] Trade bloc formed by Brazil, Argentina, Uruguay and Paraguay as member countries and by Chile and Bolivia as associate members.

Source: Magellan (1992)

Figure 2. 1. Map of South America

2.1 Solidwood Sector in Brazil

2.1.1 Forest Resources - Natural Forests and Plantations

Brazil is the world's fifth largest country with over 8.5 million square kilometers (5.3 million square miles), representing 47% of South America. About 90% of the country is located between the Equator and the Tropic of Capricorn. The long distance from North (5°N) to South (35°S), stretching over 4,500 km (2,800 miles), combined with diverse climates, geological formations and changes in elevation created varied ecosystems across the country (Tomaselli, 1998; Kengen and Graça, 1998). Brazil is subdivided into five political regions (South, Southeast, North, Northeast, and West Central), each with diverse vegetation types. Over 60% of the country is covered with natural forests, with nearly 394 million ha potentially productive forests, excluding protected forests and Indian reservations.

The Amazon rain forest, in the North along the Equator (including its extensive buffering zone in part of the Northeast and West-Central regions), is the largest concentration of natural hardwood forests in the country, comprising 320 million ha of forestland, or almost 50% of the country's area (Tomaselli, 1998). The total wood volume is estimated at 50 billion m^3, with only 10% considered of commercial use, represented by 1/6 of the 30,000 existing species (Higushi, 1985).

Another important natural ecosystem is the Paraná pine (*Araucaria angustifolia*) forest in the South. This forest type has been systematically depleted over most of the twenty century as result of agricultural clearing, logging, and urban/industrial development. Other important natural forest types include the Atlantic Rain Forest (extending throughout the Coastal zones of the South, Southeast, and part of the Northeast); the Cerrado (a Savannah-vegetation type in the West Central region); the Pantanal (a wetland forest type also in the West Central), and the Caatinga (a dry-bush vegetation type in the Northeast).

The Amazon and the Atlantic forests (hardwoods), and the *Araucaria* forests (conifer) have played a major role as sources of roundwood for the solidwood industry during most of this century. However, in the past few decades, extensive plantations with pines and *Eucalyptus* throughout the country have emerged as important sources of industrial roundwood. Pines (primarily Southern yellow pines) are concentrated in the Southernmost states, in a sub-tropical zone, and *Eucalyptus* have been planted along the Atlantic Coast from the South to the North, and inland in the West-Central region.

Nationwide, plantations are estimated at 4.6 million ha, respectively 1.7 million with *Pinus* and 2.9 million ha with *Eucalyptus* (Sobrinho, 1996). The majority of the pines are located in the Southern states of Paraná (35.8%), Santa Catarina (20.6%), São Paulo (12%) and Rio Grande do Sul. The state of Minas Gerais has the largest area of *Eucalyptus* (41 % of the country's total), which has been closely linked to the steel industries and the pulp and paper sector. São Paulo, Bahia and Mato Grosso do Sul have also established large-scale *Eucalyptus* plantations, primarily for the pulp and paper industry. Minor species account for the remaining 0.3 million ha (Tomaselli, 1998).

2.1.2 Historical Developments of the Solidwood Sector

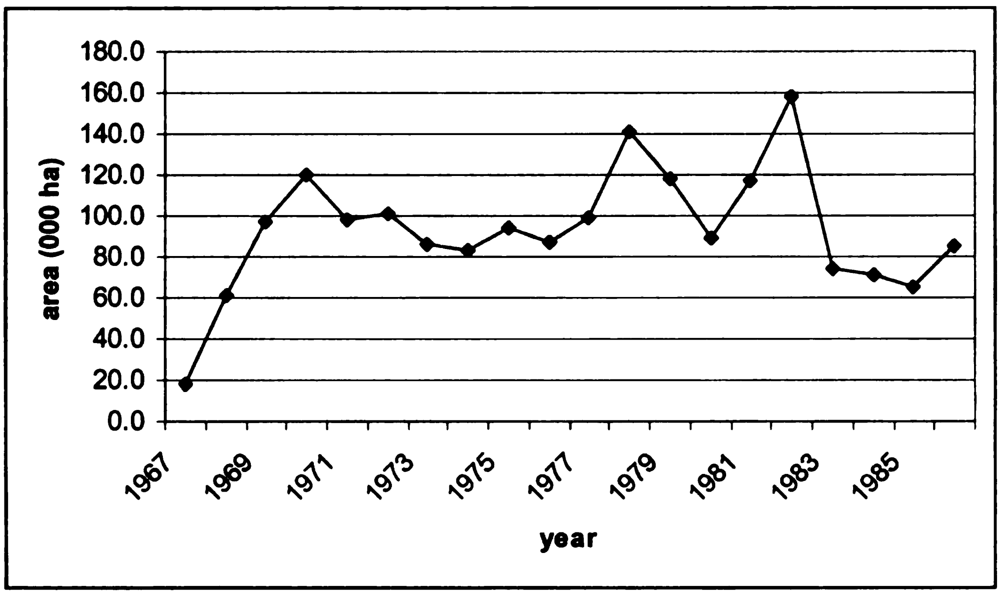
The forest activity in Brazil started at the time the Portuguese first arrived in 1500, with the harvesting of fine hardwoods for the European market. During the following four centuries harvesting was extractive and to a large extent, not linked to any industrial process. However, during most of the twenty century, harvesting of natural forests intensified significantly as result of extraction and the clearing for agriculture, cattle ranching, industrial use and urbanization (BNDES, 1995), primarily in the states along the Atlantic coast. National development policies set by the government with strong subsidies for agriculture as well as public and private investments lead to the intensification of deforestation and change of the land use in most of the country.

The solidwood industry emerged in the beginning of the twenty century in Southern Brazil, based initially on the abundant Paraná Pine forests and intimately related to the sawtimber production. Argentina remained the main export market for many years, but, as result of its high lumber quality, Paraná pine gained markets in Europe and in the US (Tomaselli, 1998). Intensification of commercial harvesting and deforestation caused by agricultural projects gradually reduced its supply. As result, the "Instituto Nacional do Pinho" (National Institute of Paraná Pine) was created in 1941, becoming the first national agency concerned with monitoring and providing incentives for plantations (BNDES, 1995).

In the 1960's, as a result of shortage of Paraná pine supply and the government strategy to develop the North region, the timber industry started to move towards the Amazon to take use of its extensive hardwood resource. The vast area of land opened to agriculture and pasture made available large volumes of high quality logs at a relatively low cost, although most of the resource did not find a commercial use. In 1966, IBDF (currently IBAMA) was created with the objective of developing national forest programs and related policies. In the same year, the federal government launched a fiscal incentive program (law 5106, 1966) allowing individuals and corporations to invest part of their tax liabilities in reforestation projects. This model offered generous terms and conditions to both domestic and foreign investors through a fiscal incentive scheme for regional development programs (Kengen and Graça, 1998). During the greatest tax relief period (1967-1974), over US$50 millions were set aside by the government for planting programs (USDC, 1991). The total area approved for reforestation from 1967-86 amounted to 6,252,483 ha, 52% (3.2 million ha) were *Eucalyptus*, 30% (1.9 million ha)

Pinus, and about 18% comprised of Paraná Pine, other native species, fruit trees, palms and others (WFI, 1995; BNDES, 1995; Kengen and Graça, 1998) (Figure 2.2).

Volume and rotation ages vary with location of the forest and species. *Eucalyptus* yield mean annual increment (MAI) from 5-35 m^3/ha.year in 7-21 year rotation. Pines' MAI varies from 8-30 m^3/ha.year in 20-25 year rotation (including intermediate thinning). However, the MAI is improving considerably and rotation ages are shortening through the use of genetically superior stock. (WFI, 1995), and more suitable management practices.



Source: IBDF (cited by Kengen, 1987 and Cottle & Schreuder, 1990)

Figure 2. 2. Area approved for pine plantation using fiscal incentives in Brazil (1967-86)

The forest plantations with fiscal incentives became a major source of industrial roundwood as well as raw-material to some energy-using industries. By establishing plantations, companies also fulfilled their 'forest recovery' programs (law 4771/1965) which requires that wood-consuming firms invest on self-production of raw-material they consume. With the incentives, firms carried out their 'forest recovery' programs and generated capital for continuous investments on industrial plants (Ramos, 1993).

The fiscal incentive policy aimed primarily at private businesses (Garlipp, 1997). Overall, private companies and large-landowners were the major beneficiaries of the program, accounting for 90% of the plantations (Kengen and Graça, 1998). Pulp and paper companies, as well as the pig-iron and steel industries, took advantage of this opportunity and established plantations to attain raw-material self-sufficiency, and some of them, primarily pine growers, became net suppliers of timber. In contrast, sawmills and the furniture and plywood industries, with a lower degree of self-sufficiency and a less organized structure, did not take part in the incentive scheme (Kengen and Graça, 1998). These authors also pointed out that the fiscal incentive program was not aimed at farmers and small landowners, and indeed they did not participate in it.

Financial problems and misuse of the incentives caused the shrinkage of the program in 1983. The program ended in 1986, with the withdrawal of the incentives leading to significant decrease in plantations. The average annual planting dropped from 400,000 ha between 1974 and 1982, to around 200,000 ha in 1983 and even less thereafter. Since the end of the program, plantations has resulted from isolated public and private actions, carried out primarily by large and usually more capitalized forest-based companies (Kengen and Graça, 1998) and by some local and state government agencies. Indeed, in recent years plantation forests have been established by more capitalized firms, such as pulp and paper companies, to fulfill their own industrial needs, with little regard to the future timber market and the sawmilling industries' demand. In addition, large forest-based firms have initiated stewardship planting programs with small landowners, with the first option of buying the stumpage by the harvesting time. It adds a burden to the less structured solidwood industries, which over the years became dependent on raw-material from those firms.

During the 1980s, Brazil faced some political turmoil and periods with high inflation rates that undermined investment, particularly in forestry. As result, only a relatively small area was planted during the 1990s, despite the growing demand for industrial roundwood. From the average of 400,000 ha planted in the mid-1970s, reforestation has been reduced to an average of 150,000 ha per year, insufficient to meet the country's future wood requirement (Leite[1], 1998, cited by Kengen and Graça, 1998).

2.1.3 The Forest Sector and Industrial Roundwood Production/Consumption

The Brazilian forest sector is formed primarily by the lumber, veneer, plywood, particle board, fiber board, cellulose and paper segments. Overall, it accounts for annual revenue of US$ 11 billion (representing 4% of the GNP), generates US$ 2.3 billion a year of foreign exchange credits, and provides 600,000 direct jobs, benefiting approximately 3.5 million people indirectly (WFI, 1995).

Wood processing in Brazil may be evaluated by grouping species used as input in the industrial process. Tomaselli (1998) indicated three major groups of industries as: (a) using native hardwood species from the Amazon basis; (b) using planted pines; and (c) using planted *Eucalyptus*. The first group is located primarily in the North region and consumes fine native wood species (e.g. mahogany, cedar, and 'virola'), producing lumber, wood panels and plywood for domestic consumption and exports. This group is formed by a large number of small mills, many originally from the South, and characterized by low productivity, technology, and poor managerial standards. Their harvesting practices have resulted in excessive waste both in the forest and in the mills, since most of the firms have not implemented strict sustainable forest management practices. The lack of a clear government policy for the Amazon, associated with the existence of Brazilian and, more recently, large Southeastern Asian sawmills make the social, economic and environmental impacts still uncertain for the region. Industries utilizing pines, are located primarily in the South, and formed by sawmills, plymills, pulpmills, and wood panel firms (particle and fiberboard). Their products are used domestically on housing, civil construction, and by the furniture industry, or exported. The group using *Eucalyptus* is formed primarily by pulp and papermills spread across the South, Southeast and Northeast and some steel companies in the Southeast. *Eucalyptus* is also used in hardboard production, primarily for export (BNDES, 1995). In recent years, *Eucalyptus* lumber started to be produced on a modest scale since problems with the product quality and market acceptance must be still overcome.

By the mid-1970s, plantations became an important source of raw-material to the growing forest industries. In particular, pulp and papermills, and some wood panel industries benefited from this new resource and expanded considerably (BNDES, 1995). Therefore, both natural forests and plantations played a major role on the development of the Brazilian forest sector during the second half of the last century. Plantations are mostly owned by the private sector, primarily by large forest-based companies although varied small businesses also own some shares of planted forests. Non-private owners are a minor category of plantation owners.

The increasing production in all categories of industrial roundwood since the

1970s is notable and indicates investments and diversification of the Brazilian forest sector (Table 2.1). Given an existing ban on roundwood exports until 1993, and negligible imports during the period (IBAMA, 1996), the production also represents the industrial roundwood consumption by forest-based industries.

Table 2. 1. Evolution of the production of industrial roundwood in Brazil (1979-99)

Year	Industrial Roundwood (000 m^3)		Sawlogs and Veneer Logs (000 m^3)		Pulpwood and Particle Board (000 m^3)		Other Industrial Roundwood (000 m^3)	
	C	NC	C	NC	C	NC	C	NC
1970	**11113**	12825	**9320**	7470	**1400**	2110	**393**	3245
1980	**25814**	35908	**19916**	16296	**5400**	15500	**498**	4112
1990	**31291**	42986	**20085**	17883	**10600**	20101	**606**	5002
1995	**33032**	51486	**21779**	26000	**10600**	20101	**653**	5385
1999(1)	**22458**(2)	30605(2)	**21779**	25000	**n.r.**	n.r.	**679**	5605
Δ70-80	132%	180%	114%	118%	286%	635%	27%	27%
Δ80-90	21%	20%	1%	10%	96%	30%	22%	22%
Δ90-99	-	-	8%	40%	-	-	12%	12%

Source: FAO Forest Products Yearbook (2000)
Notes: C – conifer; NC – non-conifer; n.r. – not reported
(1) last year reported by FAO
(2) not including totals for pulpwood and particleboard.

The highest annual growth for all categories occurred during the 1970s, which coincides with the increasing availability of planted roundwood and a strong growing economy. For the period 1980-99 a slower annual growth was observed, still with impressive increase in pulpwood consumption (96% and 30% a year respectively for conifer and non-conifer pulpwood and particleboard). With respect to conifer sawlogs and veneer logs the impressive growth during the 1970s (114%) may be attributed to higher *Araucaria* supply, since pines were not available in commercial quantities till the early 1980's (Table 2.1).

2.1.4 The Solidwood Industry and the Sawmilling Sector

Domestic production of solidwood products has increased in the past decades, mostly during the 1970s (Table 2.2). This may be an indirect result of economic expansion, population increase, and increasing demand for building and packaging materials and furniture. During the 1980s and the 1990s the average annual growth rate was variable, but still positive for all the product categories, except fiberboard.

Table 2. 2. Evolution of the production of solidwood products in Brazil (1970-99)

Year	Sawnwood (000 m^3)		Wood Panel (000 m^3)				
	C	NC	Fiber Board	Particle Board	Plywood	Veneer Sheets	Total
1970	**4535**	3500	269	112	342	96	**819**
1980	**7143**	7738	780	660	826	216	**2482**
1990	**7923**	9256	698	660	1300	234	**2892**
1995	**8591**	10500	698	660	1900	300	**3558**
1997	**8591**	10500	1150(1)	1150(1)	1900	300	**3558**
1999(2)	**8591**	10000	698	660	1500	240	**3098**
Δ70-80	58%	121%	190%	489%	142%	125%	203%
Δ80-90	11%	20%	-11%	0%	57%	8%	17%
Δ90-99	8%	8%	0%	0%	15%	3%	7%

Source: FAO Forest Products Yearbook (2000)
Notes: C – conifer; NC – non-conifer; n.r. – not reported
(1) last year reported by FAO
(2) not including totals for pulpwood and particleboard.

For sawnwood, the average annual growth in production was 1.1% and 0.8% a year, respectively for the 1980a and 1990s. However, since the late 1990s FAO estimates have been reported with the same value as for 1995 for most of the products (Table 2.2).

2.1.4.1 Domestic Production of Conifer Sawnwood

Sawmilling is the leading solidwood sector both in number of firms and production capacity (Table 2.3). In contrast to the pulp and paper sector, the sawmilling industry is formed by thousands of small, portable, undercapitalized independent mills (Kengen and Graça, 1998), and characterized by low product quality and lack of modernization. Over 80% of the sawmills have low productive capacity with production of up to 6,000 m^3 of lumber per year (BNDES, 1995). However, in recent years, some technological developments have been noticed in both the sawmill and furniture industries (Sobrinho, 1996). On the other hand, wood panel producing companies have high productivity levels, industrial modernization and automation, good product quality and more professional management structures (BNDES, 1995).

Table 2. 3. Estimated installed capacity of solidwood industries in Brazil (1993)

Solidwood Products	Firms (number)	Production Capacity (000 m^3/year)
Sawnwood (1)	8,000 e 10,000	18,000 - 22,000
Plywood (2)	around 400	2,200
Veneer (2)	40 - 50	400
Fiberboard (3)	2	700
Particleboard (4)	6	1,285

Source: (1) ABPM; (2) ABIMCI; (3) BNDES; (4) ABIPA; (cited by BNDES, 1995)

Sawmills are concentrated in the North and South regions (Revista da Madeira, 1995a). There are 8,000-10,000 sawmills nationwide in relatively small units (Table 2.4). Over 50% of these are located in the southernmost states of Paraná (2,350), Santa Catarina (1,900), and Rio Grande do Sul (1,000), and consume mostly pine sawlogs. In the South, sawlog consumption increased 163% between 1986-95, from 5 million m^3 to

13.2 million m^3, the great majority being pines (Sobrinho, 1996).

Over the 1990-2000 period, the average growth of sawnwood production in Brazil was 3.6% per year, with a clear differentiation between production of hardwood and softwood sawnwood. Over the period the average growth of softwood sawnwood was 5.5% per year and only 3.1% for hardwood sawnwood. Significant growth of *Eucalyptus* sawnwood production over the last years have been noticed, with is estimates for 2000 reaching near 700 thousand m3. (ABIMCI, 1999).

Production of value-added products (blocks and blanks, EGP, and moldings) grew from 515 thousand m^3 in 1995 to estimated 859 thousand m^3 in 2000. These volumes are significant considering the recent development of this activity in the country. Growth rates over the period are high, mainly for blocks/blanks and moldings. The production of blocks/blanks, engineered glued products (EGP) and moldings are mostly based on pines, with the main producers located in the Southern region (ABIMCI, 1999).

Conflicting estimates of sawnwood production are reported. FAO estimated 19 million m^3 of sawnwood produced in 1995 (FAO, 2000), while Revista da Madeira (1995a) reported 13 million m^3, with the South and North regions producing 5 and 8 million m^3 of lumber respectively. For the year 2000, Revista da Madeira (1995b) estimates a total sawnwood production of 20 million m^3, 8.5 million m^3 in the South and 12 million m^3 in the North. On the other hand, BNDES (1995) indicates a different scenario, with the combined South and Southeast regions accounting for 80% of the sawnwood production for 1993 (Table 2.4).

Table 2.4 reveals the leadership of both South and Southeast regions in the production of all major product categories. That is coherent with the historical pattern of industrial development and location of the major consumer markets. Although the North is responsible for only 20% of the sawnwood production it has been an important supplier of hardwood sawlogs to Southern sawmills. Even though transportation is relatively costly, the low production cost and the high price of manufactured products still make the North-South supply flow profitable.

Table 2. 4. Percentage of regional production of solidwood products by volume (1993)

Region	Sawnwood	Plywood and Veneer	Fiberboard	Particleboard
South/Southeast	80	75	100	100
Others	20	25	0	0

Source: ABPM, ABIMCI, ABIPA (cited by BNDES, 1995)

2.1.4.2 Domestic Consumption of Conifer Sawnwood

Sawnwood represents a large proportion of the forest resource utilization for intermediate industrial use in Brazil (excluding fuelwood), consumed in a diversified domestic market as well as exported. The national sawnwood consumption grew 39% during 1990-2000, resulting in an average 3,3% annual growth rate (Table 2.5). The consumption of hardwoods grew 38% (3.2% per year), while softwoods presented a growth of 41.4% (3.5% per year).

Although statistics about the role of pines in different structural wood markets is limited, the furniture industry represents an important segment with growing pine consumption. In the early 1990s, the furniture industry started to consume massive volumes of pine, representing over 80% of the furniture exports by 1996, five times more than during the 1980s. There were 13,500 furniture mills in the country in 1996, with pines representing 80% of the wooden raw-material for the RTA ('ready to assemble') furniture, primarily in Santa Catarina and Rio Grande do Sul states (Donnelly and Suchek, 1996). Increasing pine lumber consumption has also been noticed in the construction industry (Revista da Madeira, 1996).

Table 2. 5. Sawnwood consumption in Brazil (1990-2000)

Year	Sawnwood Consumption				
	Hardwood		Softwood		Total
	000 m^3	%	000 m^3	%	
1990	10,360	78	2,850	22	13,210
1991	11,510	77	3,440	23	14,950
1992	12,157	78	3,407	22	15,564
1993	12,404	77	3,670	23	16,074
1994	12,179	78	3,451	22	15,630
1995	13,022	78	3,570	22	16,592
1996	13,291	78	3,653	22	16,944
1997	13,752	79	3,648	21	17,400
1998	13,450	79	3,660	21	17,110
1999	13,860	78	3,840	22	17,700
2000 *	14,300	78	4,030	22	18,330

Source: ABIMCI and STCP (ABIMCI, 1999)

2.1.5 Markets of Roundwood and Sawnwood

2.1.5.1 Roundwood Supply and Demand

In contrast to common thought, Southern Brazil has been the major producing region of wood products nationwide with 54.1% of the total market in the early 1990s, followed by the North with 30.3%. In 1988, the Southern region produced approximately 2 million m^3, 61% from *Pinus* plantation. The remaining production came from Paraná pine and hardwood forests, whose depletion has changed the profile of the regional industry (Revista da Madeira, 1993), toward the consumption of pine species.

Demand for industrial roundwood in Southern Brazil reached 17 million m^3 in 1990, an increase of 11% since 1980. Sawmills represented the major roundwood-consuming industry (8.8 million m^3, or 52%), followed by the pulp and paper mills (7.0 million m^3, or 41%), with only 3% and 4% allocated respectively for veneer and particleboard. It reflects the importance of both sawmills and pulpmills in the region (Siqueira, 1995). Intra- and inter-regional transportation of industrial roundwood and processed and semi-processed forest products is a common practice in the Southern states. The regional industrial roundwood equivalent consumed in 1990 reached 20.5 million m^3, 6% coming from other states and 94% being regionally produced and traded. Roundwood imports in 1990 accounted for 1.2 million m^3 (a decrease of 50% from 1980) while exports were negligible. For the total sawtimber production in the South, 94% was consumed domestically and 6% was exported (Siqueira, 1995).

Nationwide, roundwood is supplied from both plantations (*Pinus* and *Eucalyptus*) and natural forests (a small proportion from regional hardwoods, Paraná pine, and hardwoods from the North). The roundwood from plantations showed impressive growth of 863%, between 1975-95 from 2.5 million m^3 to 24.5 million m^3 (Siqueira, 1995). Most of the supply in 1990 was industrial logs (17.3 million m^3), while 6.9 million m^3 and 227.4 thousand m^3 respectively were fuelwood and charcoal/firewood.

In recent years, excess supply of pine roundwood has entered the domestic market as result of a large proportion of plantations reaching harvestable ages. The supply increase has driven prices down, reducing incentives for continuing forest investment.

Fast-growing plantations are usually owned by forest subsidiaries, which are committed to supply raw-material for their associated industry (e.g., forest branches of pulp and paper mills). For such companies, prices reflect more a transfer value from the subsidiary rather than the true market price. On the other hand, sawmills to a large extent have been dependent on the excess supply of pine sawlogs from other producers such as papermills' subsidiaries. In this case, sawlog prices tend to express a competitive market price, since both buyers and sellers have the expected behavior of the demand and supply agents.

Since the end of the fiscal incentives in 1987, only the more capital intensive companies (pulp and paper mills' forest subsidiaries) have invested on plantations. Given the low price of roundwood (notably pulpwood), self-generated capital has been limited and, as result, plantations have been linked to the companies's future pulpwood requirement, with not much left as potential excess supply for sawmills. This scenario has perpetuated a situation in which capital intensive companies have established enough plantations to fulfill their needs while sawmills have not generated enough capital to invest in their own forest assets to supply their growing demand for sawlogs.

With limited forest resources and lack of policies and programs for new plantations, there is an overall concern that Southern Brazil may face a deficit of roundwood in the coming decades. Given a growing demand for roundwood in the South, Siqueira (1995) estimated a regional deficit of Pine roundwood by the year 2015, and from *Eucalyptus* by 2007. Ramos (1993), in his study about the supply and demand of roundwood in the state of Paraná, predicted that scarcity of industrial roundwood will reach the Southern state between 2003 to 2007 if the 1993 trend of consumption and planting continues. A study carried out by BRDE bank for the Southern states estimates a deficit of industrial roundwood for by 2007 (Kengen and Graça, 1998). Wiecheteck and Stevens (1996), in a gap analysis study of the pulpwood market in Brazil, identified shortages of *Pinus* and *Eucalyptus* pulpwood, respectively by 2004 and 2008 if reduced plantation area and increasing growth in domestic demand for pulpwood and sawnwood continue. Revista da Madeira (1995a and 1995b) suggests a sharp shortage of roundwood after 2005, in Southern Brazil as result of the non-continuity of forest plantations. Depending on changes in the economy, this trend could be expected (Revista da Madeira, 1995b). Bacha (2000) also suggests the potential for shortage of certain types of roundwood from plantations (mostly large logs and fuelwood) considering the balance past supply of and demand for those products. However, such forecasts are generalizations and more detailed studies are needed to effectively account for spatial and industrial aspects. Although forest resources are available to a certain extent, the forest location, the age of the stands, the lack of investments, and the growing environmental concerns are major factors limiting the area available for harvesting (Dos Santos, 1995). Bacha (2000) recommended the need for new incentive policies for reforestation. Although this author indicated that several states already have their public and private incentive programs for plantations, he stressed that these such programs should address the small and medium-size land-owners.

Dos Santos (1995) and Siqueira (1995) suggested that if continuous reforestation is not targeted and carried out, Brazil might import timber and wood products in the near future. This situation has already been noticed in some regions. Due to the limited availability of native hardwoods in the South, sawmills have “imported” sawlogs from the far North, although this situation is not likely to remain as prices of hardwoods and transportation costs increase. BNDE (1995) for instance estimated that Brazil will need around 15 million ha of industrial forests by 2010.

Few studies have reported the pattern of future plantations required to supply the increasing demand for industrial roundwood in the South. Ramos (1993), using a gap analysis of supply and demand, estimated a deficit of 40 to 80 million m^3 starting in 2000 or 2003, and the minimum planting program to be implemented to fill the future gap of roundwood in the state of Paraná. Siqueira (1995) suggested investments in new plantations in the Southern states without referring to the total area needed or the annual planting area. However, the pattern of allocation of forest plantation in order to fill this gap was not investigated in their studies.

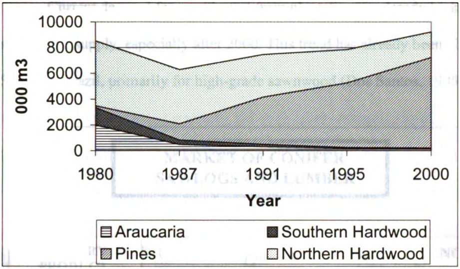
Although exports of most of the solidwood products have increased, the domestic market has been, and is expected to continue to be, more important than the international market. Besides the expectation of continuous economic and population growth, which alone would contribute to an increase in domestic demand for products in general, there are still niches to be occupied by the lumber sector, such as the construction market.

In order to fulfill the demand for forest products, some suggestions have been proposed. Among them is the production of high value-added products, and the search for markets suitable in terms of costs and product quality to the company and region's condition (Dos Santos, 1995). In addition, companies should also search for continuous performance gains, increasing their global competitiveness. Shift in sawnwood production from the South to other regions has been suggested, where smaller demand for land would favor the establishment of plantations and the management of natural forests (Revista da Madeira, 1995a). However, considering the pattern of land use by large landowners in the Amazon and the incipient government control, it may represent a threat to the sustainable development in the region.

2.1.5.2 Sawnwood

On the demand side, FAO estimated a 12% annual growth in sawnwood consumption from 1990 (17 million m^3) to 2010 (over 59 million m^3) as result of increasing population and purchasing power. Dos Santos (1995) suggested consumption of 25-30 million m^3 by 2010, a more modest annual growth rate of 3-5% and close to the expected GDP growth for the period. FAO's growth projection seems to be overestimated given the 1999 Brazilian economic turmoil and the expected low population growth.

Large-scale pine sawnwood production started in the early 1980s with a dramatic increase in volume during the 1990s (Figure 2.3). Pines substituted almost completely for *Araucaria* and hardwoods from the South and Southeast. In 1980, 98.6% of the total 9.5 million m^3 of lumber produced nationwide came from native species (24.8% Southern hardwoods, 52.9% Northern hardwoods and 20.9% Paraná pine) with only 1.4% as planted pines. After natural forests became scarce and plantations reached commercial age, an inverse trend was observed. In 1995, 63.7% of the total lumber production (9.2 million m^3) was pine, only 2.5% and 0.1% respectively Paraná pine and Southern hardwoods, but still 33.1% Northern hardwoods. This trend reflects the importance of pine to the regional lumber industry (Azeredo, 1993). In 2000, over 75% of sawnwood was estimated to come from the South and Southeast, pines accounting for over 98% of the total (Revista da Madeira, 1996).



Source: Revista da Madeira (1996); estimates for 2000

Figure 2. 3. Sawnwood production by group of species in Brazil (1980-2000)

Sawnwood production in Brazil is integrated with other related industries (Figure 2.4). The sawnwood market is estimated at 8 million m^3 of pine sawnwood a year out of 15 million m^3 (Dos Santos, 1995). Production of *Eucalyptus* sawnwood had been negligible until the recent past, with only 80,000 m^3 produced in 1994, or less than 0.5% of the national total (Revista da Madeira, 1996). Pine sawnwood has shown better wood properties than *Eucalyptus* for structural uses (Revista da Madeira, 1996) and *Eucalyptus* had been considered less well understood in terms of market potential and processing technology (Flynn et al., 1998). However, there is an overall perception that *Eucalyptus* may become a substitute for some *Pinus* sawnwood in the next decade (Revista da Madeira, 1995a), given the resource availability and technological advances in recent years. Massive investments in sawmilling capacity by major *Eucalyptus* pulp and paper companies have been made in the past years both in the South and Southeast.

Current demand for roundwood from plantations is already high and likely to surpass the supply, especially after 2000. This trend has already been observed in Southern Brazil, primarily for high-grade sawnwood (Dos Santos, 1995).

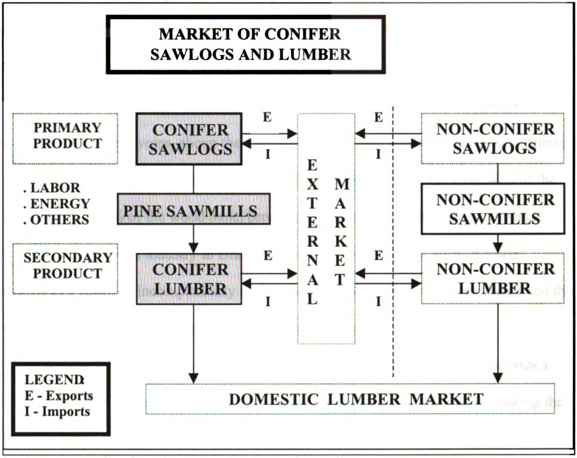


Figure 2. 4. Matrix of sawlog-sawnwood transformation

Although statistics on consumption and use of pines by structural-wood consuming industries are not available, the furniture industry is a growing market for pine sawnwood. Until the end of the 1980s, the production of furniture had steady growth, with a large utilization of native species. In the early 1990s, pine was introduced into this new market, and by 1996 it accounted for over 80% of the exported furniture (Revista da Madeira, 1996).

The domestic market has traditionally been the main market for solidwood products, given the country's large population. Most of the sawnwood is consumed in the South and Southeast, where the higher-income population is concentrated. São Paulo is the main market for wood products, although other emerging regions include the South (with the expanding market for higher quality wood, primarily pine clearwood) and the Northeast (with a growing per capita income in the past years) (Tomaselli, 1998).

A growth rate of 4-5% domestic a year in demand for solidwood products is projected for the next years, above the international average, representing an opportunity for the industrial expansion. Tomaselli (1998) pointed out that in 1998 over 90% of the sawnwood and 70% of the wood panel production was traded in the domestic market.

The sawnwood industry in Brazil is characterized by a high level of wood residues as a result of incompatibility of the specification of the product produced and the product demanded, outdated technology and the use of unskilled labor.

A close look at sawlog and sawnwood production by species group indicates a dramatic increase in the past decades. The highest annual growth was noticed during the 1970s with significant decrease thereafter, except for non-conifer sawlogs and veneer logs, which expanded during the 1990s. For conifer sawnwood, a modest, but still impressive, annual growth is observed for the 1970s (5.2% a year), followed by a steady growth of about 1% since 1980. However, conifer sawnwood disaggregated into pines and *Araucaria* shows a rather different picture (Table 2.6). Data from ABPM (1994), referring to Southern Brazil only, shows an impressive growth of 165% a year in pine sawnwood production during the 1980s, followed by a modest, but still significant, annual growth of over 16% for the 1990s.

Table 2. 6. Conifer and non-conifer sawnwood production in Brazil (1970-95)

Year	Sawnwood (000m³)			
	Non-Conifers	Conifers		
	Total (1) Brazil	Total (1) Brazil	*Pinus* (2) Southern Brazil	*Araucaria* (2) Southern Brazil
1970	**3,500**	**4,535**	*n.a.*	*n.a.*
1980	**7,738**	**7,143**	*130*	*1,990*
1990	**9,256**	**7,923**	*2,500*	*380*
1995	**10,500**	**8,591**	*5,000*	*200*
2000 (3)	**n.a.**	**n.a.**	*7,000*	*180*
%Δ 70-80	**11.0**	**5.2**	*n.a.*	*n.a.*
%Δ 80-90	**1.8**	**1.0**	*165.7*	*-7.4*
%Δ 90-95	**1.7**	**1.1**	*16.7*	*-7.9*
%Δ 90-00	**n.a.**	**n.a.**	*16.4*	*-4.8*

Source/Note:
(1) FAO Forest Products Yearbook, 1999
(2) Conifer sawnwood production in Southern Brazil (ABPM, 1994)
(3) ABPM estimate (1994)
n.a. – not available

Although the South is a major producing region of forest products in Brazil, with traditions in both plantation and wood products manufacturing, a number of problems may affect its future leadership and overall performance. A major inhibiting factor is the limited capital resources of some forest sector segments and the consequent lack of investments in plantations. Other important factors are the lack of competitive technology (primarily in the solidwood industry), the existence of low productivity and unregulated forests, and the non- participation of non-industrial private owners in the forest sector.

2.2 Forest Products Trade and Related Issues

2.2.1 World Market of Solidwood Products

The world market of solidwood products has traded over US$40 billion a year from 1995-99 (FAO, 2000b), with a total of US$43 billion in 1999. The participation of Brazil has been modest, with approximately 2% of the exports for all forest types and 4.5% for tropical hardwoods in 1997. Overall, FAO estimates of future forest products production and consumption suggest unbalanced supply and demand in the international market in the first decade of the twenty-first century. That is a function of reduced production in some Southern Asian countries such as Malaysia and Indonesia, and expected stagnation of the major producers in the Northern hemisphere as a result of environmental and social pressures (Macedo et al., 1996).

In 1996, solidwood products exports for Brazil reached US$1.1 billion in addition to exports of US$266 million worth of wooden furniture (Macedo et al., 1996). In terms of sawnwood, the Brazilian exports from 1990-96 increased 16%, reaching US$ 345 million. Exports of sawnwood have been modest, below 10% of the domestic production.

2.2.2 World Sawnwood Market

International trade of sawnwood, the strongest solidwood product, reached an average of US$25 billion a year over the 1995-99 period, with US$27.8 million in 1999 representing 119 million m^3. During 1980-99 the annual growth in conifer and non-conifer sawnwood exports was respectively 2.6% and 1.9% (Table 2.7).

Table 2. 7. International trade of sawnwood (1980-99)

Product	Year			Annual Growth 1980/99 (%)
	1980	1990	1999	
Exports – Volume (000 m^3)				
. Conifer Sawnwood	66,442	73,818	100,956	**2.6**
. Non-Conifer Sawnwood	13,186	15,185	18,278	**1.9**
Total	79,628	89,003	119,234	**2.5**
Exports - Value (000 US$)				
. Conifer Sawnwood	138	172	176	**1.4**
. Non-Conifers Sawnwood	241	303	547	**6.4**
Total	155	195	233	**2.5**

Source: FAO Yearbook – Forest Products (2000) adapted from Macedo et al. (1996)

Most of the sawnwood trade in 1999 was conifer, over 100 million m^3 or 85% of the total traded. However, for unit value of exports a rather different picture emerges. A much higher annual growth of 6.4% was noticed for non-conifer sawnwood in comparison with 1.4% for conifers over the period 1980-99 (Table 2.7).

International trade of conifer sawnwood has been attractive in recent years, reaching US$ 18 billion in 1999. Combined, the USA, Canada, and the EU account for over 80% of the world's imports and exports of conifer sawnwood (Tables 2.8 and 2.9).

In terms of imports, the US alone accounted for 45% of the world total of 100 million m^3 in 1999, followed by the EU with 32%, and Japan with 8.3%, all totaling 85% of the world's imports. In the EU, major importing countries were the United Kingdom, Italy, Germany, Denmark, Netherlands and France accounting for 85% of the region's total (Table 2.8). Egypt and China have increased imports since 1980, accounting for 3.2% of the worldwide trade in 1999. Mercosur countries are primarily exporters, with the exception of Argentina which has actually decreased imports since the 1970s as result of increasing domestic production using mature pine stands.

Table 2. 8. Major importers of conifer sawnwood (1980-99)

Countries/ Regions	Volume				Value	
	1980 (000 m3)	1990 (000 m3)	1999 (000 m3)	1999 %	1999 (million US$)	1999 %
WORLD	**64499**	**75435**	**100349**	**100.0**	**18324**	**100.0**
USA	22206	28670	44807	**44.7**	7374	**40.2**
EU (+15) (1)	25881	29003	31757	**31.6**	5791	**31.6**
. United Kingdom	5990	9826	6604	**6.6**	1356	**7.4**
. Italy	4388	4426	5550	**5.5**	994	**5.4**
. Germany	5817	5222	5319	**5.3**	976	**5.3**
. Denmark	1233	1483	3500	**3.5**	370	**2.0**
. Netherlands	2471	2547	3352	**3.3**	603	**3.3**
. France	2651	1742	2539	**2.5**	507	**2.8**
Japan	4955	7369	8372	**8.3**	2402	**13.1**
Egypt	1428	1400	2237	**2.2**	300	**1.6**
China	31	294	988	**1.0**	206	**1.1**
Norway	363	401	775	**0.8**	189	**1.0**
Canada	768	998	742	**0.7**	151	**0.8**
Saudi Arabia	919	480	721	**0.7**	110	**0.6**
USSR - Europe (2)	124	100	651	**0.6**	54	**0.3**
ROW (3)	7824	6721	9298	**9.3**	1748	**9.5**

Note: Source: FAO (2000b)

(1) European Union: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and UK;

(2) Former-USSR in Europe (1999): Belarus, Estonia, Latvia, Lithuania, Moldova, Russian Federation, and Ukraine; numbers for 1980 and 1990 represent former USSR.

(3) Rest of the world

With respect to the value of imports, countries tend to maintain their world share as for volume, although the USA showed a smaller proportion (40.2% as compared to 45% in volume) and Japan an impressive 13% (as compared to 8.3% in volume) (Table 2.8). This may be the result of interacting factors, including differences in import tariffs, price differentials, and/or non-homogeneous products. Price differential could be caused by demand-supply-price interaction in individual countries with transportation cost playing a major role. For instance, US imports come primarily from Canada, with a significantly smaller cost of transportation when compared to Japan imports, from various and more distant countries.

In terms of exports of conifer sawnwood, Canada accounted for 48% of the world's total of 101 million m^3 in 1999, followed by the EU with 29%, the former USSR in Europe with 10%, and the USA with 4.5%. These countries combined accounted for over 90% of the world's exports. Latin American countries were minor exporters with 3% of the world's total (FAO, 2000). Among them Brazil, Chile, and Argentina, contributed only 1%, 1%, and less than 0.1% of the world's exports respectively (Table 2.8). In the EU Sweden, Finland and Austria were the major exporting countries, accounting for 85% of the region's total. Other important exporting countries were the Russian federation and the USA with 6% and 3% of the world' share respectively. Emerging exporting countries with large-scale pine plantations are New Zealand, Chile and Brazil, with 3% of the worldwide share. Brazil, despite its area and the large-scale pine plantations, still has a modest performance with only 678 thousand m^3 exported in 1999, although this represents a significant increase since 1990. The in Brazilian exports of conifer sawnwood decrease from 1980-90 may be the result of a shift from pines to *Araucaria* use. The increase thereafter is possibly related to the maturing pine plantations and consequently larger production aimed at the international market. Overall, for value of exports, countries tend to maintain their ranking as for volume exported (Table 2.9).

Roundwood from natural forests has been gradually substituted for engineered products and planted roundwood. An annual 2% growth in worldwide sawnwood consumption is estimated for the next years, conifers still accounting for most of the trade (Macedo et al., 1996). Assuming that non-conifers will be supplied primarily by native species, there are opportunities for companies managing homogeneous forest plantations.

Table 2. 9. Major exporters of conifer sawnwood (1980-99)

Countries/ Regions	Volume				Value	
	1980 (000 m3)	1990 (000 m3)	1999 (000 m3)	1999 %	1999 (million US$)	1999 %
WORLD	**66442**	**73818**	**100956**	**100.0**	**17786**	**100.0**
Canada	28993	37465	48336	**47.9**	8518	**47.9**
EU (+15) [(1)]	19239	18258	29227	**28.9**	5529	**31.1**
. Sweden	5894	6235	11040	**10.9**	2140	**12.0**
. Finland	6902	4156	8269	**8.2**	1499	**8.4**
. Austria	4254	4070	5627	**5.6**	1046	**5.9**
. Germany	490	910	1969	**1.9**	310	**1.7**
. Belgium-Lux	128	347	533	**0.5**	115.	**0.6**
. France	229	459	525	**0.5**	91	**0.5**
USSR - Europe [(2)]	7187	6200	10155	**10.1**	1162	**6.5**
. Russian Fed.	*	*	6105	**6.0**	613	**3.4**
. Latvia	*	*	2447	**2.4**	333	**1.9**
. Estonia	*	*	812	**0.8**	121	**0.7**
USA	4798	7010	3225	**3.2**	792	**4.5**
Czech Republic	1048	838	1480	**1.5**	212	**1.2**
Romania	572	58	1210	**1.2**	158	**0.9**
New Zealand	614	580	1185	**1.2**	280	**1.6**
Chile	1259	1196	1143	**1.1**	163	**0.9**
Poland	690	295	760	**0.8**	105	**0.6**
Brazil	**187**	**80**	**677**	**0.7**	**161**	**0.9**
ROW [(3)]	1425	1205	2124	**2.1**	498	**2.8**

Note: Source: FAO (2000)

(1) European Union: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and UK;

(2) Former-USSR in Europe: Belarus, Estonia, Latvia, Lithuania, Moldova, Russian Federation, and Ukraine; numbers for 1980 and 1990 represent former USSR.

(3) Rest of the world

(*) not reported

2.2.3 Brazilian Conifer Sawnwood Exports

The Brazilian participation in the global market of forest products has been modest, even more modest for conifer sawnwood. Although Brazil was the fifth largest roundwood producer in 1997, the country produced with less than 2% of the world exports of high value-added forest products such as lumber, wood panels, and paper; except wood pulp with 6.3% (FAO, 2000).

A number of factors has prevented it from increasing its forest products exports. This has been the result of high and growing domestic demand for forest products, the low level of industrial technology in the solidwood sector, unregulated forests resulting in unsuitable roundwood for some high value-added uses, underdeveloped marketing of new products and species, and underinvestment in the solidwood sector until the recent past. In addition, macroeconomic factors, including government policies for resource uses (social, physical and capital), incentives and subsidies to exports, forest and environmental laws, and economic plans aiming at boosting the economy have to varying extents played a role on shaping the position of the country in the international scene. Despite its modest participation in the international market, Brazil has the potential to increase its production and exports given some competitive advantages. They include low plantation cost, scientific technology for fast-growing species, land availability at relatively low costs, shorter rotations, infrastructure to support export efforts, and a developed international market for some Brazilian forest products. However, a limiting factor for increasing forest products exports is the growing domestic consumption as result of population and per capita income increase.

Although its participation is modest in the international market, Brazil increased its exports during the 1990s. In the early 1990s exports of forest products reached record levels, as the result of growing demand from Mercosur countries and the economic recovery of the USA. For conifer sawnwood exports grew from 46 thousand m^3 in 1988 to 102 thousand m^3 in 1993, respectively US$17 million and US$ 37 million (IBAMA, 1996). The value of sawnwood exports grew from US$141.5 million in 1990 to US$344.7 million in 1996, a 16% annual increase. In 1996, 54% of the total sawnwood exports from Brazil were native hardwoods. Major importing countries from Brazil have been the USA, France and UK, accounting for over 50% of the Brazilian exports of sawnwood. However, France and UK re-export part of the Brazilian sawnwood to other European countries (Revista da Madeira, 1995).

The search for new markets has created opportunities for Brazil in the world market, however the Brazilian forest sector has faced limitations to compete in the global economy. Particularly for conifer sawnwood, exports are conducted by small to medium-size companies in Brazil, with the exception of some branches of multinational companies with more powerful marketing channels. This condition shows the vulnerability of the sawnwood exports, given that a company's size and its revenue usually do not allow significant investments in technology and marketing resources, factors needed for international competitiveness (Macedo et al., 1995).

2.2.4 Trade Partners and Flow of Sawnwood

The large domestic market, associated with lack of capital investment and technological innovation, has been one of the reasons for the poor performance of the Brazilian timber industry in the international market. However, the main export markets for Brazilian solidwood products have been the EU and the USA (Tomaselli, 1998).

Brazil is by far the largest source of wood products from Latin America for the US. In 1997, Brazil supplied nearly one-half of the solidwood products imported from

Latin America, although hardwood products are still an important component of forest products exports. Chile was the next most important source with 29%. The remaining was divided among many countries, with none holding more than a 4% share. US imports of softwood lumber from non-Canadian sources, although representing only a small portion of total imports, have been growing rapidly, Brazil being the most important source. In 1997, Brazil accounted for 30% of these non-Canadian lumber imports in the US, followed by Mexico with 22% and Chile with 20%. US imports of Brazilian softwood lumber have increased at impressive rate during the last several years, from minimal in the early 1990s to nearly 400,000 m^3 in 1997 (Flynn, 1999b).

2.2.5 The Government Role and the Free Trade

The Brazilian government has played an important role on developing and shaping the country's forest sector in the past decades. Constraints on growth in the Brazilian forest products sector over the past years have centered around the country's financial difficulties which include foreign debts, high inflation periods, sharply reduced federal spending and other industrial incentives, and reduction in foreign and domestic capital investment in market activity (USDC, 1991). Although several forest industries have dramatically expanded in the mid-1980s a number of macroeconomic problems have significantly decreased the capacity of expansion and new projects (USDC, 1991).

On the private industry side, Brazilian labor costs for forestry-related activities are significantly lower than for some developed nations. In the past , however, Brazil's high inflation, high energy and transport costs and high interest rates have reduced competitiveness in world markets for wood products (USDC, 1991).

While the government directly participates in timber management operations, the private sector handles most of the industrial and commercial activities relating to the production and sale of timber and other forest products. The government had provided the industry with a range of incentives for exports as well as import licenses for selected products. In addition, in order to increase the country's foreign exchange earnings and protect its wood processing industry from international competition the government has encouraged production and exports of high value-added manufactured products through the ban on log exports of native sources (USDC, 1991). However, in 1992 the government lifted the prohibition by allowing roundwood exports from plantations, opening new opportunities for exporting the excess supply of wood products (chips, pulpwood and high grade sawlog) from pines and *Eucalyptus* although maintaining the prohibition for species coming from native areas (Tomaselli, 1998).

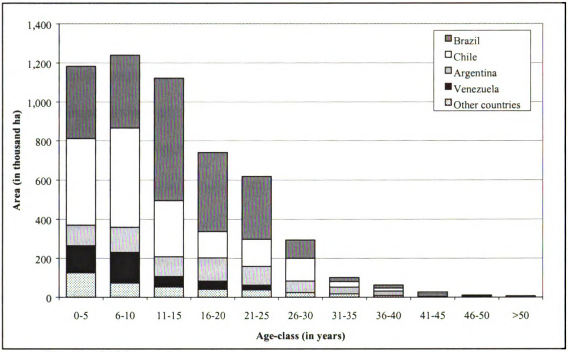
2.3 Mercosur and Regional Integration

2.3.1 Overview

With a combined market of 242 million consumers estimated for 1999, an aggregate GDP of approximately US$ 1.7 trillion, and a land area of 13.7 million square kilometers (4.7 million square miles) (CIA, 2000), the Southern Cone Common Market (Mercosur) has become an important economic regional bloc and a significant free trade pact, with remarkable initial success since its inception in 1991. The successful integration of Mercosur is expressed by the increased intra-regional trade, which has more than tripled from US$4 billion in 1990 to US$14.5 billion in 1995. Such growth can be attributed to trade liberalization, and gradual elimination of tariff and non-tariff barriers, as well as an encouraging scenario for foreign investments.

Although Mercosur has gained political commitment and, to some extent, economic success, its path towards achieving a perfect free-trade area is restricted by some important issues. Major issues include the possible trade diversion or creation for some forest products, implications of direct foreign investment, uncertain economic stability, and the recent admission of Chile and Bolivia as associate members. These factors make the future unclear for forest products trade.

In terms of plantations, the total estimated area in South America in 1995 was 8.2 million ha with 82 % of the resource distributed in three countries: Brazil (4.2 million ha; 2.7 million ha with *Eucalyptus* and 1.1 million ha with pines); Chile (1.7 million ha, mostly pines); and Argentina (0.8 million ha) (Brown, 2000). Most of the forests are used for pulpwood and sawlog production, with a maximum rotation of 25 years for pine sawlogs. Plantations in Brazil are mostly in age classes over 11 years old, mature for commercial use, with a significantly smaller proportion in below 10 year age class (Figure 2.5). Chile's plantations are in a relatively younger stage (mostly in age class 6-10, with a significant area also in classes 0-6 and 11-15). Argentina has a relatively smaller area, more evenly distributed among all age classes up to class 21-25. Such figure indicates that Brazil may face an unbalanced supply of some roundwood products, while Chile and Argentina will have a more regulated supply in the coming decades. Annual planting rates in these countries were reported as 100,000 year in Brazil and Chile and about 30,000 ha in Argentina in 1995 (Brown, 2000).



Source: Brown, 2000

Figure 2. 5. Plantation forest estimates in South American countries (1995)

2.3.2 Conifer Sawnwood Exports and Directions of Trade

A preliminary study investigated the main features of the market for forest products within Mercosur (Wiecheteck and Tella, 1997). Trends in sawnwood exports have been unstable for most of Mercosur, although Brazil has significantly increased its exports since 1991 (both coniferous and non-coniferous species). Although Chile has been successful in exporting softwood lumber to the US, Brazil has been even more successful. US imports from Brazil had been less than 100,000 m^3 in 1993, but reached 495,000 m^3 in 1998 (Flynn, 1999b).

Trade of veneer, plywood, particleboard and other forest products has shown an erratic but increasing trend since 1991. These categories are likely to remain unstable with spurts of increases and decreases in trade as a possible response to the construction industry and forest investments in each country.

All major importing countries in the bloc have shown a decreased trend in sawnwood imports since the early 1980s, that can be reversed in case a country increases its domestic demand (as result of increasing per capita income as result of overall improvement of the economy) and/or face constrained roundwood supply (as result of environmental/scarcity constraints).

For conifer sawnwood trade, Chile was the leading exporter in 1997 with over 1.5 million m^3, followed by Brazil (650 thousand) and Argentina (50 thousand), representing 96% of Mercosur trade (Table 2.10). Total trade from non-Mercosur countries to each of the Mercosur ones was almost negligible for 1997. Of the total 2.3 million m^3 trade, 98.3% represented exports to outside Mercosur countries, only 1,7% being trade within the bloc (Table 2.10). All Mercosur members trade primarily with non-Asian countries, except Chile that trades equally with the Rest of the World region (ROW) and the Asian-selected ones (Japan, China, Hong Kong, and South Korea). This is partially explained by Chile's location, targeting the Pacific Rim market, led by imports from Japan and China. Distances between regions, and consequent transportation costs, traditional trade in the past, characteristic of products, and other non economic variables can be influential in determining the actual trade flow between pairs of countries and regions.

For lumber exports, the U.S. and Argentina are the most important markets for Brazil. For Chile, Japan is a major market, but primarily for the lower grades such as packaging lumber. The Middle East is also important as a market for low-grade lumber for some of the Mercosur countries. For higher value products, such as moulding, components for doors and windows, furniture, edge-glued panels, etc., the U.S. is the most important market for Chile. A total of 75% of the value-added lumber products exported from Chile (percentage based on value) go to the U.S. (Flynn, 1996).

Table 2. 10. Direction of trade of conifer sawnwood for Mercosur countries (1997)

From ⇒ Exports To ⇓	**REGIONS**								
	Argent	**Bolivia**	**Brazil**	**Chile**	**Paraguay**	**Uruguay**	**ASIA-S (1)**	**ROW (2)**	**Total**
Argentina		0	14	4	0	0	0	2	20
Bolivia	0		0	0	0	0	0	0	0
Brazil	7	2		0	0	0	0	3	12
Chile	0	0	0		0	0	0	4	4
Paraguay	0	0	0	0		0	0	0	0
Uruguay	0	0	12	0	0		0	0	13
ASIA-S (1)	3	0	9	827	0	2		(3)	841
ROW (2)	41	16	612	733	0	14	(3)		1417
Total	51	18	649	1565	1	16	0	9	2308

Note: Source: adapted from FAO - Directions of Trade (2000)
volumes in thousand m^3
(1) ASIA-S countries: Japan, China (+ Hong Kong) and South Korea.
(2) ROW is Rest of the World: all non-Mercosur and non-ASIA-S countries.
(3) Trade between ASIA-S and ROW is not included.

One outcome of free trade areas is that traditional trade flows from lowest cost producers are sometimes disrupted as free trade blocks are formed, i.e., trade is diverted to new paths. Within Mercosur the potential for trade diversion is limited since imports of coniferous sawnwood are relatively low among members, with Brazil, Argentina and Uruguay being the major importers. However, the growing demand for conifer sawnwood in Brazil along with limited availability of future high-grade roundwood may shift this trend, creating an opportunity for other countries increase exports to Brazil.

2.3.3 Tariff and Non-tariff Barriers

Imports and exports by Mercosur countries can also be affected by tariff and non-tariff barriers. By the end of 1998, Brazil, the largest consumer market with low average tariffs for forest products, and an overvalued currency was an attractive importer; while Argentina, with the highest average tariff was the least attractive. Early in 1999 two major events in the bloc created an unlikely scenario, changing such trend. Brazil faced an economic turmoil, devaluating its currency and creating a direct impact on neighbor countries. In addition, starting on January 1st 1999, all member countries were to reduce to zero the tariff level within the bloc, phasing out their tariff levels for most products. Although Brazil has recovered economically; other events such as economic stagnation and political uncertainty in a few member countries, a recent economic turmoil in Argentina, and the possibility of Chile joining NAFTA instead of Mercosur may play a major role on reshaping the pattern of trade within and outside the bloc. The Free Trade Agreement of the Americas (FTAA), still being discussed, and with a proposed calendar to phase out tariffs in all signatary countries by 2005 could also change future scenarios for trade of conifer sawnwood among the Mercosur countries. Parallel bilateral agreements between Mercosur and other trade blocs, such as the EU, may influence future trade patterns among the Mercosur members.

Trade is also affected by non-tariff barriers, although they seem to be minimum among Mercosur countries. A ban on exporting native species as roundwood from Brazil has caused a boom in sawnwood production and exports since the 1960's. Subsidies provided to encourage pine plantations in Chile, Argentina, Paraguay and Uruguay (Garlipp, 1997) and pine/*Eucalyptus* planting incentives in Brazil have had an impact on the increase in exports of forest products in most of the members. Phytosanitary measures are possible non-tariff barrier that has had so far a minor impact in the region's trade.

2.4 Quantity and Price Analysis

The following section focuses on descriptive statistics of sawlog and sawnwood prices and quantities supplied and demanded in Brazil, Chile and Argentina. It introduces the data used in Chapter 3, their range and trends in each country since the early 1980s.

For conifer sawlogs and sawnwood in Mercosur, Brazil has had a prominent role in the past decades accounting with an average of 75 % of the total volume produced and consumed since the early 1980s. Chile follows with about 20% of the total volume, although it has increased its contribution to over 25% in recent years. Argentina, Uruguay, Paraguay, and Bolivia combined have accounted for less that 5 % in average over the period 1970-96, increasing its contribution to around 6 % since 1995.

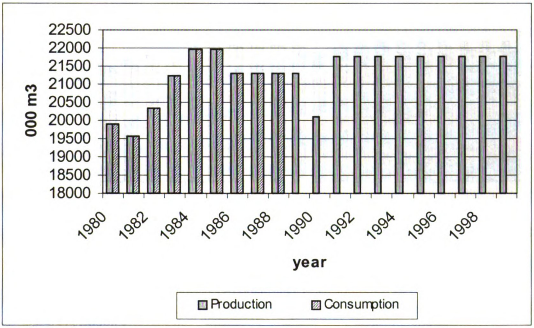
2.4.1 Brazil

2.4.1.1 Quantity Analysis

Brazil has the most extensive area with plantations in South America (mostly with *Eucalyptus* and pines), and about the same area in pine plantations as Chile. As discussed in previous sections, Brazil has gone through an intensive process of species substitution, with pines taking the place of *Araucaria* since the early 1980s. Such substitution has proved to be successful in terms of industrial production and market acceptance, both domestically and for exports.

Statistics of quantities produced and, consequently, consumed of conifer sawnwood in Brazil is highly variable and conflicting depending on the sources reporting. FAO reports around 2.5 times more volume produced during the period 1989-98 than ABIMCI/STCP does. ABIMCI/STCP's report may be a more accurate estimate, since it represents a sector study using domestically reported data, rather than FAO ones.

Aggregate conifer sawlog production and consumption (*Pinus* and *Araucaria*) increased between 1980-99, mostly during the early 1980s. Production data from FAO for the period 1992-99 is reported with the same value for each year, a highly unlikely situation, indicating possible data problems (Figure 2.6).



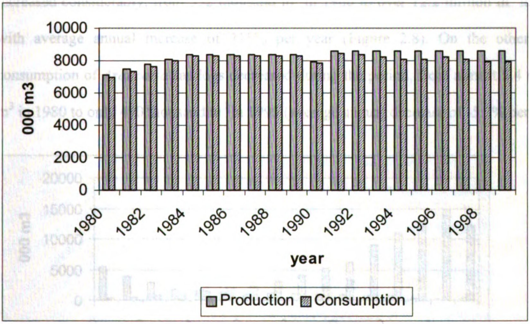
Source: FAO (2000b) (*)

(*) Consumption equals to production + imports – exports. Although sawlog imports and exports are not reported by FAO (2000b) during 1990-99, consumption assumes no imports or exports during the period.

Figure 2. 6. Consumption and production of conifer sawlogs in Brazil (1980-99)

An average annual growth of 1.7% for both production and consumption occurred for the period 1980-85, with 0.5 % for 1980-99. Consumption follows production closely given the fact that roundwood exports were banned in Brazil during most of the period of analysis and sawlog imports were negligible. With the allowance for exotic (planted) species exports by the early 1990s, modest volumes of pine sawlogs started to be exported after 1994 (Figure 2.6).

For conifer sawnwood, an increasing trend in production and consumption occurred for most of the period 1980-99 with an average annual growth of 1.0 and 0.7 % respectively (Figure 2.7).

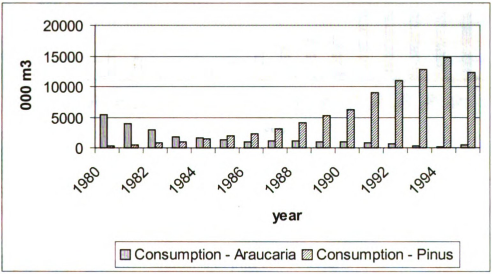


Source: FAO (2000b)

Figure 2. 7. Consumption and production of conifer sawnwood in Brazil (1980-99)

During 1980-85, both sawnwood production and consumption increased (respectively 2.9 and 3.2 % a year), and stabilized thereafter. This increase coincides with the substantial market supply of pines, which eventually substituted for *Araucaria* in the processing industries. However, unlike that observed for sawlogs, sawnwood production exceeded domestic consumption for most of the period, the difference being exported, since imports were negligible.

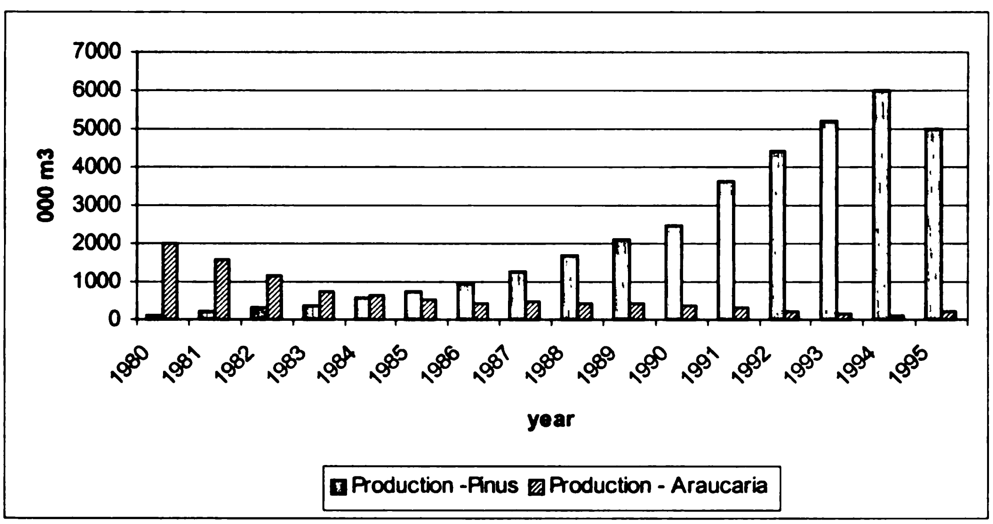
A more interesting comparison arises when the aggregate volume is broken down into the two conifer groups. Pine and *Araucaria* sawlogs (Figure 2.9) were estimated from sawnwood production data (Revista da Madeira, various years) by using roundwood equivalent ratios (from FAO data) for each year. Figures 2.8 and 2.9 illustrate opposite trends in sawlog consumption and sawnwood production of pines and *Araucaria* and are therefore not comparable to Figures 2.6 and 2.7. For pine sawlogs, consumption increased considerably, from 352 thousand m^3 in 1980 to over 12.2 million m^3 in 1995, with average annual increase of 211% per year (Figure 2.8). On the other hand, consumption of *Araucaria* sawlogs decreased during the period, from almost 5.4 million m^3 in 1980 to only 490 thousand m^3 in 1995 (average annual decrease of -5.7% per year).



Source: ABPM and Revista da Madeira (various years) (*)
(*) based on actual consumption for 1980, 1983, 1986, 1987, 1990, 1991, 1994, and 1995. Values for other years are interpolation between actual values.

Figure 2. 8. Consumption estimates of pine and Araucaria sawlogs in Brazil (1980-95)

As expected, production of pine and *Araucaria* sawnwood (Figure 2.10) showed a similar trend for consumption of sawlog. Production of pine sawnwood increased significantly from 130 thousand m^3 in the early 1980s to 6 million m^3 in 1994, decreasing slightly to estimated 5 million in 1995 (annual increase of 234% per year for 1980-95). On the other hand, production of *Araucaria* sawnwood decreased sharply between 1980-95, from almost 2 million m^3 in 1980 to only 100 thousand m^3 in 1995 (annual decrease of 5.6% a year). Pines have dominated the market of conifer sawlogs and sawnwood in Brazil since the early 1980s, and quickly became the major lumber species (Figure 2.9). *Araucaria* became a minor species as result of forest depletion and strict environmental legislation, with very limited availability to increase its contribution in the short to middle-term.



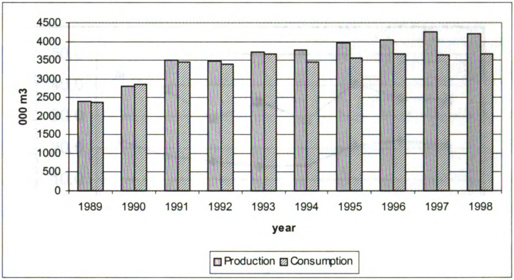
Source: ABPM – Revista da Madeira (several years) (*)
(*) based on actual consumption for 1980, 1983, 1986, 1987, 1990, 1991, 1994, and 1995. Values for other years are interpolation between actual values.

Figure 2. 9. Production estimates of pine and Araucaria sawnwood in Brazil (1980-95)

Demand for pine sawlogs is expected to increase but wood supply may not be available to support it, considering that the peak of pine planting was in the late 1970s.

As demand increases during the next decade, assuming a 20-year rotation, there comes a point around mid-decade when timber supply is likely to decline (Flynn, 1999b).

Statistics from a ABIMCI/STCP study (ABIMCI, 1999) indicates a steady increase on production and consumption of conifer sawnwood during the 1990s, with the maximum production of 4,25 million m^3 in 1997 and maximum consumption of 3.7 million m^3 in 1993. Domestic production and consumption increased respectively 7%and 5% annually between 1989-98 (Figure 2.10).



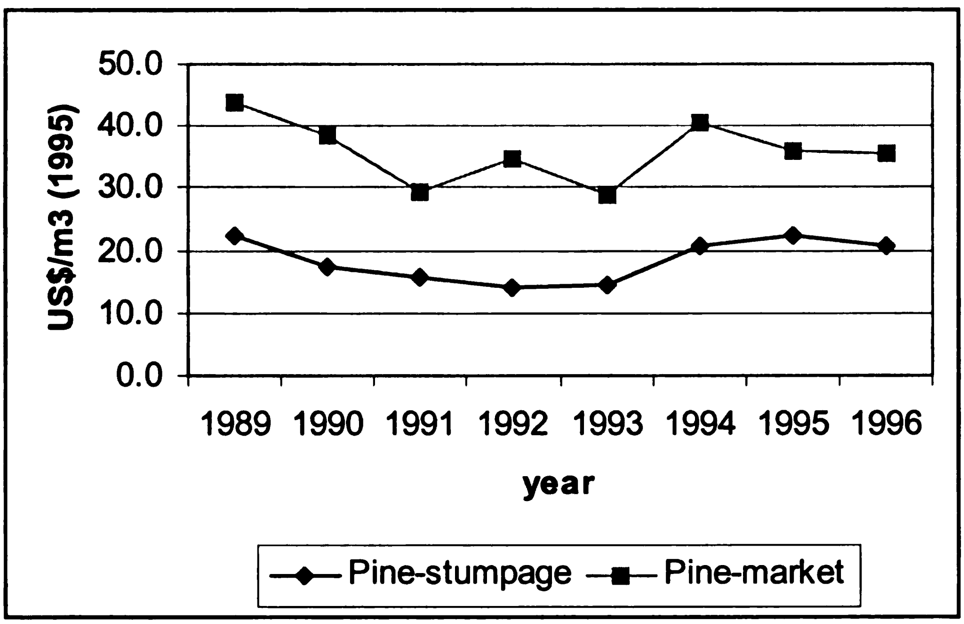
Source: ABIMCI/STCP (ABIMCI, 1999)

Figure 2. 10. Production and consumption of conifer sawnwood in Brazil (1989-98)

The domestic consumption of sawnwood (conifer and non-conifer) is linked basically by the furniture industry, packaging, and civil construction. Civil construction and the furniture industry are the major individual groups with respectively 21% and 15% of the nationwide total, and followed by wholesale, industries in general, and others, respectively 36%, 15% and 13% (ABIMCI, 1999).

2.4.1.2 Price Analysis

Sawlog and sawnwood prices are from different sources as they refer to stumpage and market prices in Southern Brazil, also including the unit value of production of higher value roundwood, a possible proxy for price (SEAB, 1998; IBGE, 1999; Revista da Madeira, 1995). Although consumption and production of pine sawlog and sawnwood increased significantly during the period of the analysis, prices tended to show an expected stationary behavior (Figures 2.11-2.13).



Note: (1) Real prices in US$/m^3 (1995)
Source: Data originally from SEAB (1998), and modified from Anadalvo's price analysis (Graça, 1998, personal communication).

Figure 2. 11. Stumpage and market prices of pine sawlogs in Paraná (1989-96)

Stumpage and market prices of pine sawlogs in the state of Paraná remained relatively stable between 1989-96, with a decrease noticed in the beginning of the period and an ascending trend in 1993-94, with stabilization thereafter (Figure 2.12). The average annual sawlog stumpage and market prices for the period were respectively

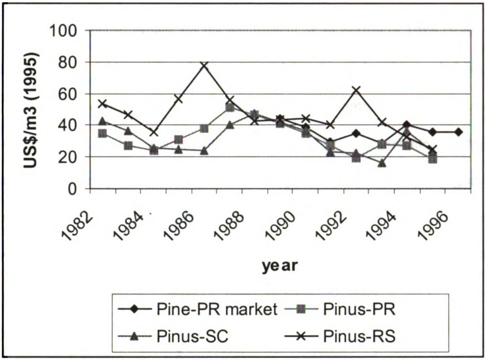
US$18/m^3 (range from US$14-22/m^3) and US$ 36/m^2 (range from US$29-44/m^3), with standard deviations respectively of 3.4 and 5.1. The difference between stumpage and market prices refers to transportation costs, taxes, and profit, accounting for 49% of the average market price.

IBGE's unit value of production of 'other roundwoods' (excluding fuelwood, firewood and pulpwood) from plantations show regional differences among the three Southern states (Figure 2.12). Pine sawlogs are the main representative in this category. To a certain extent, such unitary values could represent a proxy for the commodity price.

Trends in unit value of production of 'other roundwoods' in Paraná and Santa Catarina, where most of the pines were planted, follow a similar pattern with the increases and decreases culminating in the same periods. For Rio Grande do Sul the unit values show an opposite trend for the years 1986 and 1991. This can be related to the fact that other species besides pines formed the mix of species planted in that state, indicating a possible weighted price. IBGE's unit values of 'other roundwoods' from plantation in Paraná and Santa Catarina follow the trend observed for the SEAB's market price of pines in Paraná for 1989-95 (Figure 2.12).

As for prices of other conifers in Southern Brazil, Siqueira (1995) reported IBGE's unit values of industrial roundwood from plantations (pulpwood/higher grade logs) as proxies for prices, aggregating them into five year intervals between 1975-90. From 1975-80 prices decreased significantly in Paraná (from US$33/m^3 to about US$16/m^3), remaining stable in Santa Catarina and Rio Grande do Sul (respectively US$13/m^3 and US$18/m^3). Between 1980-85 prices decreased slightly in Paraná and Rio Grande do Sul, and sharply in Santa Catarina (from US$18/m^3 to US$10/m^3). From

1985-90 prices increased slightly in Santa Catarina and Rio Grande do Sul, decreased slightly in Paraná, with average of US$14/m^3 in all three states (Siqueira, 1995).



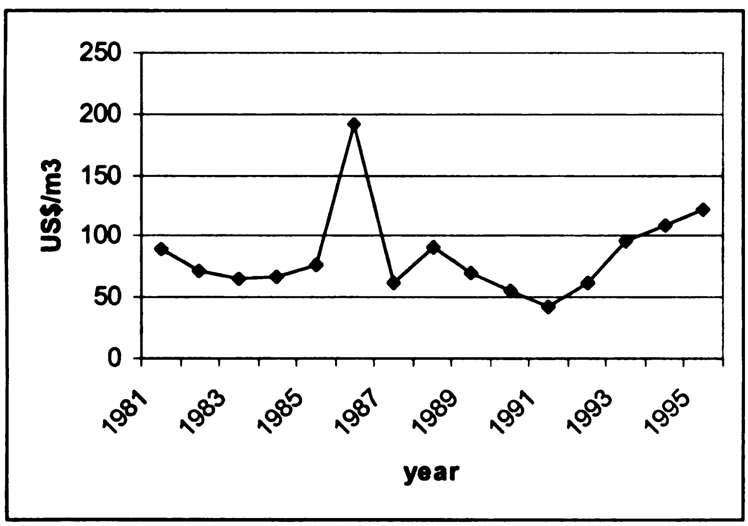
Note: (1) Real prices in US$/m^3 (1995)
(2) PR, SC, and RS stand for Paraná, Santa Catarina, and Rio Grande do Sul.

Sources: Pine-PR market (SEAB, 1995) and *Pinus*- PR, *Pinus*-SC, and *Pinus*-RS (IBGE, 1998). Prices for 1985 and 1989 were estimated as arithmetic average between the prior and following years (respectively 1984 and 1986, and 1988 and 1990), given the lack of reported prices for 1985 and an extreme outlier for 1989.

Figure 2. 12. Unit value of production for 'other roundwoods' in Southern Brazil (1982-96)

Prices of conifer solidwood products in Brazil have been lower than worldwide prices. This might be the result of high availability of stumpage and excess supply flowing into the domestic market. Considering the reduction in pine plantation in the past decades, sawlog prices are expected to increase in the next years assuming there is no direct substitute species. Increased prices could divert some of the pine pulpwood to the sawnwood market, stimulate a boom of new plantations and promote more regional trade of pine-derived products.

Prices for pine sawnwood vary over the period 1981-95 and show an expected stationary behavior, except for the occurrence of an outlier in 1986 (Revista da Madeira, 1995) (Figure 2.13). Although the nature of the change is not revealed, such a high price (US\$191/m^3) could have been the result of the economic boom after an economic plan was launched by the government in that year. The plan resulted in higher per capita income, that may have stimulated more expenditure, in consuming goods and housing construction, two important lumber demanding sectors. The average price over the period was US\$84.5/m^3 (range of US\$42 to US\$191/m^3) with a standard deviation of 36.1.



Source: Revista da Madeira (1995)

Figure 2. 13. Price of pine sawlog in Southern Brazil (1981-95)

It is important to consider that average sawlog prices of *Pinus* vary according to the log diameter class. Real 1995 prices of pine sawlogs (at the sawmill) ranging from 10-20 cm, 20-30 cm, 30-40 cm, and over 40 cm in diameter were respectively US\$8.0, US\$11.4, US\$15.8, and US\$19.7 per m^3 in Paraná in September/1997 (SEAB, 1998).

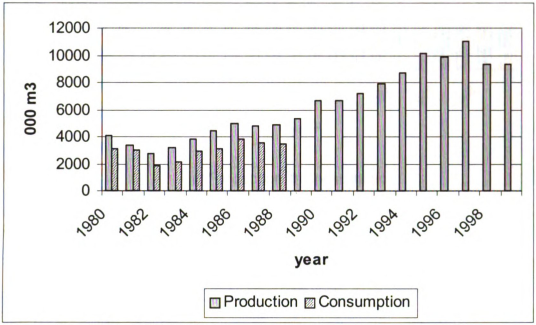
2.4.2 Chile

Commercial plantations are the source of most of Chilean forest products. Government policies have promoted the growth of large-scale plantations, and some 2 million ha are under management (Trade and Investment Guide – Chile, 1999). *Pinus radiata* is the most widely used species, accounting for 87% of the plantations. The establishment of radiata pine started in the early 1940s with average annual plantings increasing significantly after 1974. Most of the plantations are located in Southern Chile, from Concepción to Valdívia (Jélvez et al, 1989). Over the years the government has also successfully encouraged the growth of substantial value-added wood processing industries.

Overall, exports of forest products were expected to reach US$ 2.6 billion in 1996. Chile exports about three-quarters of its forest production and about 80 % of exports are in the form of white cellulose, although newsprint and manufactured wood products (sawlogs and lumber) are also growing commodities (Trade and Investment Guide - Chile, 1999).

2.4.2.1 Quantity Analysis

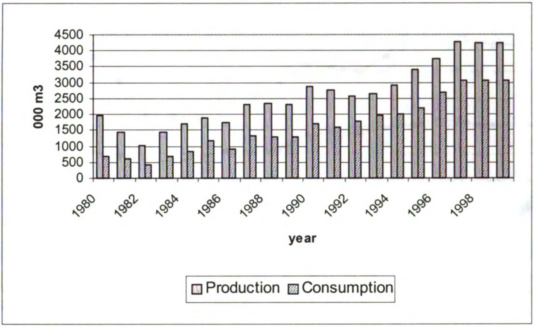
Production and consumption of conifer sawlogs in Chile has increased steadily since 1980 (Figure 2.14). The production followed cycles during 1982-87 and 1989-95, with a respective average annual growth of 12.2 and 13.0 %. Over the entire period an annual increase of 6.4 % was observed, the result of significant investments in the sector, plantations, infrastructure and installed capacity. Sawlog consumption increased 4.5 % per year during 1980-89, apparently following the production cycles. The difference between production and consumption accounts entirely for exports since no imports were observed. Commercial radiata pine sawlogs have been available since the mid-1970s, reaching over 30 % of the total production in the early 1980s.



Note: Consumption = production + imports – exports, not shown after 1989 because FAO does not report total exports and imports of sawlogs after 1989.
Source: FAO (2000b)

Figure 2. 14. Consumption and production of conifer sawlog in Chile (1980-99)

With respect to sawnwood, production and consumption increase increased beginning in early 1980s (Figure 2.15). Production has far exceeded consumption by an average of 41% a year over 1980-99 (64% in 1980 to 27% in 1999). The difference is accounted for sawlog exports, since imports are negligible. Production and consumption followed an erratic path, without well-defined cycles, although with an annual increase respectively of 5.4% and 17.1% over 1980-99.



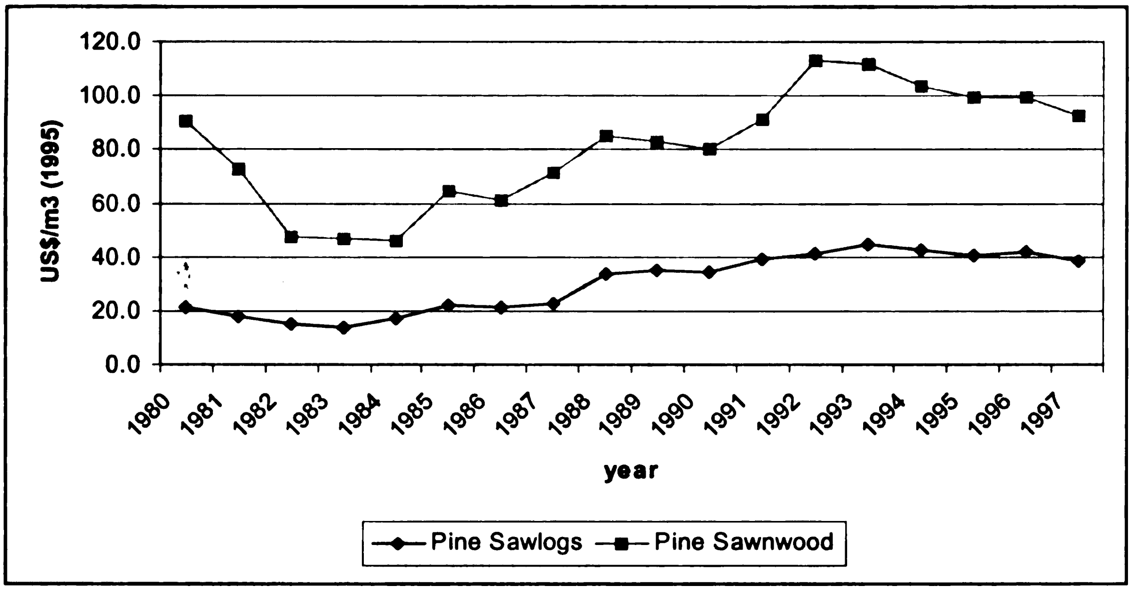
Source: FAO (2000b)

Figure 2. 15. Consumption and production of conifer sawnwood in Chile (1980-99)

2.4.2.2 Price Analysis

Prices of radiata pine sawlog increased from 1984-94, and stabilized thereafter (Figure 2.16; INFOR, 2000). The average price over the period was US$30.6/m^3 (range of US$13.9/m^3 to US$44.2/m^3), with 11.1 standard deviation. According to Cerda (1996), domestic sawlog prices have followed the same path of international sawlogs prices and domestic sawnwood prices.

Prices of radiata pine sawnwood increased over the period 1984-94, with short-term decreases observed in the yearly 1980s and between 1994-97. This pattern coincides with the consumption and production pattern of pine sawlogs and sawnwood (Figures 2.14 and 2.15). The average price over the period 1980-97 was US$80.6/m^3 (range of US$45.7/m^3 and US$113.4/m^3), and 22.2 standard deviation.



Source: INFOR (1998)

Figure 2. 16. Price of radiata pine sawlogs and sawnwood in Chile (1980-97)

2.4.3 Argentina

Production and consumption of conifer sawlogs and sawnwood in the other Mercosur countries is led by Argentina and followed by Uruguay. Paraguay and Bolivia have negligible volumes. Over the period 1980-99, Argentina accounted for an average of 74.1 % of the total production and consumption of conifer sawlogs among those countries, with Uruguay accounting for the remaining 25.9 % (FAO, 2000).

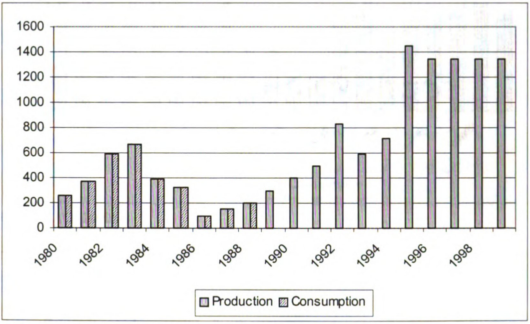
Forest plantation in Argentina started in the 1940s, currently with approximately 770,000 ha of fast-growing species (*Eucalyptus*, pines and willows) concentrated in the Northeastern region (bordering Brazil, Paraguay and Uruguay). Argentina has approximately 400,000 of coniferous plantations and almost the same in non-coniferous species (Flynn, 1999b). Provinces of Misiones and Corrientes in the Northeast have between 327,000-370,000 ha of southern yellow pine (*Pinus taeda* and *Pinus elliottii*), Patagonia has 38,000 ha of Ponderosa pine and *Pinus* "Oregón" and Cordoba has between 32,000-37,000 ha, depending on the source of information (SAGPyA, 1998; MacDonagh, 1997, Corinaldesi et al., 1999). Misiones accounts for 55% of the nation's pine plantation (SAGPyA, 1998). The industrial plantations supply pulpmills and sawmills, which combined consume 5.2 million tons per year (MacDonagh, 1997, personnal communication).

Planting was relatively steady during the early 1990s, but after the arrival of some major Chilean companies and government incentives for plantations, the planting rate increased. The resource base is expected to expand during the next decade (Flynn, 1999b), although it will take a decade or two to create an impact on the forest products market. Growth rate of pine plantations are similar to growth rates for radiata pine in Chile and southern yellow pines in Brazil, varying from as high as 25-35 m3/ha.year in Missiones and Corrientes (20 year rotation) to 18-20 m3/ha.year in Cordoba (23 year rotation) (Corinaldesi, 1999). The major consuming region is the Province of Buenos Aires and some products have also been exported. As an alternative form of transportation, railroad has been used for sawlog export, and some forest companies in Misiones are investing in port facilities along the Paraná river.

2.4.3.1 Quantity Analysis

Production and consumption of conifer sawlogs in Argentina follow the same path given that exports and imports have been negligible. They show two distinct cycles between 1980-99. An increase was noted in the early 1980s, followed by a decrease until

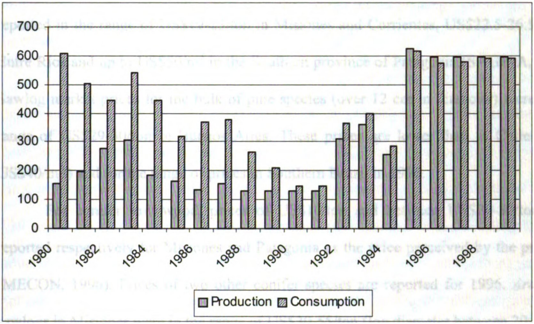
1987. Between 1987-96 a significant increase is observed (average growth of 8.8 % a year for production and consumption), with a peak of over 1.4 million in 1995 (Figure 2.17). However, no change in production and consumption was reported by FAO for 1996-99, a highly unlikely scenario. Pines accounted for the majority of the conifer production: 3.5 million m^3 of pines (94%) and 220,450 m^3 of *Araucaria* (6%) in 1996.



Source: FAO (2000b)
Note: Consumption = production + imports – exports, not shown after 1989 because FAO does not report total exports and imports of sawlogs after 1989.

Figure 2. 17. Consumption and production of conifer sawlog in Argentina (1980-99)

For conifer sawnwood the picture is quite different, with consumption far exceeding production over most of the period 1980-99 (Figure 2.18). This is a result of limited production and relatively higher domestic consumption, balanced by imports that exceeded 80,000 m^3 in 1980. However, in recent years, considering the maturity of pines and investments in sawmilling capacity, production overcame consumption, with exports growing from 5,700 m^3 in 1994 to 34,300 m^3 in 1996 (SAGPyA, 1998).



Source: FAO (2000b)

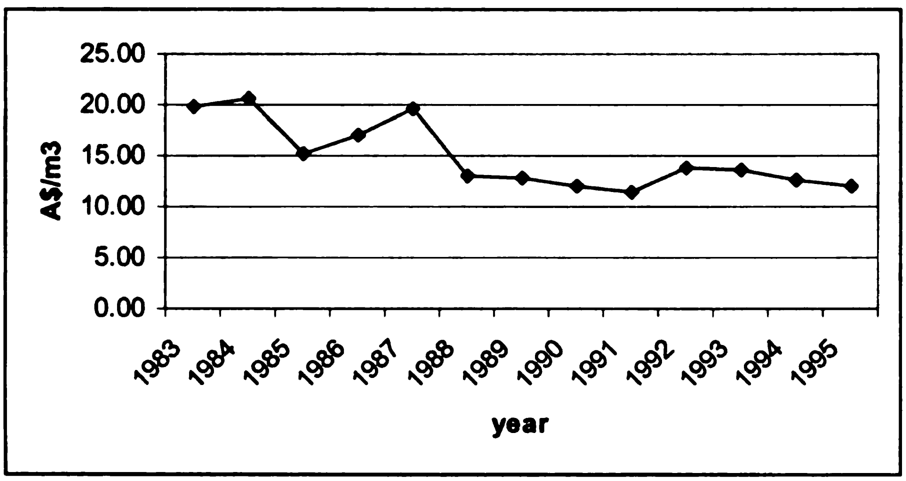
Figure 2. 18. Consumption and production of conifer sawnwood in Argentina (1980-99)

Sawmills produce mainly for the construction sector, located near the harvesting and consumption center (SAGPyA, 1998). Sawmilling is the first link in wood processing industries and its great variety of products has caused the development of low-technology sawmills in the past. This profile has improved in recent years, however, as there were 2200 sawmills with approximately 12,000 employees in 1995 (SAGPyA, 1995). Backward technology is typical of small to medium size sawmills and investment is necessary to compete both domestically and for exports as forests become mature.

2.4.3.2 Price Analysis

Prices of southern yellow pine sawlogs with diameters between 20-30 cm were reported in the range of US$19-23/ton in Misiones and Corrientes, US$22.5-26.5/ton in Entre Ríos and up to US$50/$m^3$ in the Southern province of Patagonia (SAGPyA, 1996). Sawlog market prices for the bulk of pine species (over 12 cm in diameter) were in the range of US$29-30/ton in Buenos Aires. These prices are lower than in Chile (about US$40/m3) and for the range of prices in Southern Brazil in 1996.

For conifer sawnwood, prices of US$10/ton and between US$20-30/ton were reported respectively for Misiones and Patagonia as the price perceived by the producer (MECON, 1996). Prices of two other conifer species are reported for 1996. *Araucaria* sawlogs in Misiones were in the range of US$30-55/ton (log diameter between 20-30 cm) and 'Pino Oregón' in Patagonia as US$70/$m^3$. Figure 2.19 shows the average real gross stumpage price of conifer sawlogs between 1983-95.



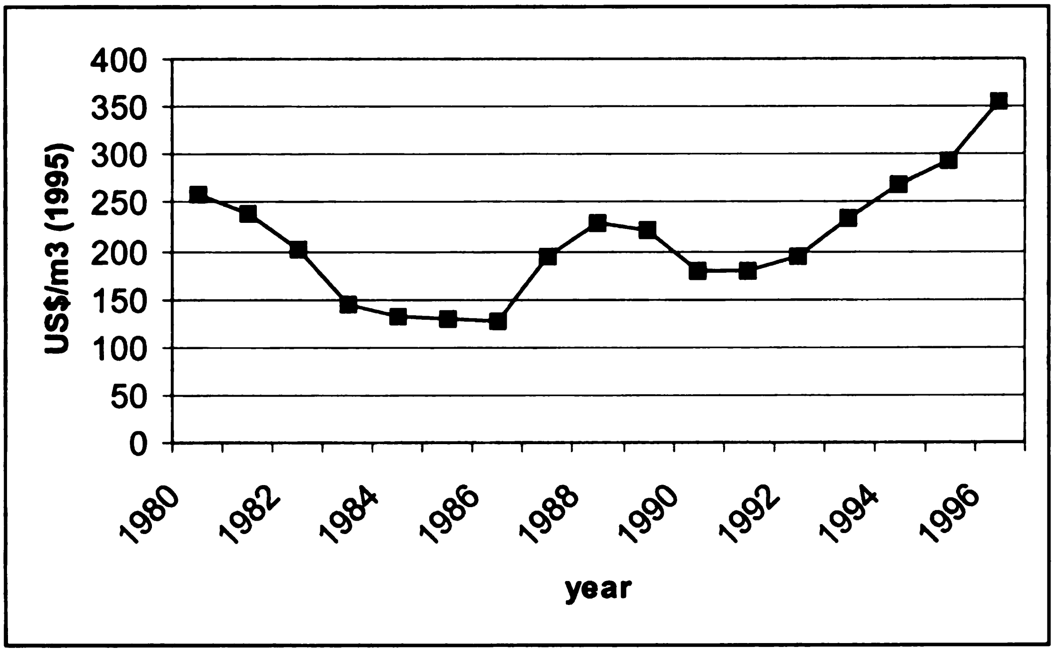
Source – SAGPyA – LaRobla (personal communication, 1999)

Figure 2. 19. Stumpage price of conifer sawlogs in Argentina (1983-95)

Assuming that during the 1980's imports accounted for over 50 % of the domestic consumption of sawnwood in Argentina and in the other minor Mercosur countries, the deflated unit value of imports from FAO (2000) could provide a rough indication of what the trend in domestic prices may look like (Figure 2.20).

Between 1980-89, the average imports of conifer sawnwood represented 50.1% of the consumption, with the unit value of imports decreasing until 1987, and increasing thereafter. The average unit value of imports was US$222.6/$m^3$ between 1980-1996. Such value far exceeds domestic prices as they include transportation costs and tariffs. Figures 2.19 and 2.20 show opposite trends, particularly during the 1990s, indicating that unit value of imports may not be a good proxy for domestic sawnwood prices in Argentina or that other variables could be playing a major role on explaining this difference. Another rough proxy for domestic sawlogs and sawnwood prices in Argentina could be prices in Southern Brazil. However, Graça (personal communication, 1999) suggested that prices in the Argentina would be expected to be higher than prices in Brazil.

Freight costs provide a better idea about the price of different products in different domestic markets. MECON (1996) reports that trucking cost from the Misiones to Buenos Aires (700 miles) was US$ 35/ton and train cost from Misiones to Ibicuy port (600 miles) was US$ 19/ton. The Paraná river is an important transportation route from Misiones, Corrientes and Entre Ríos. As result of becoming a free economy, freight costs from Corrientes or Misiones to Buenos Aires were expected to go to US$ 7/ton by 2000. International freight costs have decreased in recent years, and by 1996 they were approximately US$1,300/container (a 40 feet container with 1,600 cubic feet of wood) from Buenos Aires to Hong Kong, US$1,300-1,600 to Taiwan, and US$1,600 to the Eastern USA (MECON, 1996).



Source: FAO (2000b)

Figure 2. 20. Unit value of imports of conifer sawnwood in Argentina (1980-96)

2.4.4 Uruguay, Paraguay and Bolivia

The other Mercosur countries, Uruguay, Paraguay and the associate member Bolivia have had relatively minor developments in consumption and production of conifer sawlogs and lumber. Their relatively small population results in a smaller demand for such products when compared with Brazil, Chile and Argentina, besides the fact that other species could be substitutes for conifers in those countries.

Uruguay leads the group in area of pine plantation and production of both products. The area of plantations in Uruguay has more than doubled in the past five years, due to an attractive government incentive program, and participation by major international companies (Flynn, 1999b). In Uruguay, total plantations reached 221,616 ha, 88% planted under the new National Forest Management Plan (Law 15,939) from the late 1980's. *Eucalyptus* is the most important species group (MGAP, 1997), with about 80% of the plantations (Flynn, 1999b). For conifer resources, the author indicated that Uruguay has only 50,000 ha or so of pine plantations (mostly loblolly pine). Pine planting is starting to accelerate, but represents modest figures when comparing with other major Mercosur countries. Pines are primarily located in the northern part of the country near the border with Brazil and Argentina. Paraguay is just beginning to establish a plantation forest base, primarily with *Eucalyptus* (Flynn, 1999b). Bolivia has no reported commercial plantation of pine species.

2.5 Conclusions

The descriptive and quantitative analysis in this chapter has shown the trend in forest and industrial development followed by Brazil and the other Mercosur countries over the past decades. The overall picture indicates the search for self-sufficiency in roundwood for solidwood uses and industrial forest products, which created a tremendous opportunity for exporting high value-added products. The forest sector succeeded in establishing large-scale plantations with pines and *Eucalyptus*, which form the forest base for the fiber and solidwood industries, primarily in Brazil and Chile, followed more recently and in a smaller scale by Argentina and Uruguay.

The mix of solidwood products has changed significantly in the past decades in terms of resource use (from native conifer to planted pines) and industrial diversification. It has also changed to a certain extent due to technological advancements. Re-engineered products or raw-material from fast-growing plantations have been gradually substituted for roundwood from natural forests. However, the lack of investments in forest plantations in the recent past in Brazil has raised questions about the future supply of roundwood for industrial processing. Studies have suggested a shortage of roundwood, primarily for sawmilling in the next decade. Such a scenario can change the relative position of Brazil, moving it from a net exporter of most forest products to a net importer of primary products (e.g., sawlogs) or intermediate products (e.g., lumber).

International trade projections indicate modest participation by Brazil in the trade of the major commodities, including solidwood products such as conifer lumber. Among other reasons, this has been the result of high domestic demand. Worldwide forecasts indicate annual growth of sawnwood consumption of 2% a year for the next years

(Revista da Madeira, 1995), conifer sawnwood being a major contributor. Assuming new investments in forest plantations and industrial capacity are made, there are opportunities for Brazil and other major conifer producing countries in Mercosur to expand their participation. However, if investments in plantations for solidwood use are not re-started in Brazil, its industry may face significant challenges and consequent changes. Among them, one can consider a possible migration of sawmills to other regions where forest resources are available at a competitive costs, species substitution (e.g. *Eucalyptus* sawlogs), and even technical and administrative re-structure. Investments on new plantations is mandatory to guarantee the future supply of planted species, although it is a time demanding task that could take up to 20 years before the forests can be harvested for industrial use. On the other hand, Chile and Argentina may benefit from an increasing worldwide demand for forest products and from the comparative advantages they may have.

The solutions to the future challenges that the Brazilian solidwood sector may look complex given the existence of interrelated markets and the profile of the forest sector, which was traditionally extractivist. The demand for roundwood combined with its limited availability in given time and location requires awareness of and action toward the complete productive process: identifying competitors, partnerships, and complementary goals, from both the government and the private sector.

If Brazil is to increase its trade participation in the international arena in products for which it has comparative advantage, while meeting the growing domestic demand in a sustainable manner, immediate investments and changes in forest policies must be undertaken. On the government side, more aggressive and dynamic forest policies should be addressed, ultimately stimulating plantation forestry. In fact, a National Program for Forests was launched in 2000, aimed at creating opportunities for sustainable forest development (including plantations) across the country. On the industrial side, primarily the solidwood industries, a change in the companies' profiles toward better management of resources, managerial innovations, improved competitiveness, and economic strategies that guarantee the continuous flow of raw-material, and even its expansion, for industrial use are all issues to be addressed. In addition, the comparative advantage of Mercosur as a trade agreement and their countries in terms of climate, land availability, and labor are additional factors contributing to expansion of the regional forest sector.

Massive investment in both forestry and forest industries in Brazil, Chile, Argentina, and Uruguay can increase their production and consequent exports of forest products, generating more capital for further investments, as well as job opportunities or reduce imports. Increasing population and improvement of per capita income can play an opposite role in increasing domestic demand for specific forest products.

It is still unclear how each country will address the main forest issues affecting it, and how the free trade agreement may contribute to the overall economic development collectively or individually. However, given the path of forest-industry developments since a few decades ago, there are future opportunities for continuous forest advances in most of the Mercosur countries.

CHAPTER 3

ECONOMETRIC ANALYSIS OF SAWNWOOD AND SAWLOG SUPPLY AND DEMAND IN BRAZIL AND OTHER MERCOSUR COUNTRIES

Introduction

This chapter explores the simultaneous price-quantity relationship between supply and demand for each forest product (sawnwood and sawlogs) and region, as well as their relationship with other supply and demand shift variables. Its objective is to provide estimates of the price elasticities of supply and demand to be used in the spatial equilibrium analysis of Chapter 4. For the purpose of the analysis, the terms lumber and sawnwood are treated interchangeably. As a description, sawnwood includes sleepers, unplaned, planed, grooved, tongued, etc., sawn lengthwise or produced by a profile-chipping process and planed wood, which may also be finger-jointed, tongued or grooved, chamfered, rabbeted, v-jointed, beaded, etc.; excluding flooring (FAO, 1996). Sawnwood exceeds 5 millimeter in thickness (FAO, 1996)

3.1 Objectives

This chapter's main objectives are:

(a) to estimate the simultaneous system of price-endogenous supply and demand equations for sawnwood and sawlogs for Brazil, Chile and Argentina; and

(b) to estimate the price elasticities of supply and demand for each product and region to be used in the spatial equilibrium analysis.

3.2 Literature Review

3.2.1 Demand for and Supply of Forest Products

Decision-makers in the public and private sectors are continuously interested in models that provide equilibrium prices and quantities of wood products in national and regional markets. Foremost, sector models need to address the relevant questions as simply as possible and in an intuitively understandable manner, to contain relevant policy variables or criteria, and to be developed on a geographical scale that is relevant to the users and decision makers (Haynes and Harou, 1993).

Market equilibrium models usually require the estimation of supply and demand for specific commodities and markets under investigation. Therefore, demand and supply of a given commodity have been integral parts of either simple models (e.g. gap analysis in which prices are exogenous) or more complex and detailed models (e.g. spatial equilibrium models).

For most wood products, demand is derived from the sale of all items into which lumber, plywood, and paper (Gregory, 1987) as well as other wood composites are made. Product demand can be treated through econometric analysis, derived from input consumption or output production, and subjective assumptions and/or projections from different sources. Assuming that firms choose the set of inputs that minimizes production costs, the derived demand for each input depends upon a number of explanatory shifters. In fact, product demand in an economic context is considered a function of prices and other shifters, and often these relationships are based on major consuming segments. Demand for lumber, as with most forest products, is a derived demand from the products into which lumber is manufactured or fashioned (Gregory, 1987, and Duerr, 1993).

Hence, factors affecting the consumption of these products such as population and income, and actions of the construction industry, particularly residential housing, indirectly influence the lumber consumption (Gregory, 1987). For the US, both authors suggested that the interest rate, and especially mortgage rates, are major factors in determining the demand for housing, and consequently the demand for lumber. Duerr (1993) pointed out that demand for lumber is usually inelastic, in most of cases the elasticity falls between -0.5 and 0.

On the other hand, demand for stumpage is derived from the demand for manufactured wood products (intermediate or final consumer goods). A typical chain stretches from consumers' demand for housing to lumber to sawlogs to stumpage (Gregory, 1987). Given that there is virtually no substitute for sawlogs in manufacturing lumber, several authors have concluded that the demand for sawlogs must be inelastic (Mead[3], 1966, cited by Gregory, 1987). Duerr (1993) pointed out that derived demand tends to be less elastic than the final consumer price-demand from which is derived.

For the supply side, theorists assume that each firm's production objective is profit maximization (Gregory, 1987), and the theory states that the quantity supplied is determined by the marginal cost of production and the price of the product (Styrman and Wibe, 1986). In an economic context, product supply is the quantity produced as a function of some prices and costs and can be estimated using econometric methods. In roundwood form, this is the derived consumption of roundwood or a derived demand function if it includes price terms (Haynes and Harou, 1993). Haynes (1993) pointed out that stumpage supply is usually treated as a function of timber availability and can be

[3] Mead. J.W. 1966. *Competition and Oligopsony in the Douglas Fir Industry.* Berkeley: University of California Press.

determined from timber inventory or timberland areas, harvest regulations, government fiat, industrial demand, past trends, prices and other factors.

3.2.2 Econometric Studies of Solidwood Products

There have been few studies about the demand and supply of conifer products in Brazil, and most of them did not use an econometric approach, in which prices and quantities are simultaneously estimated. A close look at the studies reveals that the price elasticities of supply and demand for most of the solidwood products have not been estimated, nor were the most relevant econometric parameters affecting them determined. Important studies on the domestic demand and supply of forest products in Brazil include Graça et al. (1988), Sperandio[4] (1989) (cited by Ochoa, 1996), Azeredo (1993), Ramos (1993), Siqueira (1995), Tomaselli (1998) and various articles published in applied journals such as the "Revista da Madeira". However, the studies are basically descriptive, focusing primarily on the historical development of the forest sector and the potential of the forest products markets rather than on econometric modeling. The study by Sperandio (1989) for plywood is an exception.

Studies from other countries, although not related to the Brazilian and the Mercosur conifer industry, may contribute to a better understanding of the nature of the price-quantity relationship of forest products, and to the choice of the major variables affecting supply and demand for econometric modeling. Major studies focusing on the supply and demand of stumpage and solidwood products include Adams and Haynes

[4] Sperandio. J. Demand and Supply of Plywood in the State of Paraná: An Econometric Analysis. Federal University of Paraná, Curitiba, Brazil. Ph.D dissertation 147 p. 1989.

(1980), Buongiorno et al. (1981), Rockel and Buongiorno (1982), Luppold (1984), Shim (1985), Brannlund et al. (1985), Buongiorno and Chang (1986), Newman (1987), Haeri (1987), Nautiyal (1988), McKillop and Liu (1990), Hetemaki and Kuuluvainen (1992), Bigsby (1993), Buongiorno et al. (1994), Kant et al. (1996), Buongiorno (1996), and Manurung and Buongiorno (1997).

The general formulation for a derived demand for any input expresses the quantity demanded as function of demand shifting variables which may include the price of the input, the price of other inputs, and the price of the output (Mosak[5], 1938, and Ferguson[6], 1971; cited by Luppold, 1984). In Luppold's study of the US hardwood lumber market, a recursive econometric model with the causal flow originating from the demand was expressed as function of hardwood lumber price, price of substitute material, wage and interest rates, price of the demanders' output, and a time trend variable (associated with input inefficiencies). In particular, the demand for hardwood lumber was dependent on past rather than current input prices, resulting from the inability of furniture and pallet manufacturers to change their input mix in the short run, making the hardwood lumber market recursive. The price of wooden furniture was used as a proxy for the price of the output, and a price index of hardboard was used as a proxy for the price of substitute materials. In the supply equation, the quantity of lumber supplied was expressed as function of lagged supply, hardwood lumber prices, wage rates, stumpage costs, interest rates and time. A price equation and an equilibrium identity were also added to the model and a two-step, full information method was used to account for autocorrelation.

[5] Mosak, J.L. 1938. Interrelationships of production, price and derived demand. *J. Polit Econ.* 46(6): 761-788.
[6] Fergusson, 1971 *The Neoclassical Theory of Production and Distribution.* Cambridge Univ. Press, London 384. p.

In a study of spatial equilibrium of southern pine lumber in the US, Shim (1985) estimated regional linear demand and supply functions using panel data with regional dummy variables accounting for both intercept and slope (related to price) interactions. The two-stage least squares procedure was used. For the demand equations, explanatory variables included southern pine lumber prices, regional housing starts, an index of industrial production, and an index of Douglas-fir lumber prices. On the supply side, explanatory variables included southern pine lumber prices, an index of electric power prices, an index of petroleum products prices, regional average stumpage prices of southern pine lumber, average hourly earnings (in regional sawmills) and a trend variable.

Brannlund et al. (1985) carried out an econometric analysis of the sawtimber and pulpwood markets in Sweden, which were considered as two interrelated markets. The sawtimber market was assumed to be competitive, with price being determined by the equality of supply and demand, while for the pulpwood market the price was exogenous. A simultaneous system of supply and demand equations for sawtimber was estimated. The demand for sawtimber was function of the price of sawtimber, the ability to pay for sawtimber (as the difference between the world market prices of sawn products and the wage rate in the sawmill industry), and the lagged sawnwood supply. On the other hand, the supply of sawtimber was function of the sawtimber price, pulpwood price, and the harvesting cost. Linear and log-linear variations of the simultaneous model were estimated using OLS (Ordinary Least Squares), 2SLS (Two-Stage Least Squares), and 3SLS (Three-Stage Least Squares). The 3SLS estimates showed minor differences from the OLS estimates.

In a study of the structural change in demand for various forest products in OECD countries, Buongiorno and Chang (1986) estimated demand functions using distributed lags on first logarithm differences of income and price for each country and year. In the absence of consistent price data for the commodity groups for all countries of interest, unit values of imports and exports were used as proxies. The price of a commodity in a given country was estimated as a weighted average of unit values of imports and exports, the weights being the quantities imported and exported. Pooled data for ten countries and the first difference was used to eliminate country effects.

Hetemaki and Kuuluvainen (1992), using simultaneous equations for modeling the Finnish pulpwood market, found long- and short-term effects of stumpage price on demand. However, Youn (1988) argued that since roundwood prices and consumption by intermediate sectors are sometimes not available, demand for roundwood is difficult to model using production theory, explaining why most of earlier studies have been based on the consumption theory. Given data limitations, Buongiorno et al. (1994) modeled demand for forest products in Nigeria as function of per capita income only, using cross sectional and time series data combined from 37 other countries.

In an econometric analysis of the southern softwood stumpage market in the US, Newman (1987) estimated a simultaneous system of linear equations for pulpwood and solidwood. Demand for both pulpwood and sawtimber were regressed as a function of pulpwood and sawtimber prices, and the softwood inventory (as a proxy for harvesting costs). The supply of each product was treated as dependent on its own stumpage prices, the respective prices of the final goods/output (solidwood or pulpwood products), the respective prices of labor and capital and respective one-period lagged production. Since production decisions in the model were assumed to affect both the solidwood and pulpwood markets contemporaneously, the two markets' structural equations could be disturbance-related. For this reason, the three-stage least squares (3SLS) procedure was used to give more efficient, unbiased estimates of the model's coefficients. Linear and logarithmic formulations were tested, although the linear form showed better fit.

Adams and Haynes (1980) developed the Timber Assessment Market Model (TAMM), an extensive spatial modeling of the North American softwood lumber, plywood and stumpage markets designed to provide projections of price, consumption and production trends. TAMM was disaggregated into 'final products' (including lumber, plywood, and pulp) and 'stumpage'. Nine supply regions, for both product groups, and six demand regions for final product were identified. Demand region boundaries were based on the authors' estimates of areas of homogeneous end-use characteristics, while supply region boundaries were dictated by availability of aggregated forest inventory data. All equations were simultaneously estimated by using two-stage least-squares (2SLS). Product demand (in particular lumber demand) was derived by non-econometric means, in which regional demand elasticities were used to estimate the slope of the demand function, while plywood demand was estimated by econometric methods. Product supply was represented as a combination of supply equations and capacity adjustment processes, being modeled as a function of the profit margin for the producer and one period lagged supply. In the stumpage sector, the authors considered that aggregate derived demand and supply interact in each region to determine the level of timber harvest and the stumpage price. As a simplification of their model, sawtimber and pulpwood stumpage were assumed to be perfectly substitutable. The derived stumpage demand was a function of total recovery factors (for lumber and plywood), the product output (lumber and plywood), the roundwood requirement for regional pulp output, and other product outputs (including miscellaneous products, fuelwood, and log exports). Stumpage supply was modeled for public and private owners, with the private supply regressed as a simple function of the regional stumpage price and harvesting at the start of the period inventory (one period lagged supply).

Sarkar (1991), working in a long-run timber model for Bangladesh, specified a system of supply-demand equations, with equilibrium solutions obtained for price and quantity of timber on the stump. The 2SLS procedure was applied. Timber demand was a function of the weighted average real timber price, population, real gross national product and time trend (representing changes in tastes and technology in timber using sectors), using data from 1960-84.

Nautiyal (1988) listed that the main factors determining the demand for lumber in Canada and in the US were the house-building activity in North America and the per capita income, although housing starts itself is dependent on the current income in a society. A natural factor appearing to affect lumber demand is the price of lumber, however empirical work in Canada failed to indicate price as significant in this respect. The apparent paradox from the demand theory may be a problem of measurement, since lumber demand was actually significantly affected by the price of all building materials together. The estimated elasticity of demand for lumber within Canada was 0.19 with respect to housing starts, 1.34 with respect to per capita income, and 10.25 with respect to the price of construction material. The author also suggested that the US lumber market, the country's demography, prices of alternative products and interest rates should affect the demand for lumber in Canada. On the other hand, lumber prices faced by American consumers are perhaps the most important factors affecting the demand for Canadian lumber in the US. This price is determined to a large extent by the exchange rate between both currencies. Other factors such as per capita income, prices of materials and substitutes in the US may have similar effects to those in Canada on demand for lumber.

Manurung and Buongiorno (1997) constructed a non-spatial equilibrium model to simulate a ban on tropical log exports in Indonesia. The Indonesian econometric timber market model was based on Vincent (1992) and included 12 supply and demand equations and 3 equilibrium conditions. Elasticities were obtained by estimating the export supply and import demand equations and the Indonesian demand and supply equations for tropical logs, sawnwood and plywood. Price elasticities of domestic tropical sawnwood demand and supply were respectively –0.51 and 0.59, and for domestic tropical log supply it was 0.45. Domestic demand was modeled using recovery rates. For export supply and import demand price elasticities were respectively 0.49 and –0.80. The model was calibrated with actual data for 1981 and 1989.

Brooks at al. (1995) modeling forest products demand, supply and trade for 18 European countries obtained short-run (domestic and import) demand and (export) supply elasticities for different commodities by estimating system of simultaneous equations. For conifer sawnwood, price elasticities of domestic demand ranged from as low as –0.04 for Italy up to -0.52 for France, and for import demand price elasticities varied between 0.02 and 1.26, respectively for Italy and Germany. With respect to export supply, short-run price elasticities for conifer sawnwood were quite heterogeneous, with positive (0.62 for Germany, although non-significant) or negative (-3.42 and –1.30, respectively for

France and Austria, both significant) values.

A review of literature on the supply of stumpage revealed that supply has not often been related to prices and other shifting variables through econometric methods. In a spatial equilibrium study of forest products in Nigeria, Buongiorno et al. (1994) estimated future timber supply as a function of previous timber inventory and the opinion of local forest production and management experts, assuming sustainable yield in perpetuity. In another study for Indonesia, Buongiorno et al. (1981) considered the maximum regional allowable cut as the log output (supply) constraint to his spatial equilibrium model. Adams (1985), in a spatial equilibrium study of African-European trade in tropical logs and sawnwood, formulated log production as a simple function of the average tropical log price in each African region. Brooks (1987) pointed out that log supply relationships are generally difficult to model because of the strong influences from policy and institutional factors.

Econometric studies have estimated short-run price elasticities of stumpage supply and demand in the US between 0.06 to 0.99, with most being inelastic and below 0.50 (at mean price in the sampling period) (Klemperer, 1996). Short-run stumpage demand also tends to be inelastic with estimates ranging from –0.14 to –0.57 (Cubbage and Haynes[7], 1988; Hyde and Newman[8], 1991, both cited by Klemperer, 1996). The author points out that low timber supply elasticities have led some analysts to worry about the market's ability to provide timber as prices increase, although that is not necessarily a problem in the long run. In an economic framework, the shortage never

[7] Cubbage, F.W., and R.W. Haynes. 1988. Evaluation of the effectiveness of market responses totimber scarcity problems. USDA. Forest Service, *Marketing Research Report # 1149*. Washington DC. 87 p.
[8] Hyde, W.F. and D.H. Newman. 1991. Forest economics and policy analysis: an overview. *Discussion Paper 134*. The World Bank, Washington, Dc. 92 p.

occurs since shortages at one price lead demanders to bid up the price until supply equals demand. The question is not whether the market will supply enough timber since supply will equal demand in a well-functioning economy. Instead it is at which price supply will equal demand (Klemperer, 1996).

3.2.3 Studies of Solidwood Products in Brazil

In Brazil, Ramos (1996) developed a gap model for analyzing demand and supply of pine roundwood for the state of Paraná, with price being treated as exogenous. The analysis was non-econometric and based on the use of conversion factors and material balances. Supply modeling was based on timber inventory and area with plantation forests and estimates of future demand based on assumption of a constant annual growth. The author simulated different scenarios for demand, which to some extent suggested a shortage of future industrial roundwood if current plantation rates did not increase.

Sperandio (1989), cited by Ochoa (1996), in an econometric study of supply and demand of plywood for the state of Paraná, estimated price elasticities through a system of equations. Demand was regressed as function of plywood price, costs of the construction sector, and value of exports, while supply was a function of plywood price, the index of wage in the manufacturing industry, energy price, and sawnwood price. Results from 2SLS estimation showed adjusted R^2s of 0.62 and 0.93, respectively, for supply and demand. Estimates of the price elasticity of demand and supply were respectively -0.83 and 0.92. Overall, the plywood market was inelastic with respect to all variables.

Limitations on accurate and systematic statistics of supply, demand and prices of forest products may be a major reason for the lack of other econometric studies in Brazil and in other Mercosur countries. In Brazil and Chile, studies on supply and demand of forest products have been more descriptive and related primarily to the historical development of plantation forests, the industrial production over the decades, and future perspectives. For Brazil, a major concern regarding the supply and demand for pine roundwood, in particular for sawmills, is the future capacity of the forest sector to fulfill the existing and growing demand for sawlogs. This is particularly important given the close integration of the pulpwood market (a major supplier of pine sawlogs) with the pulp and papermills, as well as the fact that any adjustment to produce commercial volumes of sawlog will take a considerable period of time.

3.3 Theoretical Framework

In an economic context, market prices and quantities traded are arrived at simultaneously and endogenously as the result of interactions between consumers and producers. In case of primary products, such as stumpage, consumers are firms, which produce intermediate products for other end-uses.

With demand, supply, and prices being endogenously determined, an appropriate modeling approach using time-series data is through a simultaneous system of equations (Bigsby, 1993). A classical linear representation of a simultaneous two equation model of market equilibrium for one region consists of three (endogenous) variables, supply, demand, and price, as well as other shifter variables (here quantities are represented as the dependent variable):

$$Q_t^d = a_0 + a_1 \cdot P_t + \sum_{i=1}^{n} a_j \cdot X_t + u_t \qquad \text{demand function (1)}$$

$$Q_t^s = b_0 + b_1 \cdot P_t + \sum_{i=1}^{m} b_i \cdot Y_t + v_t \qquad \text{supply function (2)}$$

$$Q_t^d = Q_t^s \qquad \text{market clearing condition (3)}$$

where:

$Q^d{}_t$ and $Q^s{}_t$ are quantities of the product demanded and supplied respectively at time t, a_0 and b_0 are intercepts of the demand and supply functions respectively, P_t is the product price at time t, a_1 and b_1 are the slopes of demand and supply functions respectively, X_t and Y_t are the vectors of demand and supply input prices and/or shifters respectively, a_j and b_i are the vectors of coefficients of the n demand and m supply shifters respectively, and u_t and v_t are the error terms. The expression $\Sigma_n\, a_j.X_t$ can represent the price of substitutes, and the measure of intermediate or end use demand activity. The expression $\Sigma_m\, b_i.Y_t$ can represent the price of other inputs and a measure of the technology employed in the production.

In addition to the analysis of the effect that shifting demands (say lumber demand) might have on the prices (say stumpage prices), one should also consider the change in expectations and how they are formed. On the supply side, for instance, sawtimber owners could increase expectations and anticipate a decided rise in lumber and stumpage prices by observing past increases in both lumber and stumpage prices and reading about a growing consumption of lumber. This change in expectations would raise the so-called reservation price (price necessary to persuade the owner to sell a particular volume or area) of the owner's timber, making sawlogs more costly by shifting the sawlog supply curve upward and, if the increase is widespread in the industry, cutting back production. On the other hand, if the demand curve for lumber shifted inward and lumber price declined, then the opposite forces are set in motion. However, Gregory (1987) has suggested that a decline in lumber price, unless very prolonged, is unlikely to have a seriously depressing effect on price expectations of timber owners based on historical lumber and stumpage prices. On the demand side, the demand for logs is derived from an anticipated demand for lumber, and this is consequently influenced by the mill owners' expectations of consumption of products in which lumber is used, such as furniture or housing construction. Gregory (1972) indicates that since expectations are difficult to quantify, this influence will reduce the accuracy of the estimated demand, and because expectations are generally more volatile than actual occurrences one should anticipate substantial fluctuations in log demand, perhaps even more than would occur in the lumber market itself.

Unbiased parameter estimates can be obtained by estimating the reduced form of the system of equations using the OLS, or by estimating directly the system of equations by 2SLS, instrumental variables (IV) techniques (Bigsby, 1993), or 3SLS.

The model (formulas above) can be expanded to a spatial equilibrium model and formulated by econometric or operations research techniques. The equilibrium prices and quantities among separate geographic regions will be the solution for the problem.

3.4 Empirical Method

The timber species groups and products in this study were based on their end use characteristics, importance and data availability. Similar decisions were taken in defining regions of interest and the boundaries of the study.

Products were aggregated, unless otherwise noted, into two broad categories: conifer sawlogs and sawnwood as defined by FAO (1996). Regions were grouped as individual countries for Argentina, Brazil and Chile. Estimation of demand and supply equations for Brazil, however, was made for the Southern region where most of the pine plantations and sawmills are located. Given data limitations, an attempt to estimate elasticities for the other Mercosur countries (Uruguay, Paraguay, and Bolivia) was made by grouping them with Argentina. The systems of simultaneous domestic supply and demand equations for each product (conifer sawlogs and sawnwood) were regressed for each region.

Although the spatial equilibrium model is intended to estimate the optimum equilibrium for pine products (sawlog and sawnwood), conifers in general were used in this chapter for most of the regions as a proxy for pines given the lack of consistent time-series prices and quantities across the selected regions. In the Southern Brazilian states, plantations with conifers are composed of southern yellow pines (*Pinus taeda and Pinus elliottii*) and Paraná pine (*Araucaria angustifolia).* Pines have dominated the market for conifer sawlogs and secondary products since the 1980s (Table 3.1). In Chile, radiata pine (*Pinus radiata*) is the sole large-scale commercial conifer species, and therefore FAO data on coniferous species already reflects pine. In Argentina and Uruguay southern yellow pines are the primary conifers traded.

Table 3. 1. Coniferous species by region

REGIONS	CONIFER SPECIES		
	PLANTATION FORESTS		Natural Forests
	Large-scale	Small-scale	
Southern Brazil	Southern yellow pines[1]	Paraná pine[2]	Paraná pine[2]
Rest of Brazil	Tropical pines[3]	Southern yellow pines[1]	None
Argentina and Uruguay	Southern yellow pines[1]	Radiata pine[4] (Uruguay)	Paraná pine[2] (Argentina)
Paraguay and Bolivia	None	None	None
Chile	Radiata Pine[4]	None	Chilean pine[5]

Note:
[1] - *Pinus taeda and Pinus elliottii,*
[2] - *Araucaria angustifolia,*
[3] - ***Pinus caribaea*** (different varieties) and other minor tropical pine species,
[4] - *Pinus radiata,*
[5] - *Araucaria araucana.*

3.4.1 Model Structure

Consumers and producers in each region were assumed to participate in a single aggregate market, subdivided in conifer sawnwood and conifer sawlog markets (Figure 3.1). Equilibrium prices in the stumpage market affect the domestic sawnwood market (relationship 1) and vice versa (relationship 2). Such mutual effects are reflected in the system of equations by the explanatory variables, primarily prices, indices (wage and construction indices, interest rates) and quantities. The econometric models in this study extend the models reviewed from the literature by incorporating specific and important variables for each country under investigation and by comparing different specifications and estimation procedures. The models are also in accordance with the economic theory of simultaneously estimating quantities (demand/supply) and prices.

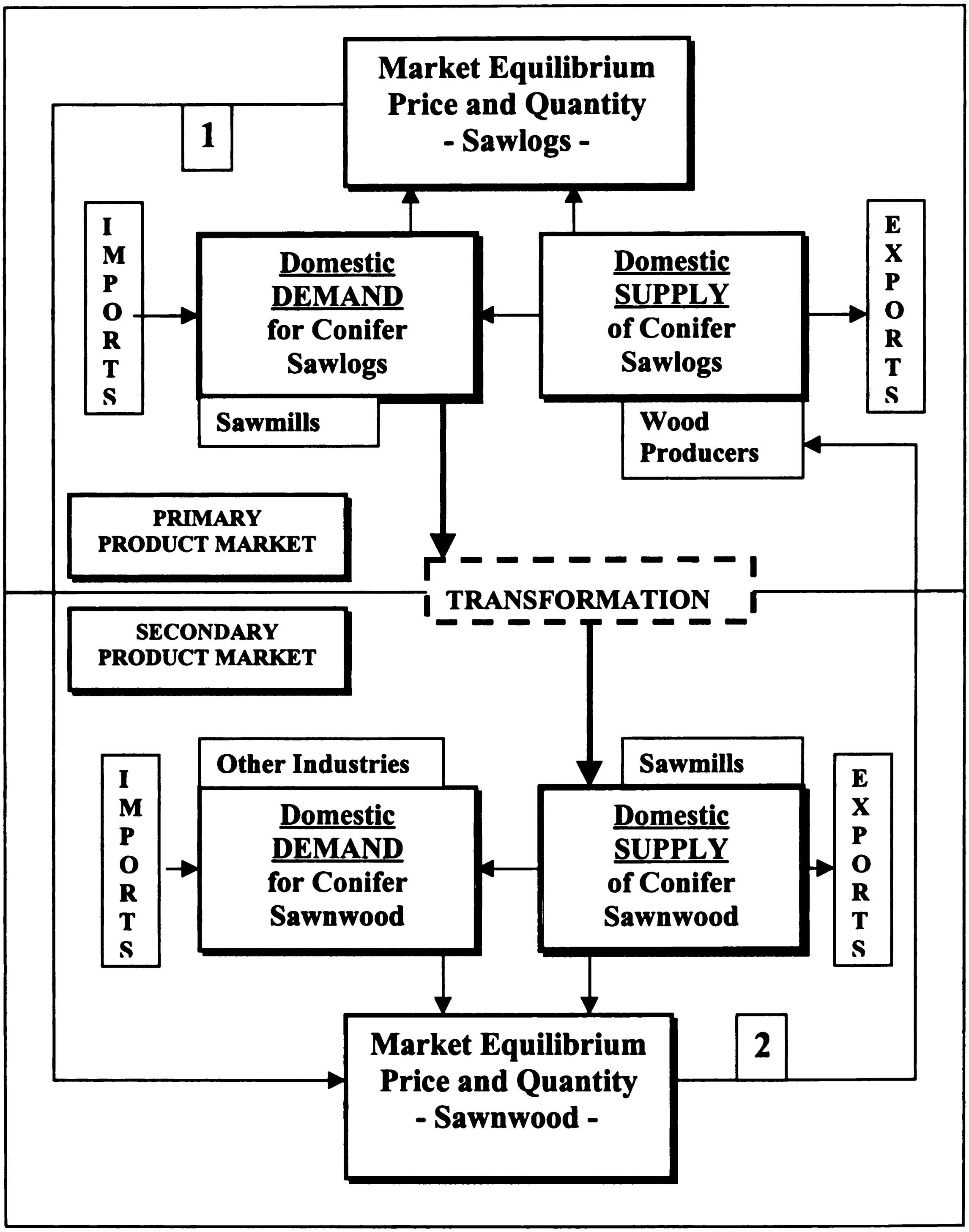


Figure 3. 1. Diagram of the regional domestic sawlog and sawnwood supply and demand model for each region

- Conifer Sawnwood Market

The general system of demand and supply equations of conifer sawnwood for each region is defined as follows:

$$D_{CSWt} = a_0 + a_1 P_{CSWt} + a_2 ICA_t + a_3 W_t + a_4 P_{NCSWt} + a_5 I_t + a_6 T + a_7 D_{CSWt-1} + u_t$$

$$S_{CSWt} = b_0 + b_1 P_{CSWt} + b_2 P_{CSLt} + b_3 W_t + b_4 P_{NCSLt} + b_5 T + b_6 S_{CSWt-1} + v_t$$

$$D_{CSWt} = S_{CSWt} + I_{CSWt} - E_{CSWt} \qquad \text{(material balance)}$$

where:

D_{CSWt} is the derived demand for conifer sawnwood, representing the forest input for the sawnwood processing industry in time t;

S_{CSWt} is the supply of conifer sawnwood, representing the sawmills' output in time t;

P_{CSWt} is the conifer sawnwood price, representing the input price for demand and the output price for supply in time t;

ICA_t is the index of construction activity, representing the price of the demand output in time t;

W_t is the index of wages, representing a price of other inputs in the demand supply equations in time t;

P_{CSLt} is the sawlog price, representing the price of the supply input in time t;

P_{NCSWt} is the non-conifer sawnwood price, and represents the price of substitute inputs in time t;

I_t is an index of economic activity expressed by per capita GDP in time t;

T is a trend variable;

$D_{CSW_{t-1}}$ is the one period lagged demand for sawnwood in time t;

P_{NCSL_t} is the non-conifer sawlog price, and represents the price of substitute inputs in time t;

$S_{CSW_{t-1}}$ is the one period lagged supply of sawnwood in time t;

I_{CSW_t} is the imports of conifer sawnwood in time t;

E_{CSW_t} is the exports of conifer sawnwood in time t;

u_t and v_t are respectively the error terms of the demand and supply equations.

The time variable is included to remove any trend associated with increased input inefficiencies or efficiencies (e.g. technological change), which may have occurred over time. Consumption was estimated by the material balance relationship for each region, with inventories assumed clear in the same year.

- Conifer Sawlog Market

The general system of demand and supply equations of conifer sawlogs for each region is defined as follows:

$$D_{CSLt} = a_0 + a_1 P_{CSLt} + a_2 P_{CSWt} + a_3 W_t + a_4 P_{NCSLt} + a_5 I_t + a_6 T + a_7 D_{CSLt-1} + u_t$$

$$S_{CSLt} = b_0 + b_1 P_{CSLt} + b_2 P_{CSWt} + b_3 W_t + b_4 P_{NCSLt} + b_5 T + b_6 S_{CSLt-1} + v_t$$

$$D_{CSLt} = S_{CSLt} + I_{CSLt} - E_{CSLt} \qquad \text{(material balance)}$$

where:

$DCSL_t$ is the derived demand for conifer sawlogs, representing the forest input for the sawmills in time t;

$SCSL_t$ is the supply of conifer sawlogs, representing the output of wood producers in time t;

$PCSL_t$ is the conifer sawlog price, representing the input price for demand and the output price for supply in time t;

$PCSW_t$ is the conifer sawnwood price, representing the price of the sawmill output in time t;

W_t is the index of wage, representing a price of other inputs for demand and supply in time t;

$DCSL_{t-1}$ is the one period lagged demand for sawlogs in time t;

$PNCSL_t$ is the price of non-conifer sawlogs, and represents the price of substitute inputs for demand or the price of substitute outputs for supply in time t;

I_t is an index of economic activity expressed by per capita GDP in time t, (an indirect explanatory variable since demand for sawlogs - the dependent variable - is a derived demand);

$SCSL_{t-1}$ is one period lagged supply of sawlogs in time t;

T is a trend variable;

$ICSL_t$ is the imports of conifer sawlogs in time t;

$ECSL_t$ is the exports of conifer sawlogs in time t.

u_t and v_t are respectively the error terms of the demand and supply equations.

The systems of equations for sawnwood and sawlogs were estimated separately. In order to link both systems, which where estimated independently, the price of conifer sawnwood was used as the output price in the sawlog demand equation, and the price of conifer sawlogs was used as an input price in the sawnwood supply function (Figure 3.1).

The simultaneous systems were modeled by testing linear and logarithmic functional forms for each commodity and region. The 2SLS and 3SLS procedures were used to determine the parameter estimates.

3.5 Data Sources

Secondary annual data for the estimation of the system of equations were obtained from various sources. Aggregate data at country level were used for Brazil, Chile, and Argentina, and for Southern Brazil depending on data availability (Appendices 2-8).

Production, exports and imports of conifer sawlogs and sawnwood, as well as total value of exports and imports for each individual country were taken from FAO Forest Products Yearbooks, 1980-1998 (FAO, 2000). The quantity consumed was estimated as the sum of production and imports minus exports. For Brazil, FAO data on conifer sawlog production have been reported as almost constant values since the early 1980s and a preliminary attempt to use those quantities failed to generate meaningful and reliable coefficient estimates. As an alternative, data for domestic production and consumption of conifer sawlogs were taken respectively from IBGE and ABPM. Production of conifer sawlogs is the total 'other roundwoods' production from plantations (except pulpwood and firewood/fuelwood) between 1980-96. Such production is assumed to represent primarily pine sawlogs, given that sawlogs from other major plantation species were negligible until very recently. Consumption of conifer sawlogs was estimated for 1983-95 from data on pine lumber production reported for the years 1980, 1983, 1986, 1987, 1990, 1991, 1994 and 1995 (Revista da Madeira, 1996) by using the ratios of conifer sawlogs to conifer sawnwood from FAO for each year. Quantities for years not reported were estimated through interpolation by using average growth per year between two contiguous reported periods.

All monetary values were expressed in domestic currencies and deflated to 1995. Current prices and other monetary values were deflated using the Consumer Price Index (CPI) for each country from IADB (2000). For Brazil, the specific deflator was the "General Price Index" (IGP - 1994=100) for the period 1980-97 (FGV, 1998).

Prices of conifer sawlogs and sawnwood were computed from various sources depending on the country. For Brazil, unit values of production of IBGE 'other roundwoods' production from plantations for Southern Brazil between 1980-95 were used as proxies for market prices of pine/conifer sawlogs. Annual prices of pine roundwood (stumpage and market prices) for the state of Paraná between 1989-95 from SEAB-EMBRAPA/CNPF were used for comparison. Prices of conifer sawnwood in Brazil between 1981-95 came from APBM, published in Revista da Madeira (1996). For Chile, domestic prices of radiata pine sawlogs and sawnwood, as well as for some hardwood species, between 1980-98 came from INFOR (2000) and from FAO-Chile (personal communication, 1997). For Argentina, domestic prices of conifer sawlogs were obtained from SAGPyA (personal communication, 1999) from 1983-95, and unit values of imports came from FAO (2000).

Other sawlog prices for Brazil and Argentina, although not used in the regression analysis, were used for verification and use in the spatial equilibrium analysis (Chapter

4). They included monthly pine sawlog prices for the state of São Paulo/Brazil from 1993-96 (FF, 1998); Revista da Madeira (various years); and Angelo (1998). For Argentina, additional time-series price data came from SAGPyA (1996).

Exchange and interest rates, consumer price indexes, population and total and per capita GDP were obtained from the IADB internet database (IADB, 2000) and from the World Tables (Word Bank, 1995). The World Tables were also the source of GDPs and GDP deflators. Average hourly earnings (or a wage index), and construction cost indexes came from varied sources depending on the country (Appendices 1-8).

The systems of equations were estimated using EViews®, version 3 (EViews, 1998a and 1998b). In EViews®, F-statistic is reported only if the equation is specified in list form and since systems cannot be specified in list form, the F-statistic cannot be directly reported (EViews, personal communication). The equivalent of the F-statistic was obtained by carrying out a joint test that all slope coefficients are equal to zero as a Wald coefficient test.

3.6 Results and Discussion

The period of the analysis varies by country and commodity. For Brazil and Argentina the period is from 1982-95 and for Chile, from 1980-98, for which time-series of domestic prices of sawlogs and sawnwood were available. Combinations of explanatory variables in each system of equations were tested in both the linear and logarithmic functional forms using both 2SL and 3SLS estimation procedures. Results of the estimates represent the equations with the most meaningful coefficient and overall goodness-of-fit. The major criteria for choosing models were the expected signs and magnitude of the coefficients of the price variables, t-statistics, adjusted R^2, and the Lagrangean Multiplier (LM) test statistics. In some cases, more parsimonious models without some of the proposed explanatory variables (Section 3.4), generated better results.

3.6.1 Brazil

The initial estimation of the structural equations using conifer sawnwood and sawlog data from FAO failed to provide meaningful results. This may be related to the fact that FAO data on production, exports and imports of conifer sawlogs were reported with almost the same values between 1985-89, and 1991-95. In addition, the data aggregated both *Araucaria* and pine products, which are not homogeneous. Alternative estimates were obtained with domestic data from IBGE (1999) and ABPM (1994).

Results of the structural equations estimation (log and linear forms, through 2SLS and 3SLS) for conifer sawnwood and sawlogs are shown in Tables 3.2 and 3.3, respectively. For serial correlation, the Breusch-Godfrey test statistic, also called Lagrange Multiplier (LM) test statistic is reported. It is an appropriate test for systems of equations and when lagged dependent variable is present in an equation. The Durbin-h statistic (DW-h) is another alternative to test serial correlation in autoregressive models, however it is a large-sample test. The LM test is statistically more powerful not only in the large samples but also in the finite, or small, samples, being preferable to the DW-h test (Gujarati, 1995; Korosi, Matyas and Szekely, 1992). The LM test statistic was computed for each equation to the 5th order autoregressive for residuals using 2SLS.

Results obtained using the 3SLS procedure tended to generate more significant coefficients, although their magnitude did not depart significantly from the 2SLS results. Discussion in this section focuses on the 3SLS results. Overall, the signs and magnitudes of the own-price coefficients are consistent with production and consumption theory, and within expected bounds. The adjusted R^2s are close to 50% for the supply and between 61%-68% for the demand. The F statistic was highly significant for all the equations.

Table 3. 2. Estimated structural equations for conifer sawnwood in Southern Brazil (1982-95)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
- Demand for Sawnwood (m^3)				
Intercept	3.88 (1.51)	2346984 (1.59)	4.50 (2.52) *	2663738 (2.59) *
Conifer sawnwood price (1995 R$/m^3)	**-0.04** **(-1.81)**	**-513** **(-2.20)** *	**-0.04** **(-2.53)** *	**-480** **(-2.96)** **
Dummy for 1986	0.04 (1.34)	700661 (1.92)	0.03 (1.78)	653502 (2.59) *
Interest rate	0.005 (0.67)	6006 (1.05)	0.003 (0.65)	4849 (1.23)
GDP (1995 US$)	0.23 (3.60) **	2.8E-06 (3.56) **	0.19 (4.39) **	0.000 (4.43) **
Real minimum wage (index 1990)	0.08 (3.30) **	4568 (3.05) **	0.07 (4.75) **	3996 (3.85) **
Lagged demand for sawnwood (m^3)	0.35 (2.09) *	0.40 (2.42) *	0.38 (3.25) **	0.41 (3.53) **
Adjusted R^2	0.68	0.62	0.66	0.61
LM statistic ***	0.17	0.19	0.17	0.19
- Supply of Sawnwood (m^3)				
Intercept	10.03 (3.67) **	5699225 (3.79) **	9.55 (4.14) **	5452035 (4.31) **
Conifer sawnwood price (1995 R$/m^3)	**0.005** **(0.27)**	**748.40** **(0.55)**	**0.002** **(1.15)**	**565.56** **(0.49)**
Conifer sawlog price (1995 R$/m^3)	-0.05 (-1.86)	-13601.44 (-1.95)	-0.04 (-1.70)	-11224.90 (-1.93)
Lagged supply of conifer sawnwood (m^3)	0.38 (2.22) *	0.37 (2.14) *	0.41 (2.84) *	0.39 (2.69) **
Adjusted R^2	0.48	0.49	0.47	0.48
LM statistic ***	0.28	0.27	0.27	0.28
F-statistic	2.1E+07	77696	3.2E+07	117658

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5th order autoregressive using 2SLS estimator

- **Conifer Sawnwood**

For conifer sawnwood, the demand equation was a function of its own price, a dummy variable (=1 for 1986 to account for price variability for that year), interest rate, the total GDP, wage index, and one-year lagged demand. In the supply equation, explanatory variables were the own-price, the input price (conifer sawlogs), and one-year lagged supply (Table 3.2). Time trend was not included to reduce collinearity problems. The resulting, adjusted R^2s were relatively low (0.47-0.49) for the supply equations and higher (0.61-0.68) for the demand equations, depending on the estimation procedure. The LM test statistics do not show evidence of serial correlation for either equation or specification. The own-price coefficients (conifer sawnwood price) were both with the expected sign and significant at the 1% level for demand (linear form-3SLS) and non-significant for supply.

For sawnwood demand, the logarithmic function showed a slightly higher adjusted R^2 than for the linear form. In both forms the coefficients were mostly significant and with the proper signs: demand for sawnwood was negatively related to its own-price, and positively related to GDP and one-year lagged demand. Although unexpected positive signs were found for wage index, a possible explanation for this sign could be the economic of scale of lumber-consuming companies. The own-price elasticity was significant and negative, with an extremely low value of -0.04 and -0.05, respectively for the log and linear forms in the 3SLS (Tables 3.2 and 3.9 - about discussion on elasticities).

For sawnwood supply, in both functional forms and estimation procedures, supply was positively related to its own price although non-significant (Table 3.2). A significant coefficient with the expected positive sign was noted for the lagged supply. An expected negative sign was found for sawlog price (although not significant), indicating an inverse relation with sawnwood supply. The own-price elasticity was positive but not significant, with an extremely low value of 0.002 and 0.006, respectively for the log and linear forms (Tables 3.2 and 3.10 – about discussion on elasticities). Given the data limitations for sawnwood demand, an attempt was made to estimate a single equation for sawnwood supply using ABPM data from 1982-96. Results through the OLS procedure failed to provide meaningful coefficients.

- Conifer Sawlogs

For conifer sawlogs, the failure to obtain meaningful results using FAO data led to the use of a combination of IBGE (production and proxy for prices) and ABPM (consumption estimates) data and the estimation of models, with good fit and some highly significant coefficients (Table 3.3). The demand equation was regressed as a function of its own price, the price of the output (conifer sawnwood), the interest rate, wage index, and a proxy for the price of hardwood sawlogs. The supply equation was regressed as function of its own price, time trend, and one-year lagged supply. Data were assumed to represent production and consumption of conifer sawlogs (primarily pines) in Southern Brazil, where the sawmilling of softwood species is traditionally concentrated. Overall, demand and supply equations of conifer sawlogs had adjusted R^2s above 0.80 for the logarithmic specification and above 0.65 for the linear form. In general, coefficients were significant at 1% or 5% significance level. The LM test statistics do not show evidence of serial correlation for both specifications.

Table 3. 3. Estimated structural equations for conifer sawlogs in Southern Brazil (1983-96)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
- Demand for Sawlogs (m^3)				
Intercept	8.59 (2.61) *	6060691 (0.91)	9.35 (3.84) **	5626561 (1.14)
Conifer sawlog price (1995 R$/$m^3$)	**-2.18** **(-2.32)** *	**-557287** **(-2.03)**	**-1.94** **(-2.93)** **	**-519079** **(-2.61)** *
Conifer sawnwood price (1995 R$/$m^3$)	-0.20 (-0.54)	8391 (0.30)	-0.40 (-1.65)	-4369 (-0.22)
Interest rate	0.24 (1.63)	39113 (0.33)	0.29 (2.84) **	54392 (0.62)
Real minimum wage (index 1990)	3.17 (4.43) **	163124 (2.37) *	3.17 (6.08) **	171348 (3.36) **
Non-conifer sawlog price (R$/$m^3$)	0.13 (0.18)	45775 (0.45)	-0.06 (-0.12)	37950 (0.51)
Adjusted R^2	0.81	0.65	0.82	0.65
LM statistic ***	0.73	0.23	0.73	0.23
- Supply of Sawlogs (m^3)				
Intercept	7.12 (1.92)	-2600873 (-0.94)	5.74 (1.95)	-2631568 (-1.12)
Conifer sawlog price (1995 R$/$m^3$)	**0.24** **(1.13)**	**61024.60** **(1.19)**	**0.26** **(1.43)**	**59906.40** **(1.38)**
Time trend	0.06 (3.38) **	370089 (2.91) **	0.05 (3.80) **	327161 (3.12) **
Lagged supply of conifer sawlogs (m^3)	0.46 (2.10) *	0.63 (2.97) **	0.55 (3.17) **	0.70 (3.99) **
Adjusted R^2	0.83	0.84	0.83	0.84
LM statistic ***	0.72	0.24	0.72	0.24
F-statistic	200136	915	252558	1153

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5^{th} order autoregressive using 2SLS estimator

For sawlog demand, a high adjusted R^2 (0.82) was obtained with the log form. The price of sawlogs was highly significant and with the expected negative sign. The interest rate and the real minimum wage rate were unexpectedly positively correlated to the demand for sawlogs, and significant depending on the functional form and estimation procedure (Table 3.3). One explanation for the positive signs of these variables could be related to the economy of scale of sawmills.

For sawlog supply, both functional forms showed higher adjusted R^2s, around 0.83. Serial correlation was corrected by adding lagged supply as an explanatory variable. In both functional forms the signs of the coefficients were as expected for all variables, although not necessarily significant. The supply of sawlogs was positively related to its own price and with the trend variable, which confirms the increased production of pine sawlogs from plantations since the early 1980s in Southern Brazil (Table 3.3).

Estimates of short-run price elasticities of supply and demand of sawnwood and sawlog in Brazil are summarized in Table 3.9. Discussion and comparison with findings from other studies are also presented.

3.6.2 Chile

Estimations of the logarithmic and linear functional forms for both conifer sawnwood and sawlogs were performed for Chile (Tables 3.4 and 3.5). Overall the signs and magnitude of the coefficients are consistent with production and consumption theory and within the expected bounds, except for a few variables in both equations. The adjusted R^2s are high (over 0.80), the F statistics are significant, with an overall good fit for the equations. Coefficient estimates obtained through 2SLS and 3SLS procedures differed to a certain degree, and 3SLS tended to generate more significant coefficients.

- Conifer Sawnwood

The conifer sawnwood demand equation was regressed as function of its own price, an index of construction cost, the interest rate, and the exchange rate. Both the log and linear functional forms generated equations with high adjusted R^2s (0.89 and 0.88 respectively) either with 2SLS or 3SLS procedures and significant F statistic for all the equations (Table 3.4). However, the linear form equations seemed to show a better fit, with more coefficients being significant. This is particularly true for the estimates of the own-price coefficient which were highly significant (α=0.01) in the linear form and not significant in the log form. Coefficients with unexpected positive signs and which were highly significant were the construction cost index and the exchange rate. As construction cost increases, demand for conifer lumber would be expected to decrease since it represents a cost for consumers. An explanation for the positive sign is the possibility that the construction cost index includes materials other than conifer lumber, and therefore lumber could be a substitute for other construction materials. For the exchange rate, an increase in the rate would favor more exports to the detriment of the domestic market, although an indirect effect of a higher exchange rate could favor an increase in the derived demand. Although there is no clear explanation for such signs, both variables were kept in the model as they improved the overall fit of the system. Demand for conifer sawnwood was negatively related to its own-price and to interest rate, as expected. Adding GDP as an explanatory variable to the demand equation failed to generate a system with a good fit and meaningful results (not shown).

Table 3. 4. Estimated structural equations for conifer sawnwood in Chile (1980-98)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	**Linear**	**Logarithmic**	**Linear**
- Demand for Sawnwood (m^3)				
Intercept	-3.92	-2135616	-0.64	-1883579
	(-0.68)	(-2.37)*	(-0.15)	(-2.49) **
Conifer sawnwood price (1995 P\$/m^3)	**-0.29**	**-57.15**	**-0.17**	**-55.28**
	(-0.84)	**(-3.35)** **	**(-0.59)**	**(-3.79)** **
Construction index	2.40	2199	1.85	2060
	(2.46) *	(3.69) **	(2.49) *	(4.09) **
Interest rate	-0.26	-20185	-0.28	-20720
	(-1.45)	(-1.84)	(-2.12)*	(-2.39) *
Exchange rate (1995 P\$/m^3)	0.69	6979	0.64	6848
	(5.01) **	(6.90) **	(6.21) **	(8.22) **
Adjusted R^2	0.89	0.88	0.89	0.88
LM statistic ***	0.48	0.35	0.48	0.35
- Supply of Sawnwood (m^3)				
Intercept	8.11	584156	10.49	579352
	(2.66)*	(1.40)	(4.94) **	(1.72)
Conifer sawnwood price (1995 P\$/m^3)	**0.11**	**13.57**	**0.84**	**28.19**
	(0.13)	**(0.32)**	**(1.39)**	**(0.89)**
Lagged sawnwood exports (m^3)	0.42	0.59	0.14	0.44
	(1.44)	(2.46) *	(0.91)	(2.60) *
Time trend	0.04	109132	0.07	139878
	(1.18)	(1.85)	(2.79) **	(3.18) **
Real minimum wage (index 1990)	-0.19	-1539	-0.38	-1021
	(-0.57)	(-0.33)	(-1.70)	(-0.29)
Conifer sawlog price (1995 P\$/m^3)	-0.03	-70.44	-0.60	-108.59
	(-0.03)	(-0.59)	(-1.00)	(-1.21)
Adjusted R^2	0.85	0.90	0.84	0.90
LM statistic ***	0.02	0.02	0.02	0.02
F-statistic	283070	2347	267710	2436

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5^{th} order autoregressive using 2SLS estimator

The conifer sawnwood supply equation was regressed as function of its own price, the one-year lagged exports, the one-year lagged supply and the one-year lagged price (Table 3.4). Both functional forms showed adjusted R^2s above 0.82, with most of the coefficients significant. Signs of most of the coefficients were as expected. Domestic supply of conifer sawnwood was positively related with its own-price and with the one-year lagged supply and negatively related with the exports. The positive sign of the lagged supply coefficient indicates that supply tends to increase from one year to another, as observed. Increasing exports in the previous year may lead to a decrease in the supply of the domestic market. The sign of the coefficient of the one-year lagged own price, however, was not as expected.

For sawnwood demand, the LM test statistics do not show serial correlation, for both functional forms and estimation procedures (Table 3.4). The LM statistic, however, shows slight evidence of serial correlation for the supply function at 3% and 4% level, respectively for the linear and logarithmic functions. Attempts to correct the problem by adding other variables (as suggested by Gujarati, 1995) did not improve the results. Estimates of price elasticities derived from equations with LM statistic below 5% were not used in the spatial equilibrium model of Chapter 4.

- Conifer Sawlogs

For conifer sawlogs, the demand equation was regressed as function of its own price, the price of the output (conifer sawnwood), interest rate, and a time trend. The supply equation was regressed as function of its own price, one-year lagged supply and a wage index. Estimates of both the log and the linear systems showed an overall good fit with adjusted R^2s above 0.90 (Table 3.5). The linear function, however, is preferred over the logarithmic one since it gave a greater number of more significant coefficients, including the own-price coefficients. For sawlogs both test statistics did not indicate serial correlation for the supply equation, although the LM statistic suggests evidence of serial correlation for the linear equation.

For sawlog demand, higher adjusted R^{2s} (over 0.91) were obtained for both functional forms. Coefficients were overall highly significant in the linear form and signs were as expected, except for interest rate. The own-price coefficient was highly significant and inelastic and with the expected negative sign. The coefficient of the output price was expectedly positive and significant. The unexpected positive sign for interest rate (significant only in the 3SLS) could indicate that the composite rate used is not representative of the rate that the sector faces. Other explanations may be related to the mechanisms used for capital borrowing and use in the conifer lumber sector (Table 3.5).

For sawlog supply, both functional forms showed high adjusted R^2s of 0.93 with highly significant coefficient (α=0.01). Serial correlation was corrected by using one-year lagged supply as an explanatory variable. In both functional forms the signs of the coefficients were as expected from supply theory for all variables, and significant except for the wage. Sawlog supply was positively related to its own-price and to lagged supply, although negatively related to the wage. In the logarithmic form, the price coefficient (elasticity) of supply was positive and inelastic with value between 0.7-0.8 (Table 3.5).

A summary with the estimates of the short-run price elasticities of supply and demand of sawnwood and sawlogs in Chile is shown in Table 3.10. A discussion and comparison with findings from other studies are also presented.

Table 3. 5. Estimated structural equations for conifer sawlogs in Chile (1980-98)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
- Demand for Sawlogs (m^3)				
Intercept	8.35 (4.44) **	-3395066 (-2.01) *	6.66 (4.58) *	-3718588 (-2.90) **
Conifer sawlog price (1995 P$/$m^3$)	**-0.60** **(-1.13)**	**-651.49** **(-2.15)** *	**-0.74** **(-1.64)**	**-711.99** **(-2.87)** **
Conifer sawnwood price (1995 P$/$m^3$)	1.07 (2.37) *	252.94 (2.74) **	1.34 (3.65) **	280.33 (3.96) **
Interest rate	0.16 (1.01)	48272 (1.47)	0.23 (2.08) *	50223 (2.17) *
Time trend	0.11 (4.25) **	765018 (5.25) **	0.11 (5.14) **	777265 (6.33) **
Adjusted R^2	0.93	0.91	0.91	0.91
LM statistic ***	0.02	0.31	0.02	0.31
- Supply of Sawlogs (m^3)				
Intercept	1.67 (1.48)	297454 (0.27)	1.87 (1.89)	756784 (0.86)
Conifer sawlog price (1995 P$/$m^3$)	**0.27** **(1.59)**	**152.77** **(2.01)** *	**0.34** **(2.42)** *	**138.54** **(2.10)** *
Real minimum wage (index 1990)	-0.18 (-1.03)	-5770 (-0.58)	-0.09 (-0.69)	-10412 (-1.34)
Lagged supply of conifer sawlogs (m^3)	0.79 (4.44) **	0.80 (5.502) **	0.71 (4.99) **	0.83 (6.76) **
Adjusted R^2	0.93	0.93	0.93	0.93
LM statistic ***	0.51	0.09	0.51	0.09
F-statistic	562354	2698	481692	2285

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5th order autoregressive using 2SLS estimator

3.6.3 Argentina and other Mercosur countries (Uruguay, Paraguay and Bolivia)

A major constraint in estimating the sawnwood equations for the Argentina, Uruguay, Paraguay, and Bolivia was the unavailability of long-period price series for conifer sawnwood. The price of conifer sawnwood imports for Argentina and a weighted price of pine lumber for Brazil and Chile were considered as proxies for the sawnwood prices. The supply and demand equations were estimated initially only for Argentina. Argentinean social-economic variables, including wages (real minimum wage index), the GDP, and an index of construction costs (Revista Construir, 1999) were used as explanatory variables.

- Conifer Sawnwood - Argentina

For conifer sawnwood, the demand equation was regressed as function of a proxy for its price, the index of construction cost and the GDP. The supply equation included a proxy for its price, the input price (sawlogs) and the cross-price variable.

For sawnwood demand and supply the logarithmic specification gave higher adjusted R^2s than did the linear form. Results obtained using 3SLS generated a greater number of significant coefficients, although their magnitude was comparable to those obtained through 2SLS (Table 3.6). Estimation of sawnwood demand and supply equations for Argentina failed to generate equations with a good overall fit for adjusted R^2s and signs of some coefficients. Adjusted R^2s were low (0.50-0.56) for the demand and even lower (0.16-0.36) for the supply equation, the explanatory variables failing to account for the variability to a large extent. However, signs, magnitude and significance of the own-price coefficients for the demand and supply equations were as expected.

For sawnwood, GDP, as expected, was positively related to demand while the index of construction cost showed a significant and unexpected positive sign. The elasticity with respect to GDP was also highly elastic and significant, with a value of 4.4. It should be noted, however, that this is a derived demand and GDP is an indirect explanatory variable through the chain of consumption from primary products (sawlogs) to the final or manufactured goods (furniture and housing construction). The LM statistics do not show evidence of serial correlation for either functional form. Future estimates using specific price and quantity data, as they become available may eventually confirm such range of coefficients. The fact that the R^2s and some coefficient estimates were not as expected, requires caution in interpreting and using the coefficients as true measures of the price elasticities (Table 3.6).

For sawnwood supply, the logarithmic function showed a better fit than did the linear form for adjusted R^2, more coefficients were significant, and coefficients were more highly significant. Both functional forms showed the expected signs for the own-price coefficients, but not for other coefficients. The own price coefficient of supply was elastic for the logarithmic form, with an estimated value of 1.7. Unexpectedly, the input price coefficient (sawlogs) was positive, highly elastic, and significant and the non-conifer sawnwood price (eucalyptus and poplar species) was negative, highly inelastic, and significant. Insufficient data may be a likely cause of such results (Table 3.6). Although some caution should be practiced in using the coefficient estimates from the supply and the demand equations, they are a starting-point for finding the price elasticities of conifer sawnwood in Argentina.

Table 3. 6. Estimated structural equations for conifer sawnwood in Argentina (1982-95)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
- Demand for Sawnwood (m^3)				
Intercept	-139.35 (-3.93) *	-1347222 (-2.93) *	-138.06 (-4.68) **	-1240328 (-3.41) **
Conifer sawnwood price - proxy (1995 A$/$m^3$)	**-1.28 (-1.88)**	**-1955.14 (-1.60)**	**-1.34 (-2.39)** *	**-2200.98 (-2.24)** *
Construction index	1.53 (2.61) *	2330.82 (2.37) *	1.40 (2.96) **	1925.23 (2.81) *
GDP (1995 A$)	5.68 (4.10) **	4.76E-06 (3.45) **	5.67 (4.92) **	4.81E-06 (4.19) **
Adjusted R^2	0.56	0.51	0.55	0.50
LM statistic ***	0.18	0.06	0.18	0.06
- Supply of Sawnwood (m^3)				
Intercept	12.29 (1.54)	-77206 (-0.17)	13.85 (2.14) *	126931 (0.38)
Conifer sawnwood price - proxy (1995 A$/$m^3$)	**1.77 (2.36)** *	**2521.72 (2.11)** *	**1.69 (2.74)** *	**2255.37 (2.34)** *
Conifer sawlog price (1995 A$/$m^3$)	2.75 (2.76) *	19244.10 (1.88)	2.74 (3.31) **	19056.10 (2.24) *
Non-conifer sawnwood price (1995 A$/$m^3$)	-3.22 (-2.54) *	-2324.13 (-1.82)	-3.42 (-3.29) **	-2793.48 (-2.89) **
Adjusted R^2	0.34	0.16	0.36	0.18
LM statistic ***	0.33	0.10	0.33	0.10
F-statistic	35709	226	40201	285

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5th order autoregressive using 2SLS estimator

- Conifer Sawlogs

For conifer sawlogs, the demand equation was regressed as function of its own price, the cross price, the output price (conifer sawnwood), and wages. The supply equation includes the own-price, a trend variable, the wage, and one-year lagged supply. The logarithmic form showed a better fit than did the linear form, with adjusted R^2s of 0.61 and 0.63, respectively, for the demand and supply equations (3SLS) (Table 3.7).

For sawlog demand, signs of the own-price and cross-price coefficients are consistent with demand theory, although they were highly elastic and significant (Table 3.7). The output price (conifer sawnwood) was highly significant with an unexpected negative sign. The data used in the estimation may have played a role in generating such unexpected signs. The wage index may not account for the changes within the sector and the output price was a proxy for the actual price. Both variables however, remained in the equation to improve the overall fit. The cross-price elasticity for non-conifer sawlogs is positive, as hypothesized, and high in magnitude (elasticity of over 4.0 in the log form). The LM statistic shows evidence of serial correlation for the linear demand function (at 3% level). Estimates of price elasticities from equations with LM statistic lower than 5% were not used in the spatial equilibrium model of Chapter 4.

Results for sawlog supply show a better fit for the logarithmic function, with adjusted R^2s of 0.65 and 0.63 using respectively 2SLS and 3SLS (Table 3.7). All coefficients showed the expected signs, although only the one-year lagged supply was significant, depending on the specification. The own-price elasticity of supply for the log function was positive although non-significant (0.7 to 1.0). The LM test statistics do not show evidence of serial correlation for the supply equation.

Table 3. 7. Estimated structural equations for conifer sawlogs in Argentina (1982-95)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
- Demand for Sawlogs (m^3)				
Intercept	9.7 (1.43)	-324066 (-0.37)	10.82 (2.03)	-285074 (-0.42)
Conifer sawlog price (1995 A$/$m^3$)	**-4.87** **(-2.77)** *	**-76755.40** **(-2.20)** *	**-4.39** **(-3.23)** **	**-73745.70** **(-2.77)** *
Real minimum wage (index 1990)	2.95 (1.29)	12725 (1.06)	2.20 (1.24)	11334 (1.27)
Non-conifer sawlog price (1995 A$/$m^3$)	4.33 (3.84) **	99530.50 (3.02) **	4.06 (4.62) **	97715.30 (3.83) **
Conifer sawnwood price (1995 A$/$m^3$)	-1.66 (-2.94) **	-4536.59 (-1.63)	-1.28 (-3.12) **	-3840.65 (-2.48) *
Adjusted R^2	0.61	0.42	0.61	0.42
LM statistic * **	0.09	0.03	0.09	0.03
- Supply of Sawlogs (m^3)				
Intercept	14.03 (1.95)	167960 (0.15)	12.710 (2.27) *	141303 (0.20)
Conifer sawlog price (1995 A$/$m^3$)	**0.69** **(0.58)**	**11190.90** **(0.46)**	**0.99** **(1.08)**	**11635.00** **(0.70)**
Real minimum wage (index 1990)	-2.83 (-1.76)	-5800.23 (-0.73)	-2.56 (-2.04)	-5726.18 (-0.96)
Lagged supply of conifer sawlogs (m^3)	0.76 (3.60) **	0.84 (2.13) *	0.66 (4.22) **	0.83 (3.37) **
Time trend	0.02 (0.33)	37127 (0.88)	0.05 (1.10)	38292 (1.70)
Adjusted R^2	0.65	0.50	0.63	0.50
LM statistic * **	0.53	0.72	0.72	0.53
F-statistic	21986	127	25528	116

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5th order autoregressive using 2SLS estimator

- Combined Estimation of Conifer Sawlog System – AUPB countries

As the results of the system estimation for conifer sawlogs in Argentina were partially satisfactory, an attempt was made to improve its overall goodness-of-fit by aggregating data from Argentina, Uruguay, Paraguay, and Bolivia (AUPB countries). A more parsimonious model was estimated by excluding wage rate (a non-significant and erratic variable) from the demand equation. The demand equation was regressed as function of its own price, the output price and the cross price. The supply equation included its own-price, a trend variable, wage and one-year lagged supply.

Overall, the regression analysis for the AUPB countries showed a better fit for the system in comparison with Argentina only, with an increase in the adjusted R^2s for both demand and supply (Table 3.8). The logarithmic form showed a better fit than did the linear form. Adjusted R^2s were 0.80 and 0.67, respectively, for the demand and supply equations (2SLS). The LM test statistic shows slight evidence of serial correlation for the linear form of the demand equation at 3% significance level.

For sawlog demand, signs of the own-price and cross-price coefficients are consistent with demand theory. The magnitude of the coefficients was relatively high (over 2.6), and significant in the log equation. The sawlog price was significant and with the expected sign, although smaller than those estimated for Argentina alone (over 4.0). The output price (conifer sawnwood) was highly significant in the log form and with an unexpected negative sign. The cross-price elasticity for non-conifer sawlogs was positive, as hypothesized, and high in magnitude (elasticity of over 2.5 in the log form) (Table 3.8).

Table 3. 8. Estimated structural equations for conifer sawlogs in the AUPB countries (1982-95)

EXPLANATORY VARIABLES	REGRESSION COEFFICIENTS			
	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
- Demand for Sawlogs (m^3)				
Intercept	17.95 (12.11) **	927297 (2.15) *	17.40 (14.50) **	877998 (2.52) *
Conifer sawlog price (1995 A$/$m^3$)	**-2.66 (-6.32)** **	**-58783.70 (-4.12)** **	**-2.67 (-7.64)** **	**-59245.50 (-4.99)** **
Non-conifer sawlog price (1995 A$/$m^3$)	2.60 (5.83) **	83170.80 (3.80) **	2.56 (6.91) **	83146.12 (4.57) **
Conifer sawnwood price (1995 A$/$m^3$)	-0.80 (-3.35) **	-2741.93 (-1.39)	-0.64 (-3.53) **	-2090.88 (-1.69)
Adjusted R^2	0.80	0.60	0.79	0.59
LM statistic * **	0.06	0.03	0.06	0.03
- Supply of Sawlogs (m^3)				
Intercept	1.68 (0.40)	-735869 (-0.72)	1.18 (0.55)	-863733 (-1.23)
Conifer sawlog price (1995 A$/$m^3$)	**0.93 (0.74)**	**13194.31 (0.33)**	**1.23 (1.33)**	**32420.55 (1.25)**
Real minimum wage - AUPB (index 1990)	-0.32 (-0.67)	345 (0.12)	-0.40 (-1.17)	-1741 (-1.06)
Lagged supply of conifer sawlogs – AUPB (m^3)	0.72 (2.75) *	0.591 (1.24)	0.66 (3.48) **	0.81 (2.67) *
Time trend	0.08 (1.63)	76847 (1.65)	0.09 (2.63)*	59064 (2.15) *
Adjusted R^2	0.67	0.61	0.65	0.52
LM statistic * **	0.09	0.09	0.09	0.09
F-statistic	59413	233	62635	212

Notes:
Numbers in parentheses are t-statistics
(*) significant at the 5 % probability level
(**) significant at the 1 % probability level
(***) probability of obs*R^2 of 5th order autoregressive using 2SLS estimator

The sawlog supply results did not show a significant improvement from combining data for the AUPB countries. The adjusted R^2s remained around 0.65

regardless the estimation procedure. All coefficients showed the expected signs, although only the one-year lagged supply and the trend variable became significant, depending on the specification. The own-price elasticity of the supply for the logarithmic function (0.9 to 1.2) was positive although non-significant. The magnitude of the wage index reduced considerably using an aggregate index from the countries under investigation (Table 3.8).

A summary of the short-run price elasticities of supply and demand of sawnwood and sawlogs in Argentina is shown in Table 3.11. A discussion and comparison with findings from other studies are also presented.

3.6.4. Pooled Data Estimation

An alternative to overcome the problem of the low number of observations for the three countries in this analysis, was to create panel data and run a cross-sectional and time-series analysis. Although such an analysis is feasible from an econometric standpoint, it is not economically sound for the region under investigation given the heterogeneous nature of the countries, which are subject to specific market forces and different national policies. It would not be justifiable to pool certain variables such as the national GDP of each country or their wage rates and use them as explanatory variables in the simultaneous equation estimation of demand and supply in a given country. A cross-sectional data analysis, however, that was tried for both the sawlog and sawnwood demand and supply failed to generate meaningful results, although it improved its degrees of freedom (not shown). Although some results in this study were not ideal from the econometric standpoint, they are the best estimates for each country, considering the data constraints.

3.6.5. Own-Price Elasticities of Supply and Demand for All Regions

This section concentrates on the estimation of the price elasticities of supply and demand for the products under investigation as that is the main focus of the spatial equilibrium analysis of Chapter 4. Estimates of short-run price elasticities of supply and demand for sawnwood and sawlogs in Brazil, Chile, and Argentina (and in the AUPB countries) are summarized respectively in Tables 3.9, 3.10, and 3.11. Price elasticities of demand and supply for the linear equations were computed at the sample means. Overall, the estimates of the own-price elasticities were all with the expected signs, and mostly within the range found in the literature for similar products in other countries.

For Brazil, sawnwood demand and supply were highly inelastic (close to zero) and sawlog supply was inelastic (0.24 to 0.26), indicating that relatively large changes in price cause relatively smaller changes in quantity demanded or supplied. Sawlog demand was highly elastic (-1.9 to –2.5), indicating an opposite trend. Low elasticity estimates for Brazil may have been influenced by the data, which may not accurately reflect the average market transactions. For comparison reasons, arc-elasticities of demand and supply of sawlog and sawnwood were estimated using various sources of data. Results, however, were highly variable, with some unexpected signs and magnitudes (not shown).

For Chile, price elasticities were variable. Supply of sawnwood (0.37 to 0.77) and sawlogs (0.27 to 0.34) were inelastic for either functional form. However, demand for sawnwood and demand for sawlogs were inelastic and not significant in the log form (-0.34 to -0.47 for sawnwood, and -0.60 to -0.74 for sawlogs) and elastic in the linear form (about -1.1 for sawnwood, and -1.5 for sawlogs). The linear form, using either estimation procedure, gave a greater number of significant elasticity estimates than did the log form.

Table 3. 9. Price elasticities of supply of and demand for conifer sawnwood and sawlogs in Brazil

Price Elasticities (Conifers)	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
Sawnwood Demand	- 0.04 (*)	- 0.06 (**)	- 0.04 (**)	- 0.04 (***)
Sawnwood Supply	0.005	0.008	0.002 (*)	0.006
Sawlog Demand	- 2.18 (**)	- 2.471 (*)	- 1.94 (***)	- 2.30 (**)
Sawlog Supply	0.24	0.24	0.26	0.24

(*) significant at the 10 % probability level
(**) significant at the 5 % probability level
(***) significant at the 1 % probability level

Table 3. 10. Price elasticities of supply of and demand for conifer sawnwood and sawlogs in Chile

Price Elasticities (Conifers)	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
Sawnwood Demand	- 0.29	- 1.20 (***)	- 0.17	- 1.16 (***)
Sawnwood Supply	0.11	0.07	0.85	0.14
Sawlog Demand	- 0.60	- 1.38 (**)	- 0.74	- 1.50 (***)
Sawlog Supply	0.27	0.30 (*)	0.34 (**)	0.27 (**)

(*) significant at the 10 % probability level
(**) significant at the 5 % probability level
(***) significant at the 1 % probability level

Table 3. 11. Price elasticities of supply of and demand for conifer sawnwood and sawlogs in Argentina and in the AUPB countries

Price Elasticities (Conifers)	2SLS		3SLS	
	Logarithmic	Linear	Logarithmic	Linear
Sawnwood Demand	- 1.28 (*)	- 1.09	- 1.34 (**)	- 1.22 (**)
Sawnwood Supply	1.77 (**)	2.08 (**)	1.69 (**)	1.86 (**)
Sawlog Demand - Argentina	- 4.87 (**)	- 4.38 (**)	- 4.39 (***)	- 4.21 (**)
- AUPB	-2.66 (***)	-2.48 (***)	-2.67 (***)	-2.50 (***)
Sawlog Supply - Argentina	0.69	0.64	0.99	0.66
- AUPB	0.93	0.56	1.23	1.37

(*) significant at the 10 % probability level
(**) significant at the 5 % probability level
(***) significant at the 1 % probability level

For Argentina, signs of most of the elasticities were in the expected range and significant, although the magnitude varied significantly for demand and supply of both products. Sawnwood demand and supply price elasticities were both elastic and were higher for supply (1.7 to 2.1) than for the demand (-1.1 to -1.3). Sawlog demand was highly elastic for Argentina (-4.2 to -4.8) and for the AUPB countries (-2.5 to –2.7) indicating that relatively small changes in demand price cause relatively larger changes in quantity demanded. For sawlog supply the elasticity was in a range of inelastic (0.6) to unit elastic for Argentina, and between 0.6 to 1.3 to the AUPB countries depending on the estimation procedure. It is noteworthy that the sawnwood price used in this analysis was a proxy for conifer sawnwood price.

- Comparison of Price Elasticities - Conifer Sawnwood

The estimates of price elasticities of conifer sawnwood supply were positive for all countries and products, and significant depending on the specification and estimation method (Tables 3.9, 3.10 and 3.11). Comparatively, the elasticities varied from as low and inelastic as 0.002 to 0.008 for Brazil (significant in the logarithmic specification, 3 SLS) and from 0.07 to 0.85 for Chile (non-significant in both forms and procedures) to as high and elastic as 1.70 to 2.10 for Argentina (significant in all forms and estimation methods). Although these values differ significantly from each other, they are in the range reported in other studies, except for Brazil (Appendix 9). Kant et al. (1996) found low price elasticities of solidwood and wood- manufacturing production in Canada from

0.15 to 0.32, with an average of 0.21. Chen, Ames and Hammett (1988) in a study of softwood lumber demand and supply in the US found a significant price elasticity of 0.31 for supply. McKillop and Liu (1989), modeling disaggregated demand and supply of softwood lumber (Douglas-fir and Hemlock-fir) in the Western US estimated a wider range of price elasticities varying from 0.39 to 0.68 for Hemlock-fir clears, 1.35 to 1.37 for Hemlock-fir commons, and 2.40 to 2.13, for all Hemlock-fir, using conventional and quadratic programming estimation procedures respectively. Adams and Haynes (1980), in their study of the North America softwood lumber, plywood, and stumpage markets (TAMM) found a range of elasticities for the lumber supply, between 0.21 (Pacific Northwest-West) and 0.79 (South Central region). The price elasticity of lumber supply for Canada stayed in the middle, with a positive and inelastic value of 0.47 (Appendix 9).

The estimates of the price elasticities of conifer sawnwood demand were negative and significant for all countries (Tables 3.9, 3.10 and 3.11). Comparatively, the price elasticities varied from as low and inelastic as -0.04 to –0.06 for Brazil (significant in all forms and estimation methods) to as high, significant and elastic as –1.16 to –1.20 for Chile (linear form, respectively 3SLS and 2SLS) and from -1.09 to -1.34 for Argentina (significant in the linear form with 2SLS and 3SLS, and in the logarithmic form with 2SLS). Estimates of price elasticities of demand for conifer sawnwood from other studies are highly variable depending on the location, product, and species group. Zhang, Buongiorno and Zhu (1997), in a study of consumption, production and trade in the Asia-Pacific region estimated low price elasticities of demand for conifers in the range of -0.07 to -0.13, respectively for low and high GDP countries, with an average of –0.08 to the world. Kant et al. (1996) estimated price elasticities of demand for Canadian (solid) wood in the range of -0.3 to -1.1, with average of -0.47, higher than the ones estimated for Brazil but close to the ones found for Chile and Argentina (upper level). McKillop and Liu (1989), estimated price elasticities of demand from –0.88 to –0.95 for Douglas-fir clears, -2.83 to -2.91 for commons, and -2.13 to -2.27 for all products for the Western US, using conventional and quadratic programming estimators respectively. Chen, Ames and Hammett (1988) found a low and non significant -0.03 price elasticity of demand for softwood lumber in the US, and Merrifield and Haynes (1983) estimated price elasticity of lumber and plywood products demand as -0.36 for the Pacific Northwest region of the US. In a study of demand for forest products in OEDC countries, Buongiorno and Chang (1986) found a significant price elasticity of -0.24 for coniferous sawnwood. In a study about the demand for softwood lumber in the residential construction market in the US, Rockel and Buongiorno (1982) estimated significant price elasticity of -0.91. From a review of literature on the subject, these authors cited elasticities varying from 0 to –0.87. Adams and Haynes (1980), in TAMM, found price elasticities of demand for softwood lumber in six regions of the US in a close range between -0.3 to -0.4 (Appendix 9).

In Brazil, price elasticities for conifer sawnwood were close to zero, indicating almost perfectly inelastic demand and supply and a situation where large changes in price would cause relatively small changes in quantity (Table 3.9). This market is expected to be somewhat inelastic, given the limitations on installed capacity and the resource base expansion. The estimates, however, may be a result of the limited FAO data on production of the commodity. Alternative estimates using more specific data, as they become available could eventually confirm such low price elasticities.

- Comparison of Price Elasticities - Conifer Sawlogs

The estimates of the price elasticities of conifer sawlog supply were positive for all countries and products but significant only for Chile (Tables 3.9, 3.10 and 3.11). The price elasticities of supply were inelastic for all countries, except for the AUPB region. Comparatively, elasticities were low and stable for Brazil (0.24 and 0.26) and Chile (0.27 to 0.34) and higher for Argentina (0.69 to almost 1.00) and for the AUPB countries (0.56 to 1.37) depending on the functional form and estimation procedure. Price elasticities of sawlog supply were also stable for the linear specification in Argentina (0.64 to 0.66), depending on the estimation procedure. Although these values differ from each other, they are in the range found in other studies. Price elasticities of supply of coniferous sawlogs tend to be in the range between 0 and 1.0. Newman (1987), in a study of stumpage roundwood for lumber or plywood in Southern US found significant elasticity of supply of 0.55. Haeri (1987), in a spatial equilibrium model of the wood products industry in the US, estimated regional elasticities of private stumpage supply varying from 0.11 and 0.14, respectively for Rocky Mountains and the Southwest, to 0.46 and 0.49, respectively for the Northwest and South. Some price elasticities of sawlog supply in this study were in the range of Haeri's elasticities. Merrifield and Haynes (1983), found price elasticity of stumpage supply of 0.80 in the Pacific Northwest. Adams and Haynes (1980), estimated price elasticities of stumpage supply for forest industries and other private owners. For forest industries, they were as low as 0.06 (Rocky Mountains) up to 0.99 (North Central region). However, they remained between 0.26 to 0.47 for most of other regions. For other private owners, the elasticities also ranged from 0.06 (Pacific

Northwest-West and Pacific Southwest) to 0.99 (Northeast), although for most of the other regions they remained between 0.12 and 0.39. In their study, price elasticities that were unreasonably high were constrained to levels found in a neighboring region (as it was the case for the South Central – forest industry, for which the elasticity from Southeast was assumed to hold) (Appendix 10).

The estimates of the price elasticities of conifer sawlog demand were all negative and significant for all countries, depending on the functional form and estimation procedure (Tables 3.9, 3.10 and 3.11). Comparatively, the estimates of elasticities were usually elastic in all regions, except for the logarithmic specification in Chile (although not significant). The sawlog demand elasticities were as high and elastic as - 2.0 and over for Brazil (significant in both functional forms and estimation procedures), over -4.0 for Argentina (significant in both forms and estimation procedures), and around –2.5 for the AUPB countries. For Chile, price elasticities were significant and from -1.38 to -1.50, for the linear form using the 2SLS and 3SLS respectively. These elasticities are higher than the elasticity of 0.55 found by Newman (1987), although his study referred to lumber and plywood in the Southern US (Appendix 10). Klemperer (1996) also suggested that short-run price elasticities of stumpage demand tend to be inelastic with estimates from other studies ranging from –0.14 to –0.57 (Cubbage and Haynes, 1988; Hyde and Newman, 1991). The results from this study, however, indicate a different trend in the Mercosur countries during the period of analysis. This may be related to the characteristics of the conifer lumber market in those countries, which faced a transition period in terms of species substitution, product acceptance (domestically and for exports), and forest and industrial investments.

3.6.6. Model Testing - Residuals

Considering the relatively low number of individual observations in each system's equations, an investigation of their residuals was carried out. The analysis revealed that most of the estimates during the period of investigation are within less than one standard error (SE) of the regression using the linear equations (either estimation procedure), with a few exceptions depending on the region and product. Overall, this indicates that the model is able to estimate the quantity demanded and supplied within an acceptable range of the actual data.

Results of the residuals with respect to the standard error of the regression for conifer sawnwood and for conifer sawlogs are shown respectively in Figures 3.12 and 3.13 for the linear demand and supply, considering the 2SLS estimation procedure. Residuals expressed in terms of the standard error of the regression using either the 2SLS or the 3SLS procedures gave similar results (comparison not shown). An investigation of Figures 3.12 and 3.13 indicates that a long-term time effect is not influencing the data, or has been accounted for by a time trend explanatory variable. This implies that the assumptions that the errors are independent, have zero mean, a constant variance, σ^2, and follow a normal distribution do not appear to be violated (Draper and Smith, 1966).

The validation of the models for years outside of the range used to build the model proved difficult for the time being. Data from the same series and sources for all the explanatory variables used to estimate each model, for years either before or after the period of the analysis are not yet available. Although data for some variables are available, others are not. The models, therefore will be tested for validity as data from the appropriate series become available.

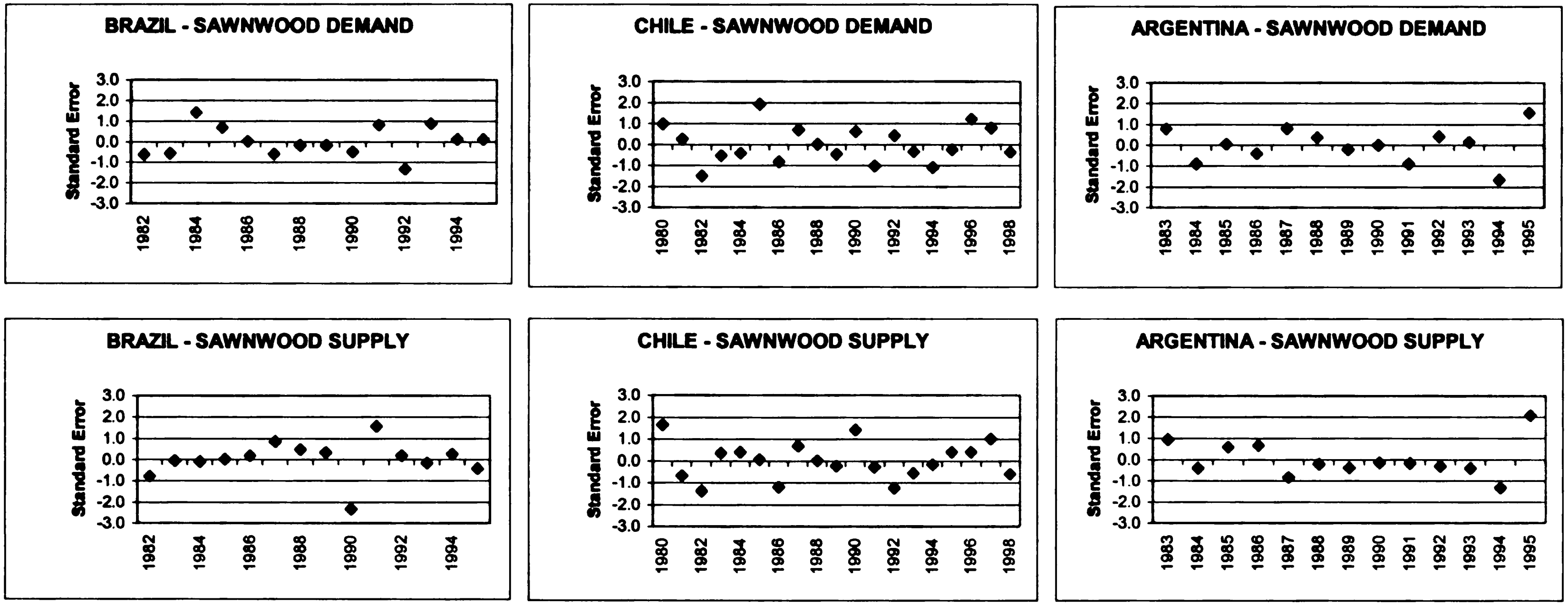


Figure 3. 2. Standard errors of the regression for the conifer sawnwood linear demand and supply equations (2SLS)

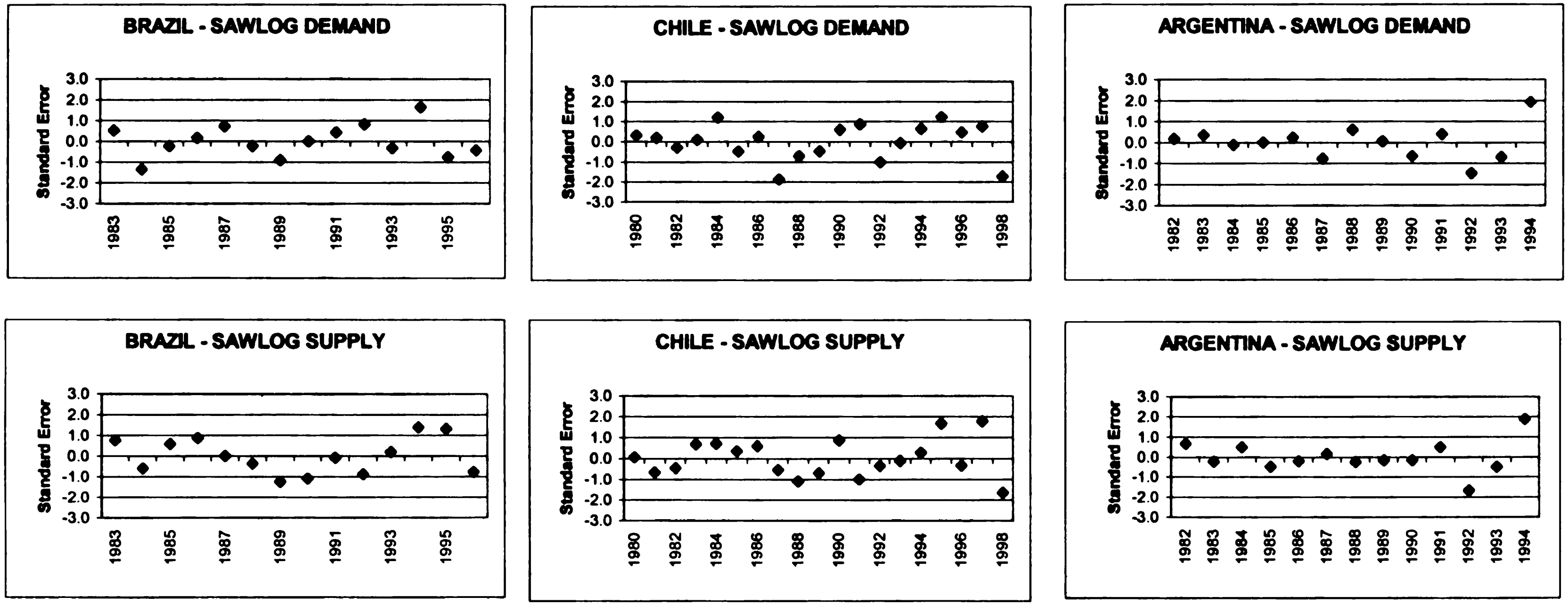


Figure 3. 3. Standard errors of the regression for the conifer sawlog linear demand and supply equations (2SLS)

3.7 Conclusions

This study represented the first attempt to obtain coefficient estimates of price elasticities of supply of and demand for conifer sawlogs and sawnwood for some Mercosur countries through regression of systems of simultaneous equations. This analysis investigated the main sawlog and sawnwood demand and supply shifting variables in Brazil, Chile and Argentina. It indicated some significant results, including the range of the price elasticities and the coefficients and elasticities of other major variables affecting demand and supply. Some coefficient estimates may be restrictive for forecasting and for policy analysis, given data limitation for products and countries, although they provide the range of elasticities for the products under investigation. Important inferences based on the aggregate estimation of the systems are summarized as follow:

- For the derived demand for conifer sawnwood, the major explanatory variables are its own price, the wage index, the cost of construction, the price of substitute inputs, and the lagged demand. Not all of these were significant for each country or group of countries,
- The total GDP is a macroeconomic variable that drives the consumption of sawnwood and became a significant indirect variable for specific countries,
- As for the input product – sawlogs - some of the major factors affecting its derived demand by sawmills included its own-price, the index for wage, the lagged consumption, the output price (sawnwood), and, indirectly, the GDP,
- For the supply of conifer sawnwood, its own price, the input price (sawlogs), the wage index, the price of a substitute product for the industry (e.g. non-conifer

sawnwood), the lagged supply, and sometimes the lagged export price of the product, and a time trend were the major variables explaining its variability,

- For the supply of conifer sawlogs, besides its own-price, other variables explaining supply were the export price, time, and the lagged supply.

The above inferences, signs and magnitude of different macro-variables can be useful in designing short-term strategies for production and consumption of the forest products under investigation. Such strategies make investment decisions more objective, both in the forest product industries and in the forest management of conifer species, such as pines in the Mercosur countries.

As more observations become available and are collected in each country, further econometric studies may be carried out and the results compared with the ones from this study. It may give an idea of the changes in the parameters and coefficients of the main variables over time. Selected elasticities, combined with others from the literature, are used in the spatial equilibrium model of Chapter 4.

CHAPTER 4

A SPATIAL EQUILIBRIUM ANALYSIS OF TIMBER MARKETS IN SOUTHERN BRAZIL AND IN THE OTHER MERCOSUR COUNTRIES

Introduction and Rationale for the Study

The Southern Brazilian states of Paraná, Santa Catarina, and Rio Grande do Sul, although maintaining specific individual characteristics, form a distinctive geographic region with some common climatic and topographic characteristics that have defined the profile of the regional forest sector. One of its main distinctive characteristics, as discussed in Chapter 2, is the large scale forest plantation with pines and the consequent regional industrial profile, led by the emergence of the conifer lumber industry (and their related markets) as well as the pulp and paper and other minor forest products industry.

Over the past decades, conifer lumber has been produced and traded into both the domestic (regional and national) and international markets. The southern region trades domestically with other Brazilian states, notably with the highly populated southeastern region. It also shares border with other Mercosur countries (Argentina, Paraguay, and Uruguay), although it is geographically separated from the associate members (Chile and Bolivia). It has had continuous trade with North America, EU, Asia, and other markets through some of the major Brazilian ports, some located in the region.

The combination of the regional production of distinctive forest products, with the limited supply of industrial roundwood, the consequent shortage estimates of sawlogs in the coming years, and the existence of spatially separate markets (within and outside the region) raise the question about the sustainable production, consumption, and trade of conifer products in the region, and in a large extent in Brazil as a whole.

Only few quantitative studies about the supply of and demand for forest products in Brazil and in the other Mercosur countries. None of them, however, contemplated the conifer lumber market where quantities and prices are endogenously determined in the solution process in accordance with the economic theory.

The problem under investigation in this study fits with in the concept of a spatial equilibrium problem, where two or more regions with known supply and demand functions produce and consume homogeneous product(s) with the regions separated but not isolated, by known transfer (e.g. transportation, tariffs, taxes) costs. This chapter focuses on the spatial equilibrium analysis of the demand and supply of solidwood products (notably conifer sawlogs and sawnwood) in Brazil and their commercial partners within and outside Mercosur. The main research question in this study is about the final competitive equilibrium of prices in all markets under investigation (sawlogs and lumber), the quantities supplied and demanded at each region, and the pattern of exports and imports between each pair of regions.

4.2 Objectives

The primary objective of any spatial equilibrium problem is to determine the optimum level of production, consumption, and price in each region and the interregional equilibrium trade flows of commodities between regions. Thus, the basic feature of a spatial equilibrium problem involves the estimation of a set of prices that equate supply and demand among regions.

The sequential objectives of this chapter are:

(a) Developing a spatial equilibrium model of supply and demand for conifer sawlogs and lumber for Mercosur;

(b) Solving the model in order to estimate the competitive equilibrium of prices and quantities for all markets and regions in the base-period (static phase) and in multi-periods (dynamic phase);

(c) Performing sensitivity analyses by changing the base scenario, primarily in terms of changes in the major demand and supply shifting variables.

(d) Verifying major findings of the study by comparison with observed data for the base-scenario.

4.3 Literature Review

4.3.1 Forest Sector Models - Overview and Application to the Forest Sector

Long-run projections of forest products market demand and availability of the forest resources to achieve such demand are basic tools for any development planning, in both public and private sectors. Succinct but comprehensive reviews of forestry sector models are provided by Adams and Haynes (1980), Harou (1992), and Buongiorno (1996). Previous forest sector studies can be categorized as 'gap', non-spatial market, quasi-spatial market, and spatial market models, based on whether or not they provide estimates of equilibrium prices and quantities, and the extent to which they recognize the spatial attributes of forest products markets (Adams and Haynes, 1980). Andersson et al. (1986) suggested that forest sector models can be disaggregated in a number of ways, including disaggregation of inputs and outputs, treatment of time, treatment of regions, treatment of nonconvexities and nonlinearities of relations (such as economies of scale), and behavioral criteria such as optimization of single or multiple criteria.

In a synthesis of forest sector modeling, Buongiorno (1996) provided a detailed overview of the evolution of different methods used in quantitative analysis and forecast of forest sector markets. He showed that since the 1950s, forest sector modeling has gone from strict applications of econometrics, mathematical programming, or system dynamics to a combination of these methods in large models, with the idea of benefiting from the best features of each approach. In his historical overview, the author pointed out that during the 1980s forest economists pursued more complete models of sectors, particularly in the US, with the desire to use the models for policy analysis, the Timber Assessment Market Model (TAMM) (Adams and Haynes, 1980) for solidwood, PAPYRUS (Gilless and Buongiorno, 1985) for pulp and paper, as well as others, with the culmination of the Global Trade Model (GTM), developed by an international team of forest economists (Kallio et al., 1987) at the International Institute for Applied Systems Analysis (IIASA).

4.3.2 Simple Sector Models

Basic forest sector models have consisted of 'gap models', which attempt to determine the difference between the potential demand for and supply of a given forest product over time at a specified price level or price trend (Adams and Haynes, 1980; and Harou, 1992). Although flexible in accommodating different levels of data available, gap models do not show where and by how much production of raw materials should change to fulfill future requirements, nor how much should be produced domestically or imported (Buongiorno et al., 1994). Haynes (1993) pointed out that gap models do not account for the fact that in a market economy a gap between demand and supply will result in a price increase, which increases supply and decreases demand, automatically filling the gap (also in Zhang and Buongiorno, 1994).

Despite the shortcomings with this approach, it has been a popular analytical framework in analyzing forest sectors in developing countries (Haynes, 1993). As forestry statistics and technical expertise improve, 'market equilibrium models' can replace gap analysis.

4.3.3 Market Equilibrium Models

Market equilibrium models are characterized by a supply and demand adjustment process, which endogenously determines both prices and quantities. It can be done for one region (non-spatial market models), from one region to another (quasi-spatial market models) or for various regions or markets that compete among themselves (spatial equilibrium models) (Adams and Haynes, 1980; Harou, 1992, Bergh et al., 1996). In another study, Adams and Haynes (1987), revising the major approaches for modeling spatial markets, cited Thompson's[9] (1981) taxonomy of models, identifying five broad classes: (1) two-region, non-spatial models; (2) multiregion, non-spatial price equilibrium models; (3) spatial equilibrium models; (4) trade flow and market share models; and (5) transportation models.

Spatial equilibrium analysis has been formulated by many researchers and has a

[9] Thompson, R.L. 1981. A Survey of Recent US Developments in International Agricultural Trade Models, Bibliographies and Literature of Agriculture # 21 (ERS, USDA, Washington, DC).

variety of economic applications. Spatial equilibrium models differ from all other models, in that demand and supply quantities, prices, and bilateral trade flows are determined endogenously in the model solution process.

4.3.3.1 Spatial Equilibrium Models

In 1951, Enke[10] formulated the problem of competitive equilibrium among spatially separated markets, suggesting a solution in the case of linear market functions. Proceeding from the Enke formulation, Samuelson (1952), presented the theoretical foundations for the computable spatial equilibrium modeling, showing how this purely descriptive problem in non-normative economics can be cast mathematically into a maximum problem, and related the Enke specification to a standard problem in linear programming (the so-called Koopmans-Hitchcook minimum-transport-cost problem). Samuelson suggested that, after the problem in descriptive price behavior is converted into a maximum problem, it can be solved by trial and error or by a systematic procedure of varying shipments in the direction of increasing social payoff. He established the desired formal equivalence between the equilibrium of interregional trade and a maximum problem, restricted to a single commodity (in numerous markets). His argument was that given equilibrium quantities, the equilibrium pattern of trade will minimize total transportation costs (Meister et al., 1978). His formulation was developed in the context of a spatial equilibrium model in which market supply and demand are fixed and given exogenously (Meister et al., 1978; and Willet, 1983).

Samuelson (1952) formulated his study in terms of maximum net social pay-off

(NSP), defined as the sum of the social pay-offs (difference between the areas under the excess supply curve) in each region minus the transport cost. Samuelson illustrated his concept by using two exports and two import regions, and respective local prices and transport costs between and within regions (Appendix 11). Using the primal approach, he showed that market equilibrium can be achieved through either the minimization of transportation costs or the maximization of the net social payoff function.

Takayama and Judge (1964, 1971) extended Samuelson's concept to a multi-commodity equilibrium among spatially separated markets using a quadratic programming formulation, assuming appropriate linear dependencies between regional supply, demand and price. A computational algorithm was specified to obtain directly and efficiently the competitive optimum solution for regional prices and quantities and regional flows. They represented manufacturing activities in a spatial equilibrium model by activity analysis, i.e., in terms of the inputs per unit of output, the unit cost of manufacturing net of these inputs, and regional manufacturing capacities (Gilles and Buongiorno, 1985). Although Takayama and Judge's formulation has been extensively used in the determination of spatial price equilibrium, particularly in the agriculture economics literature, some authors (cited by Brooks and Kincaid, 1987) have questioned their imposition of symmetry conditions, particularly to demand equations, constituting a restriction to the problem formulation. A simplified exposition of the quadratic single and multi-commodity models of spatial equilibrium is found in Martin (1981).

Following the initial studies on spatial equilibrium, several theoretical extensions and empirical applications have been implemented to different sets of commodities and

[10] Enke, S. 1951 Equilibrium among spatially separated markets: Solution by electric analogue. *Econometrica* 19: 50-57.

regions. In the solution of spatial equilibrium models, some direct optimization or iterative scheme are used to find a set of demands, supplies, prices, and trade flows that satisfies the conditions for market equilibrium for the particular market structure (competitive or not) (Adam and Haynes, 1987).

4.3.3.2 Spatial Equilibrium Models in Forestry

Many studies incorporating spatial equilibrium models applied to forestry and trade of forest products have been developed in the past decades. A review of literature of spatial equilibrium in forest sector and trade models (Buongiorno et al., 1981; Shim, 1985; Adams, 1985; Greber and Wisdon, 1985; Kallio et al., 1986; Andersson et al., 1986; Buongiorno, 1986; Fowler and Nautiyal, 1986; Cardellichio et al., 1987; Kallio et al., 1987; Sarkar, 1991; Zhang, Buongiorno, and Ince, 1993; Buongiorno, 1996; Buongiorno et al., 1996; Valverde et al, 1999 and others) has revealed different aspects of model construction regarding the objective of the study, the optimization tool, the products under study, and the period of time involved.

In terms of the objective function, studies have either maximized the net social welfare (the sum of both producer and consumer surpluses), as well as market requital, profits, and increase of GNP, or minimized total costs (including transportation and processing costs). Several optimization tools have been used, including econometrics, linear or quadratic programming, mixed integer programming, goal programming, chance-constrained, and reactive programming, depending on the nature and objectives of the problem. Limitations or specific problems with one or another programming tool have also been a justification for the use of alternative tools.

In terms of the products involved, studies have been classified into single or multi-products, the latter involving one or more stages of production, which requires more detailed data and a different theoretical framework. Regarding the time period involved, models can be subdivided in static or dynamic. In such models prices and quantities have been either endogenously or exogenously determined, although endogenous price-quantity models are more theoretically consistent and require more detailed data and information in comparison with price-exogenous models.

Models of spatial equilibrium applied to forest have been developed since the early 1980's. Adams and Haynes (1980) developed a spatial econometric model of the North America softwood lumber, plywood, pulp, and stumpage markets, which provided long-range projections of price, consumption, and production trends. In their study, six geographic demand regions and nine supply regions were considered. The model, called the Timber Assessment Market Model (TAMM), is sub-divided into 'final product's and 'stumpage', and is based on a combination of systems of equations for each industry, with prices of the products as the driving variables. The model was used for policy simulation evaluating the impact of levels of harvesting, tariffs, and lumber costs.

Gilles and Buongiorno (1985) developed a spatial equilibrium model of the North American pulp and paper industry (PAPYRUS), which was designed to provide long-range projections of production, consumption, imports, exports, equilibrium prices, and fiber inputs. Their model is described to consist of price endogenous linear programming that describes the industry in each year, and a set of recursive relationships that update this linear programming from year to year to reflect endogenous and exogenous changes. The optimal solution is a competitive equilibrium for each year. The model consists of 14 commodities, 11 supply and 9 demand regions, with the rest of the world consisting of 3 net demand regions. As an extension of that model, Zhang, Buongiorno, and Ince (1993) developed a price endogenous linear programming system (PELPS III), combining both regional demand and supply equations (with their respective price elasticities), transportation costs, as well as specific information of the forest industry, existing tariffs, and exchange rates. This system models multiregional equilibrium, for one or multi-products, determining quantities and prices that satisfy the market conditions under static or dynamic phases. The PELPS model has been applied to different market conditions and its flexibility seems to accommodate a wide range of different market profiles and interactions.

In a study of the market of southern pine lumber in the US, Shim (1985) evaluated the current and future demand-supply and estimated the optimum allocation and pricing pattern. He integrated a system of regional demand and supply functions using a quadratic spatial equilibrium formulation as developed by Takayama and Judge (1964a) and Liew and Shim[11] (1978). In estimating the demand and supply functions, a panel data was considered and regional dummy variables were used in to derive the functions for each area. The author validated his model indicating, in the optimal spatial solution, what prices, production, and consumption, and flows of trade should have been in 1981 and should be in 1984 subject to specific constraints. His study represents a theoretical improvement over traditional methods of planning since it incorporated demand equations into a spatial model, allowing price and quantity demanded in each region to fluctuate in response to changes in either available timber supplies or the level of total demand. A comparison of that actual behavior with the optimal behavior for 1981 indicated the regions where the optimum shipment was achieved.

Spatial equilibrium models for other countries have also been studied in recent years. Buongiorno et al. (1994) developed a model to find the optimal economic location and timing of new forestry projects in Nigeria, representing wood production, processing and transportation, and meeting the needs of each state at least costs. Given severe data limitation on roundwood prices, the demand for forest products was framed in terms of future uses consistent with estimates of future income and population growth. The supply of forest products was based on the resources available by state and set in terms of possible production under sustainable yield. A 'gap analysis' indicated a deficit of all future wood raw-materials at national level, and a linear programming model (as stated by Samuelson, 1952) was developed to balance the demand and supply of each product in each state, minimizing the total cost of production, transportation, and capacity expansion. The results indicated the economic location and magnitude of changes in production in forestry and forest industries throughout Nigeria.

In a previous study, Buongiorno et al. (1981) developed a model to evaluate long-term development strategies under economic efficiency for the Indonesia's forestry sector. Given specific targets for domestic demand and exports of timber products, the model (a static mixed integer programming with goal programming variables) estimates the economic and geographic patterns of timber production, industrial processing and transportation that minimized total costs. The constraints represented resource limitations, industrial capacity utilization, balance of raw materials and final products, processing, residues formation, product transshipment, port-handling capacity constraints, location of export facilities, and domestic and foreign demand achievements.

[11] Liew, C.K. and Shim, J.K. 1978. A Spatial equilibrium model: another view. *J Urban Econ*. 5: 526-534.

Results showed domestic and foreign supply, resources utilization, industrial expansion, ports activity and location of export outlets, and inter-islands shipping patterns. The model is viewed as a description of methodology rather than a recommendation for policy, and it could be improved by further product disaggregation and inter-temporal linkages. It is flexible on analyzing the effects of various aspects of a given strategy.

Adams (1985) developed a spatial equilibrium model of African-European trade in tropical logs and sawnwood. His model was designed to simulate sawnwood production and consumption in tropical Africa and Europe, log production in Africa, and the prices and trade flows resulting from market exchange. Assuming competitive markets, a system of supply and demand equations representing different products (sawnwood and logs) and regions (East, Central, and West Africa; and Europe) was initially estimated. The spatial equilibrium solution was given by the reactive programming algorithm of Tramel and Seale[12] (1959), and the Gauss-Seidel method for solution of simultaneous equation systems. His study involved two interrelated market levels (logs and sawnwood), with the relation between both markets being viewed as two groups of simultaneous equations linked by vectors of prices. The combined approach demonstrated the flexibility of reactive programming in dealing with multilevel spatial market problems. The Gauss-Seidel reactive programming, as pointed out by the author, was the first such application of the technique, adding to the pool of solution tools (e.g., linear and non-linear programming) with some possible advantages relative to other techniques. Results for bilateral trade flows appeared to be consistent with the limited available flow data for 1980. The resulting solution minimized the transportation cost,

[12] Tramel, T.E. and Seale, A.D. Jr. 1959. Reactive Programming of Supply and Demand Relationships - Applications for fresh vegetables. *J. Farm Econ.*, 41: 1012-1022.

given the optimal set of regional production and demand levels.

Sarkar (1991) developed a long-run timber model for Bangladesh, using a system of semi-logarithmic supply-demand equations, with equilibrium solutions obtained for stumpage price and quantity of timber. The model also provided the optimal land, labor and capital allocation for timber production. The theoretical basis was the multi-period production theory using the premise that the optimal level of output maximizes the present net social benefits, or the end-value of net benefits in any given target year.

In a review of available spatial price equilibrium studies, Webb et al. (1994) indicated that those models are either single commodity multi-region models or multi-commodities and multi-region models for which all regions are forced to have identical demand and supply functions (e.g. assuming no cross price effects). He developed a multi-crop model for China encompassing commodities with multiple cross price effects in the supply and demand functions.

A few studies have been focused on spatial equilibrium markets in Mercosur countries. Ochoa (1996) studied the effects of Mercosur on the plywood industry in the states of Paraná/Brazil and Misiones/Argentina, focusing on the effect of the program of tariff reduction over the net social payoff as proposed by Samuelson (1952), of both regions. Ochoa used the static phase of PELPS III as the mathematical programming tool, and made use of price elasticities of demand and supply previously estimated by Sperandio[13] (1992). He found a significant effect of the creation of Mercosur on the regional net payoff, quantities demanded and supplied, and prices in both countries.

Valverde et al. (1999) analyzed the impacts of international agreements on the

[13] Sperandio. J. Demand and Supply of Plywood in the State of Paraná: An Econometric Analysis. Federal University of Paraná, Curitiba, Brazil. Ph.D dissertation 147 p. 1989.

Brazilian forest economy as a whole. The market liberalization agreements were the Uruguay Round, Mercosur, NAFTA, the inclusion of Chile in Mercosur, FTAA and the Mercosur-EU agreement. The authors used the Global Trade Analyses Project (GTAP), a general equilibrium model (citing Hertel and Tsigas[14], 1997). In their study forest products were aggregated as one single commodity. Overall results indicated that the agreements affect more the international trade rather than the domestic production. Specifically for the inclusion of Chile in Mercosur, results indicated that the impact is non significant for the production, however it can affect the international trade, increasing imports and reducing exports, contributing to the trade deficit. Their study, however, did not address the conifer lumber market specifically.

Analyzing international trade of agriculture products among Mercosur countries, Waquil and Cox (1995) formulated a spatial equilibrium model using quadratic programming allowing the existence of stages of production with intermediate products. The model took into account the economic allocation of sets of primary and final commodities among spatially separated markets, given that all primary and final commodities could be traded among regions. The model considered a quantity formulation, in which the decision variables are quantities in terms of production, consumption and trade flows. Starting from restricted cost functions, the authors maximized the net social payoff, as cast by Samuelson (1952), by using the Takayama and Judge (1964a) formulation. The model was implemented with four stages of production, analyzing the optimal allocation and pricing of animal products, grain and oilseeds in the Mercosur countries.

[14] Hertel, T.W. and M.E. Tsigas. 1997. Structure of GTAP. In: Hertel, T.W. (ed) *Global Trade Analysis: Modeling and Applications*. New York: Cambridge University Press. 403 p.

Many studies of long-range projection procedures have ignored the spatial characteristics of forest products markets. This reduces the value of the projections to decision makers and may preclude the possibility of identifying opportunities or needs for specific policy actions (Adams and Haynes, 1980). The studies presented above provide, to different extent, possible approaches and methods to be combined in the development of this proposed study.

The theoretical basis for the approach of finding a competitive solution to the spatial equilibrium problem may be found in the multiproduction theory (with intermediate products) using, for instance, the premise that the optimal level of output in a base year is that which maximizes the net social payoff (NSP), or the sum of the excess demand and excess supply subtracting the transportation cost, as proposed by Samuelson (1952) and later extended by Takayama and Judge (1964, 1971).

4.3.4 The Conceptual Model

The conceptual spatial equilibrium model (SEM) can be approached either with prices as the dependent variables (in the quantity domain) or quantities as the dependent variables (in the price domain). The model presented here considers the maximization of Samuelson's net social payoff as the objective function, with a quadratic programming representation in a quantity domain (primal), in which the decision variables are quantities (production, consumption, trade flows). The Lagrangean multipliers are interpreted as shadow prices. When the model is presented in a price domain (dual), in which the decision variables are prices, the Lagrangean multipliers are interpreted as shadow quantities.

Assuming the existence of known linear supply and demand functions for each product (primary or intermediate) and for each region, the representation (here price expressed as the dependent variable) can be shown as follow:

$$P^{D}_{nit} = a_{ni} + b_{ni} \cdot D_{n,i} + \dots + u_{t}$$ demand function for intermediate products (1)

$$P^{S}_{ki} = d_{ki} + e_{ki} \cdot S_{k,i} + \dots + v_{t}$$ supply function for primary products (2)

where:

i - 1, ..., I regions,

k - 1, ..., K primary products,

n = 1, …, N intermediate products,

D_{ni} - quantity demanded at different prices for intermediate product 'n' in region 'i',

S_{ki} - quantity supplied at different prices for primary product 'k' in region 'i',

P^{D}_{ni} - demand price at different output levels for intermediate product 'n' in region 'i',

P^{S}_{ki} - supply price at different output levels for primary product 'k' in region 'i',

a_{ni} - intercept of the demand response function for intermediate product 'n' in region 'i',

b_{ni} - the slope of the demand response function of D_{ni} to P^{D}_{in} in region 'i',

d_{ki} - intercept of the supply response function for primary product 'k' in region 'i',

e_{ki} - the slope of the supply response function of S_{ki} to P^{S}_{ki} in region 'i',

Demand and supply shifter variables may also be included in the equations above.

The conceptual framework is developed with production occurring in a two-stage process, using a multiproduct formulation, adapted from Waquil and Cox (1995) and

Zhang, Buongiorno, and Ince (1993). Considering the allocation of a set of primary products (k), and a set of secondary (intermediate) or final products (n), among spatially separated regions (i), the primary products can be produced and processed into secondary (or final) products in each region, the secondary/final products can be consumed in each region, and all primary and secondary products can be traded among regions. The production of secondary products involves two kinds of inputs: the primary products and other inputs. With more than one stage of production, it is necessary to know and subtract from the objective function the cost of transformation (e.g.: manufacturing) in each stage. The cost of transformation can be considered fixed per unit of production or variable and represented as function of explanatory variables such as prices and quantities of the inputs. Following the Zhang, Buongiorno, and Ince formulation (1993), a fixed cost of transformation is considered in this study.

Samuelson's maximization of the net social payoff (NSP) objective function for one commodity and two-regions can be extended to multi-commodities and multiregions. This can be done by aggregating the NSP functions across commodities and regions and subtracting the costs of transportation of products from one region to another, and (in case of multi-stages of production) the cost of transformation (Waquil and Cox, 1995).

The maximization of the aggregate NSP objective function is subject to a constraint set which consists of two conditions that characterize a competitive spatial market equilibrium solution. The first condition states that demand in any region is less than or equal to trade flows to that region (either as a primary or intermediate product), while the second condition states that trade flows from a region must be less than or equal to production in that region. The first constraint set eliminates the possibility of excess demand in the optimal solution while the second set allows for the possibility of excess supply. Non-negativity constraints are another set of constraints.

The model described in this section is adapted and adjusted to the purpose of the study considering its objectives, the characterization of the regions, and the proposed maximization function. Based on the previous premises and assumptions, the mathematical formulation for the objective function can be written as:

Maximize:

$$NSP = \sum_i \{ \sum_n \int_o^{D_{n,i}} P^d_{ni}(D^d_{ni})dD - \sum_k \int_o^{S_{k,i}} P^s_{ki}(S^s_{ki})dS - \sum_n \int_o^{PF_{n,i}} CT_{ni} \}$$

$$- \sum_k \sum_i \sum_j TP_{kij} XP_{kij} - \sum_n \sum_i \sum_j TF_{nij} XF_{nij} \quad (3)$$

where:

'k' holds for the primary product (conifer sawlog)

'n' holds for intermediate product (conifer sawnwood)

'i' and 'j' hold for regions (e.g. Brazil, Chile, and Argentina)

$P^S{}_{ki}$ = price-dependent supply function for the primary product 'k' in region 'i',

$P^D{}_{ni}$ = price-dependent demand function for the intermediate product 'n' in region 'i',

S_{ki} = quantity supplied of primary product 'k' in region 'i', for k= 1,...,k and i= 1,...,j

D_{ni} = quantity demanded of intermediate product 'n' in region 'i', for n= 1,...,n and i= 1,...,j

PF_{ni} = quantity produced of intermediate product 'n' in region 'i', for n= 1,...,n and i= 1,...,j

CT_{ni} = cost of transformation for the intermediate product 'n', in region 'i',

XP_{kij} = exports of primary product 'k' from region 'i' to region 'j', for k= 1,...,k,

i= 1,...,j, and j= 1,...,j

XF_{nij} = exports of intermediate product 'n' from region 'i' to region 'j', for

k= 1,...,k, i= 1,...,j, and j= 1,...,j

TP_{kij} = unit cost of transportation of the primary product 'k' from region 'i' to region 'j',

TF_{nij} = unit cost of transportation of the secondary/final product 'k' from region 'i' to

region 'j',

D_{ki} and S_{ni} are represented as functions of their own-prices and cross-prices, possibly including lagged quantities. CT_{ni} is a fixed cost, although it can be a variable function.

Substituting linear demand and supply functions (from equations (1) and (2) simplified here as function only of their respective prices) in (3):

$$NSP = \sum_i \{ \sum_n \int_o^{P_{n,i}} (a_{ni} + b_{ni} D_{ni}^d) dD_{ni}^d - \sum_k \int_o^{P_{K,i}} (d_{ki} + e_{ki} S_{ki}^s) dS_{ki}^s$$

$$- \sum_n CT_{ni} \} - \sum_k \sum_i \sum_j TP_{nij} XP_{kij} - \sum_n \sum_i \sum_j TF_{nij} XF_{kij} \quad (4)$$

which becomes a quadratic expression in D (demand) and S (supply) - area under all demand curves minus the area under all supply curves, subtracting the transportation costs of all trade flows:

$$NPS = \sum_i \{ [\sum_k a_{ik} D_{ni}^d - \sum_k d_{imk} S_{ki}^s + \frac{1}{2} \sum_k b_{imk} D_{n,i}^{d\ 2} - \frac{1}{2} \sum_k e_{imk} S_{ki}^{s\ 2}]$$

$$- \sum_n CT_{ni} \} - \sum_k \sum_i \sum_j TP_{nij} . XP_{kij} - \sum_n \sum_i \sum_j TF_{nij} . XF_{nij} \quad (5)$$

Subject to the following constraints (equations 6):

1. $S_{ki} \geq \Sigma_j XP_{kij}$ – where production of a primary commodity (k) in region (i) should be greater or equal to the exports of primary commodity (k) from region (i) to all other regions (j);

2. $\Sigma_j XP_{kji} \geq \Sigma_n a_{kni} Pf_{ni}$ – where total exports of primary commodity (k) from region (i) to all other regions (j) has to be greater than or equal to the production of intermediate commodity (n) in region (i);

3. $PF_{ni} \geq \Sigma_j XF_{nij}$ – where production of intermediate products (n) in region (i) should be greater than the exports of the intermediate commodity (n) from region (i) to all other regions (j);

4. $\Sigma_j XF_{nij} \geq D_{ni}$ – where exports of the intermediate commodity (n) from all regions (j) to region (i) should be greater or equal to the consumption of the commodity (n) in region (i);

5. $S_{ki} \geq 0$; $XP_{kij} \geq 0$; $PF_{ni} \geq 0$; $XF_{nij} \geq 0$; $D_{ni} \geq 0$ - all non-negativity constraints (6)

In this study, the transformation of primary into secondary/final products is given by fixed coefficients, where $a_{k,n,i}$ is the amount of primary product 'k' used as input to produce one unit of the secondary or final commodity 'n' in region 'i'. The Kuhn-Tucker conditions for optimality are derived after substituting constraints (equation 6) in the maximization problem (equation 3) (see Appendix 12 for details).

This is the general formulation for spatial price equilibrium for multiple products. Takayama and Judge (1971) proved that this type of programming formulation is solvable and would yield a solution that satisfies the competition equilibrium condition. The equilibrium prices and quantities for individual products in a specific region are then used to calculate the net social benefit (NSP).

Zhang, Buongiorno, and Ince (1993) proposed the solution of this problem with linear programming efficient computation, by using stepwise approximations to the area under these non-linear curves using PELPS III. Other authors as well have suggested different approximations in the attempt to linearize quadratic formulations like the NSP objective function (Willet, 1983; and Apland, 1986). The flexibility of PELPS III (versions FPL-TPELPS1 and the GFPM) and easy adaptation to different conditions, make it a suitable tool for the solution of the problem.

The optimal solution to this problem is characterized by three equilibrium conditions. First prices differ between any two regions by an amount that is less than or equal to the transfer costs. For the second condition it is assumed that the quantity of a good which is produced and consumed in the same region is viewed as a trade flow to that region itself, with the demand in a given region being equal to the sum of the trade flows to that region. The third condition implies that equilibrium prices and quantities must lie on the supply and demand functions (Willet, 1983).

In the solution of spatial equilibrium models, direct optimization or iterative scheme are used to find a set of demand, supply, prices, and trade flows that satisfies the conditions for market equilibrium for the particular market structure (Adam and Haynes, 1987). The optimal solution may be obtained through the use of different quadratic programming (QP) solvers. In Waquil and Cox's model of agriculture commodities (1995) the optimal solution for the QP problem was obtained by using LINDO or GAMS (General Algebraic Modeling System) software. Other studies have considered different algorithm solvers. Zhang, Buongiorno and Ince (1993) developed the Price Endogenous Linear Programming System (PELPS III), a specially designed interface which interacts with LINDO in the solution process. Buongiorno et al. (1994), in solving a GAP analysis for timber production in Nigeria used the Excel solver in the solution process. Adam and Haynes (1987) used reactive programming and the Gauss-Seidel method to find the spatial market equilibrium of timber trade for some African countries. In this study, the quadratic programming formulation of net social surplus (from Samuelson, 1952) is found by using the so-called FPL-TPELPS1, a version of PELPS III adapted by the FPL/USFS (Lebow, 1999, personal communication).

4.3.5 Description of PELPS III and its latest versions

The price endogenous linear programming system, PELPS III (Zhang, Buongiorno, and Ince, 1993) is a general microcomputer system for modeling economic sectors and combines regional information on supply and demand curves, manufacturing technologies, and transportation costs into spatial sector models. PELPS III extends concepts that have been applied in previous interregional models of the forestry sector, including TAMM – Timber Assessment Market Model (Adams and Haynes, 1980) and the Global Trade Model (Kallio et al., 1987; Zhang, Buongiorno, and Ince, 1993).

Although PELPS was developed to model the pulp and paper sector in North America, it accommodates other economic sectors, becoming an useful and powerful tool in forest products modeling. PELPS III has a static and a dynamic phase. In the static phase, a multiregion, multicommodity equilibrium is computed with the solution given by quantities and prices that clear all markets at a point in time. In its dynamic phase, the evolution of the spatial equilibrium is predicted over time, explaining how a sector adjusts gradually to changes in exogenous variables.

PELPS' static phase solves a generalized version of Samuelson's (1952) classical spatial equilibrium problem represented by production, transport, transformation, and consumption of one or more commodities in two or more regions. For each region, price-quantity relationship through domestic demand and supply curves are used to determine the equilibrium prices in all the markets, the supply and demand in each place, as well as the trade flow (Zhang, Buongiorno, and Ince; 1993). Commodities are described as a primary raw material, recovered waste or a consumed commodity (virgin or recycled). Demand and supply regions are described by equations that give quantity as function of prices. The system has also manufacturing regions, where the output production, and the input consumption are modeled as processes described by activity analysis. Each process has a limited capacity, with a commodity made with input mixes, defined by manufacturing coefficients giving the amount of each input needed per unit of output, with a corresponding manufacturing cost. The solution of the static phase is obtained by price endogenous linear programming (Hazell and Norton[15], 1986; cited by Zhang, Buongiorno, and Ince, 1993). The equilibrium quantities produced, transformed, transported, and consumed are given by the maximization of the sum of the producer and consumer surplus throughout the sector, minus the transportation and transformation costs. As result, the static phase gives the price that clears all markets at a given point in time, subject to the positions of each pair of supply and demand curves, the capacities of production by region and process, the transformation and transportation costs, the taxes and exchange rates, and the recycling constraints, if applicable.

In its dynamic phase, PELPS breaks down a multiperiod spatial equilibrium

[15] Hazell, P.B.R. and Norton, R.D. 1986. *Mathematical Programming for Economic Analysis in Agriculture*. New York: MacMillan, 400 p.

problem into a sequence of problems, as in the recursive programming approach described by Day[16] (1973) and cited by Zhang, Buongiorno, and Ince (1993). It is characterized as a succession of static phases, one for each period of the forecast, simulating partial long-run optimization behavior. The static calculation in each period gives the short-term equilibrium, subject to the demand, supply, costs, and capacity in that period. The parameters of the programming problem that condition the equilibrium change from period to period as function of exogenous changes and of changes in capacity are determined endogenously by the model (Zhang, Buongiorno, and Ince; 1993). The capacity of production in the next period is a function of the shadow price of capacity in the previous period, past production, and the cost of increase in capacity.

PELPS III maximizes the net social payoff, which is defined by the area under all demand curves minus the area under all supply curves, also subtracting the transformation and transportation costs. Although these areas are by nature non-linear functions, PELPS III linearizes them by using stepwise approximations to the area under these curves so that the spatial equilibrium can be computed efficiently by linear programming. More details on the theoretical approach used by can be found in Zhang, Buongiorno, and Ince (1993). In recent years, some versions had incorporated additional features. The USFS-Forest Products Laboratory's version, FPL-TPELPS1 includes a resource worksheet (Lebow, 1999; personal communication) to deal with the resource base, and the Global Forest Products Model - GFPM (Zhang, Buongiorno, and Zhu, 1997) includes trade inertia specification (Buongiorno, 2000; and Turner, 2000, personal communication).

[16] Day, R.H. 1973. Recursive programming models. In: Judge. G.G. and T. Takayama, eds. *Studies in Economic Planning over Space and Time.* American Elsevier. 329-344.

4.4 Empirical Method

In section 4.3.4, a conceptual framework for the multiregional, multi-industry model was outlined and detailed. Based on the theoretical aspects and information about the forest sector in Brazil and in the other Mercosur countries an empirical industry-specific spatial equilibrium model is described. The model is based on the mathematical programming formulation developed by Samuelson (1952) and extended by Takayama and Judge (1964a), using the USFS/FPL version's of PELPS III, the FPL-PELPS1 (Lebow, 1999, personal communication).

The model is both static and dynamic and involves partial equilibrium. The model also assumes perfect competition and homogeneous products. Prices and quantities are determined along supply and demand functions, which remain unchanged in the basic model, since no structural changes in either supply or demand are considered from a starting point to a new equilibrium. Production takes place in specific regions, which are separated from each other and from consumers, with trade incurring a transportation cost. There are no barriers to trade and local producers can compete freely. Whether locations trade, however, depends on the underlying parameters of the model.

Since pines are vastly dominant as the primary species in conifer sawmills, *Araucaria* and hardwoods were not part of the analysis. Including them would require additional data, some nonexistant. With respect to products, the model focuses on primary (sawlogs) and intermediate (lumber or sawnwood) products and by-products (sawmill residues). Residues from sawmills can be consumed as firewood, woodchip for papermaking, or simply burned and were considered in a broad category in the analysis.

4.4.1 Boundaries of the Study

The problem of establishing model boundaries is a frequent issue in econometrics and systems modeling. Although there is no definitive rule, some of the characteristics that shape the model and the trade-offs that must be weighted in its construction can be identified. Adams (1987) pointed out that basic characteristics to be taken into account are: (a) the question being asked (or the user's information needs), (b) the characteristics of the regional markets for the products of interest, and (c) the cost and resources needed to build and use the model under alternative degrees of model complexity. Regarding the information needs, one basic criterion is the scope of direct (target region) and indirect (regions outside the target region) trade flows, the projection period, and the simulation needs. As for market characteristics, the array of products to be incorporated into the model is defined by the purpose of the analysis and the information needs of the users.

The boundaries in this analysis differ slightly from the boundaries in the multiple regression analysis (Chapter 3), primarily for Brazil, which was split in two regions to account for the profile of the conifer sawmilling sector in the Southern region. In this model, six regions were considered: Southern Brazil (S-BZ), Rest of Brazil (RBZ), Chile (CHI), Argentina (ARG), Rest of Mercosur (ROM - formed by Uruguay, Paraguay and Bolivia), Asia (ASIA-S formed by Japan, China, Hong Kong, and Republic of Korea), and the Rest of the World (ROW). The ASIA-S and ROW regions are modeled in terms of their import demand from Mercosur, simplifying the model while allowing Mercosur to trade with outside members, a more realistic representation of the real world. The sawlog and lumber demand and supply regions are listed in Table 4.1, which identifies a representative geographic demand and supply center for each region.

Table 4. 1. Conifer sawlogs and lumber supply and demand regions

#	Regions	Producer and Consumer Centers	Supply and/or Demand Regions
1	**S-BZ** **(Southern Brazil)**	Northern Paraná/PR Curitiba/PR	D S
2	**RBZ** [1] **(Rest of Brazil)**	São Paulo/SP Western São Paulo/SP	D S
3	**CHI** **(Chile)**	Santiago Concepcion	D S
4	**ARG** **(Argentina)**	Buenos Aires Misiones	D S
5	**ROM** [2] **(Rest of Mercosur)**	North-Central Uruguay Montevideo, Uruguay	D S
6	**ASIA-S** [3]	Nagoya, Japan	Imported D
7	**ROW** [4]	Savannah/GA, USA	Imported D

Note: D for Demand, S for Supply
[1] RBZ – all the country, except Southern Brazil
[2] ROM – formed by Uruguay, Paraguay, and Bolivia
[3] ASIA-S - Japan, China, Hong-Kong, and Republic of Korea
[4] ROW – Rest of the World

4.4.2 Economic Actors and Major Elements

The transformation process from conifer sawlogs into lumber, common to most of the countries under investigation is characterized by technological, geographical and market-oriented specialization. The economic actors of the study are suppliers and consumers of conifer sawlogs and lumber, assumed to operate under perfect competition (Figure 4.1). Conifer sawlog producers in Southern Brazil, as well as in most of the other Mercosur countries, are primarily pine plantation owners (either private companies, or small to medium non-industrial private owners). Sawmills processing pine sawlogs are both conifer sawlog consumers and lumber producers. Lumber consumers are all categories of industries or lumber-related sectors, including furniture companies, the construction sector, and lumber exporters, the latter also represented by sawmills.

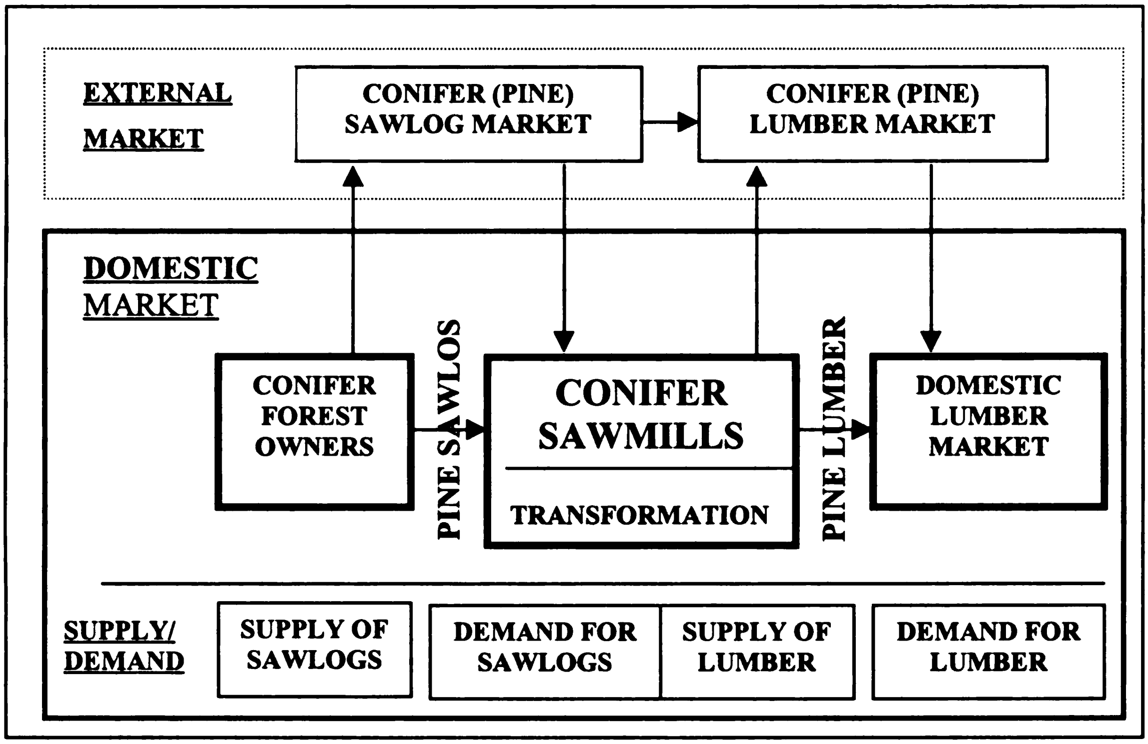


Figure 4. 1. Product linkages in the conifer lumber market in Southern Brazil and in other Mercosur countries

Conifer sawlog and lumber producers in the ROW countries, notably in North America and EU, differ from Mercosur producers in terms of the source of raw-material (forest type and ownership) and lumber end-uses. In North America, conifer sawlog supply comes mostly from natural forests (Northern/Western US and Canada) and from plantations (Southern US) from both public and private lands, and conifer lumber is consumed primarily in housing construction and wood-manufacturing industries.

The major elements of the static phase of the study are the demand and supply of sawlogs and lumber in each region, their own-prices, sawlog availability, the industrial capacity and production, the sawmilling-processing costs, the import tariffs and the export taxes, the transportation costs, and the exchange rates.

As an optimization model the maximizing objective function is subject to various constraints. Sawlog supply constraints were related to the annual growing stock and harvesting levels, which are related to the commercial area with pines, age distribution, and yield in each region. Environmental aspects related to legal forest protection, the legal requirement of reforestation for wood-consuming companies and restrictions on harvesting native species, although relevant as policy issues were not direct part of the model. Lumber supply constraints were related to the existing industrial capacity and investment capital in each region. Demand constraints were related to the existing industrial capacity in both the sawlogs and lumber markets, which are somehow related to macroeconomic factors such as income, population growth, the overall performance of the economy, the terms of trade, as well as production and transportation costs.

In multicommodity models, the inclusion of stages of production with intermediate products seems to be more realistic, particularly for forest products that are freely traded. In a competitive world, each region has the option of producing both primary and intermediate products regionally, importing primary products and transforming them regionally into intermediate products or directly importing intermediate products. In each stage, the products are allocated as intermediate products for the production of new products in the next stage. In each stage, commodities are potentially transported between regions.

In this study, one transformation process (sawmilling) and two stages of production (sawlogs being processed into lumber and residues) were considered. The final consumption is not modeled, given that lumber may go through several processes before being transformed into diverse final products.

According to Waquil and Cox (1995) previous studies dealing with intermediate products assumed constant costs of processing, which in fact may differ among regions. Waquil and Cox's formulation (1995) assumed transformation cost functions. Given the lack of time-series on costs of transformation of sawlogs into lumber in the countries under investigation, the cost of transformation is assumed to be fixed.

4.5 Data Requirements and Sources

Specific data was required to run FPL-TPELPS1 under the static and the dynamic phases of the model. For the supply and demand of each commodity in each region, basic data were the price of the commodities and their respective quantities demanded and supplied (in the base-period and in one lagged-period), their own-price elasticities of demand for conifer sawnwood and supply of conifer sawlogs, and the upper bound in the quantity supplied of sawlogs and lower bound in the quantity demanded of sawnwood in each region. For the manufacturing activity, data include the net manufacturing cost, the input mix, and the amount of input commodity per unit of output commodity. For the transportation costs and taxes, data included the freight cost of shipping one unit of commodity from origin to destination, the import ad-valorem tax rate, and the export ad-valorem tax rate. In addition, specific data on the manufacture activity and industrial capacity were considered (Appendices 13 to 21).

For the dynamic phase, changes in exogenous variables were modeled considering some of the major regional demand and supply shifters over the period of the analysis. Some possible changes included, but are not restricted to: shift in demand or supply curves, changes in net manufacturing costs, new manufacturing coefficients, new capacities, depreciation rates, capacity costs, changes in transportation costs, and changes in import and export ad-valorem rates, and changes of exchange rates.

The base-period was set in the year 1995, for which data on trade between some pairs of countries are available. Monetary values were all in a common currency, in the case the US dollar. Prices and quantities for the base-period and for the period before the base-period for each commodity and region come from different sources (Appendices). Price elasticities of demand and supply come from the elasticity estimates for each commodity for Brazil (Southern), Chile and Argentina from Chapter 3 (Table 4.2). For Brazil, considering that the price elasticity of demand obtained from Chapter 3 was close to zero (0.005) and is related to events in a period (1980-1995) that may not reflect the period of the analysis (1995-2010), a different set of elasticities were used. For both Southern Brazil and the RBZ region, price elasticities of demand of –0.40 were used, which are average for other regions cited in the literature (see discussion in Chapter 4). The price elasticities of import demand for ASIA-S and ROW from Mercosur products were intermediate values reported from other studies. Prestemon and Buongiorno (1996), investigating the Mexican demand for imports of US softwood lumber found price elasticities of softwood imports between -0.32 (other softwoods) and –2.30 (Douglas-fir), with intermediate elasticities of –0.72 and –0.77, respectively for ponderosa pine and Southern pine. Hseu and Buongiorno (1993) estimated price elasticities of US import demand of Canadian softwood lumber between –0.94 and –1.01. In another study, Chen et al. (1988) found price elasticity of –0.84 for US demand for imports of Canadian softwood. In this study, the price elasticities of import demand of conifer sawnwood and sawlogs for both ASIA-S and ROW regions were set as –0.50, within the range found in the literature for import demand of softwood lumber in some countries (Prestemon & Buongiorno, 1996; Hseu & Buongiorno, 1993; Chen, Ames & Hammett, 1988).

Secondary data was obtained from various sources. Production and unit value price of roundwood products and some aggregate secondary products for Brazil were obtained from IBGE. For Brazil, price of pine roundwood/sawlogs was from SEAB/PR (SEAB, 1998 obtained through CNPF/EMBRAPA) unit value of 'other roundwoods' production was from IBGE, and time-series on price of pine lumber was from Revista da Madeira. For Chile, radiata pine sawlog and lumber prices came from INFOR (2000), and for Argentina were from SAGPyA and LaRobla (personal communication, 1999). Import sawlog and sawnwood prices for the ASIA-S and the ROW regions came (or were estimated) respectively from FAO and from RISI (1997).

Table 4. 2. Price elasticities in different regions

Region	**Source**	**Conifer Sawlog Supply**	**Conifer Sawnwood**	
			Demand	**Supply**
S-BZ	Chapter 3	0.256	-0.40 [3]	0.002 [C]
RBZ [1]	Chapter 3	0.256	-0.40 [3]	0.002 [C]
Chile	Chapter 3	0.268 ([B])	-1.081 [B]	0.739 [C]
Argentina	Chapter 3	0.993	-1.342 [B]	1.693 [B]
ROM [2]	Chapter 3	0.993	-1.342 [B]	1.693 [B]
ASIA-S	Assumption	-	-0.50	-0.50
ROW	Assumption	-	-0.50	-0.50

Notes:[1] RBZ – Rest of Brazil, repeated from estimates for Southern Brazil;
[2] ROM – Rest of Mercosur, repeated from estimates for Argentina;
[3] Assumption of higher elasticity as compared with estimated –0.05 from Chapter 3
[A] significant at 1% level
[B] significant at 5% level
[C] significant at 10% level

Production, exports and imports of conifer sawlogs and sawnwood were available from FAO for all countries and various years. Consumption in each region was derived from those data in a material balance formulation. Specific demand and supply data for Brazil, in particular for Southern Brazil, came from ABIMCI (1999) - pine lumber – and ABPM, ANFPC (1994), STCP (2000, personal communication), and IBGE (1999, pine sawlog supply as 'other roundwoods' production). For Chile, data on production of pine sawlogs and lumber was obtained from INFOR. For Argentina, data on pine sawlog production also came from SAGPyA-INDEC (1999).

Estimates of the limiting supply of pine roundwood (sawlog in particular) in Brazil came from various studies including Ramos (1993), Tomaselli (1998), and Dos Santos (1995). For other countries, estimates were from INFOR (Chile), INDEC-MECON (Argentina), and information from papers by Flynn & Associates (several years, including 1996, 1999a, and 1999b). Forest growth and roundwood production by category of product for pines were estimated using Ramos (1993)'s procedure, adapted specifically for Southern Brazil using data from IBAMA (ex-IBDF).

Exchange rates and import tariffs came from various sources including the WTO and the IADB online database. Socio-economic data from all Mercosur countries (such as population, producer price indexes - PPI, interest rates) were obtained from IADB. Specific demographic and economic data for Brazil came from FGV (1998), IPEA (1998), and IBGE (1980-1995 and 1996-2000).

Prices represent average prices of each product in each region and, as all monetary values, are expressed in a common currency (e.g. US$), deflated by the producer price index (PPI). Import tariffs and export taxes between each pair of regions were considered when appropriate and data was obtained from the IADB (2000) and Valverde et al. (1999). In addition, secondary data on prices, quantities, costs came from varied sources including papers, online database, and expert opinion (Graça, 1996-2000, Jmendes, 2000, STCP, 2000, Wiecheteck, M.R.S., 2000 – personal communication).

Import prices and quantities (from Mercosur) in ASIA-S and ROW came from various sources. For conifer sawlogs, proxies for prices and quantities were estimated with 1995 data of exports of 'conifer saw, veneer logs' obtained from the International Trade Statistics Yearbook (UN, 1996). Proxies represent weighted quantities and weighted unit value of exports, with the weights being the proportion of the total exports (volume and value) of 'wood, conifer rough, untreated' (SITC classification) from Mercosur to ASIA-S and ROW obtained from UN (1995). The same procedure was used to estimate proxies of prices of conifer sawnwood, except that the data of sawnwood exports are from FAO (2000a). Exports of 'conifer saw, veneer logs' from Mercosur to ASIA-S and ROW in 1995, as reported by the UN (1996) were lower than expected and unrealistic.

Data on directions of trade of conifer sawnwood from Mercosur to ASIA-S and ROW (FAO, 2000a and FAO, 200b) between 1995-1997 indicated an increase of 108% and 11.9% respectively. This increase was incorporated in the model in Period 3 of the dynamic forecast (corresponding to 1997). The total conifer sawnwood quantity exported from Mercosur to those regions in 1997 reached 2.34 million m^3. However, FAO (2000a) reports only 1.82 million m^3 as being exported, showing conflicting reports. Most of this difference is related to Chilean exports.

- Transportation cost estimates

Based on each center's distance to the other regions (Appendices 18 and 19), transportation costs (in common currency per m^3) between pairs of regions were estimated through simple regression equations taking into account the method of transportation (either trucking or shipping) and range of distances (short-, middle- and long distances). Separate equations were estimated for short and middle-distance (trucking transportation) and for long-distance (shipping transportation) (Table 4.3.). Unitary cost of transportation ($\$/m^3$.mile) was regressed as function of the distance between two respective centers.

Data for the regression were obtained from SIFRECA/Brazil (1998) and from international shipping freight costs (Hardwood Review, several years). Distances of transportation between trade points were obtained from the DNER (2000) and from World-Port (2000). Estimation of inland distances, within Mercosur, was made (when data was not readily available) by approximation using road maps for South America.

4.6 Results and Discussion

A model for analyzing conifer timber markets in Mercosur was developed in order to analyze and forecast conifer sawlogs and sawnwood consumption, production and trade within and outside the bloc. The model followed the theoretical framework proposed by Samuelson (1952) and used FPL-TPELPS1, a FPL/USFS version of PELPS III (Zhang, Buongiorno, and Ince, 1993), taking into account the assumptions outlined in the previous section, which reflect the most likely scenarios given the data availability.

Table 4. 3. Transportation cost equations

Distance	Method	Fitted Equation	Adj. R^2	Obs.
Short - Sawlogs (<350 km)	Trucking / roundwood *	tcss = 0.047859 -5.994E-05.d (1.1E-12) (0.00033)	0.50	20
Short – Lumber (<350 km)	Trucking / roundwood *	tcsl = 0.037603 -4.7096E-05.d (1.06E-12) (0.00033)	0.50	20
Medium - Sawlogs (1000-3000 km)	Trucking / general load **	tcms = 0.06436 - 9.73E-06.d (3.92E-05) (0.00229)	0.84	07
Medium - Lumber (1000-3000 km)	Trucking / general load **	tcml = 0.05057 - 7.64E-06.d (3.92E-05) (0.00229)	0.84	07
Long - Sawlogs (5,000-23,000 km)	Ocean freight / container ***	tcls = 0.00628 -1.78E-07 (1.79E-66) (3.90E-31)	0.68	119
Long – Lumber (5,000-23,000 km)	Ocean freight / container ***	tcll =0.0049 - 1.40E-07 (1.79E-66) (3.90E-31)	0.68	119
Conifer Sawlogs	Wisdom (1987) ****	tcs = 0.690*exp(3.69+0.398lnD-0.049lnQ)		
Conifer Lumber	Wisdom (1987) ****	tcl = 0.541*exp(3.84+0.319lnD)		

Note: Numbers between parenthesis are p-values.

All estimate were significant at $\alpha<0.01$

(*) Short-distance trucking transportation cost (tcss and tcs1) in R$/m3.km within State of São paulo/Brazil (source: SIFRECA, 2000 - online source at http://sifreca.esalq.usp.br/madeira.htm), distance (d) in km.

(**) Medium-distance trucking transportation cost (tc2) in R$/t.km from Brazil to Argentina (source: Associação Brasileira do Transporte Internacional – ABTI cited by Avogrado, 2000 at http://www.artrade.com/esp/info/sintrans.htm#costo),distance (d) in km.

(***) Long-distance sea shipping transportation cost (tc3) in US$/m3.km (source: Hardwood Review Export, Jul/98 at http://www.hardwoodreview.com/); distances between ports were estimated mostly using 'World Port Distances' (http://www.distances.com/) and some using the 'Bali online system' (http://www.indo.com/cgi-bin/dist), the latter based on information from the U.S. Geological Survey.

(****) Transportation cost equations for conifer sawlogs (tcs) and conifer lumber (tcl) by Wisdon (1987); distance (D) in Nautical miles and quantity transported (Q) in Ton.

Results of the empirical analysis of the spatial equilibrium model are presented for the base scenario - base period (static phase) and for multi-periods(dynamic phase) projected up to 2010. In addition, results of the sensitivity analysis from changes in the base scenario are presented.

4.6.1. Base Scenario

4.6.1.1. Base Period (Static Phase)

The base period was set as 1995, considering this was the latest year when most of the data was available for all the countries and regions under investigation. The results of the static phase serve to calibrate the model and to outline the pattern of production and trade among the regions, from which the dynamic forecast is based on. The summary statistics of the model is shown in Appendix 22, which also indicates the total value of the objective function.

- Conifer Sawlogs

Estimates of the supply of conifer sawlogs in the Mercosur, were within 17.5% of the actual data, with estimates for Brazil about 5.7% and 2.2% above the observed values, respectively for Southern Brazil and the RBZ. Estimates for Argentina and ROM were 17.5% and 11% above the actual data respectively (Figure 4.2).

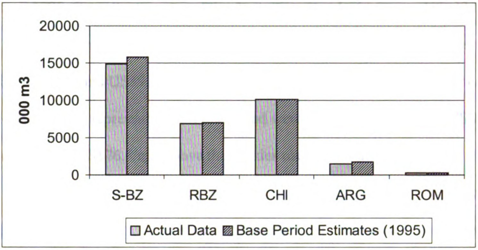


Figure 4. 2. Conifer sawlog supply by region for base period and published data

The largest individual producing region was Southern Brazil with 15.8 million m^2 of conifer sawlogs, followed by Chile (10.1 million m^3), and the RBZ (estimated 7.0 million m^3). Although the RBZ region produces pine sawlogs, the observed quantity is not reported. The quantity used in the model was a proxy assuming that all the 'other roundwoods' reported by IBGE for the RBZ (31.4% of the Brazil's total in 1995) represents the regional production of conifer sawlogs. Argentina and ROM were minor producers, with 1.7 million m^3 and 300 thousand m^3, respectively. The results of the model suggest its ability to predict the levels of conifer sawlog supply produced in each region within an acceptable range (Figure 4.2).

Estimated domestic prices of conifer sawlogs in all the Mercosur countries remained between 14.7% to 29.4% above the 1995 observed prices (or proxies), except for Chile, with prices 1.8% below its observed value (Figure 4.3). This difference indicates that some actual prices were undervalued in the Mercosur countries, except in Chile, in that year. That could be the case in Brazil considering that conifer roundwood, as opposed to that in Chile, had not been internationally traded in commercial volumes until 1995. Overall, estimates of the domestic prices laid between US$32.6/m^3 (Argentina) and US$42.3/m^3 (RBZ). In Southern Brazil and Chile, prices were US$37.7/m^3 and US39.8/m^3, respectively. For regions outside Mercosur (ASIA-S and the ROW), prices represent import prices and were, respectively, 26.7% (US$91.4/m^3) below and 21.5% (US$76.5/m^3) above the proxies used in the model.

These differences could be related to the way proxies for prices were estimated for the ASIA-S and the ROW countries using UN (1996) data. Proxies represented weighted averages of the unit value of exports of conifer saw/veneer logs from Mercosur countries and may not represent, to a certain extent, the actual conifer sawnwood import prices in both ASIA-S and ROW. Another explanation could be the fact that conifer sawlogs are, to a certain extent, a non-homogeneous product. For the purpose of the analysis, and considering the data availability, sawlogs were assumed to be homogeneous and traded inter-changeably in this model. The model, however, showed that prices in the ASIA-S region tends to be higher than in the ROW, as expected, given the higher transportation costs from Mercosur.

Estimates of the demand for conifer sawlogs can be derived from the estimates of the sawnwood production (using conversion factors), also adding the total net volume traded (exports and imports) following the material balance formulation (values not shown).

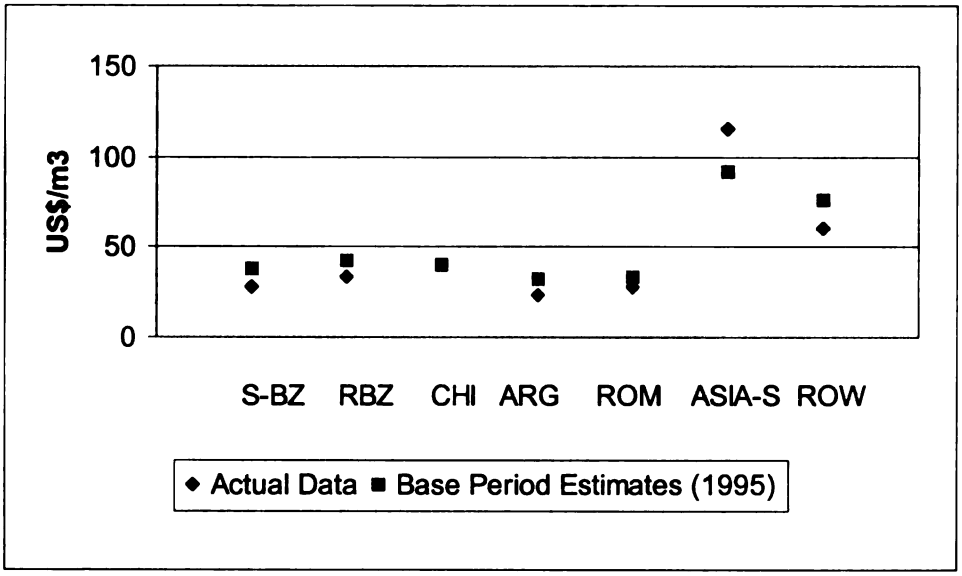


Figure 4. 3. Conifer sawlog prices by region for base period and published data

- Conifer Sawnwood

Estimates of the demand for conifer sawnwood in the Mercosur were within 13.6% of the actual data range (Figure 4.4). For Southern Brazil and ROM, the estimates were respectively 2.7% (5.05 million m^3) and 3.1% (103 thousand m^3) below the actual data used in the model, and the same value for RBZ (2.9 million m^3). For Chile and Argentina respectively, estimates were 2.9% above and 13.6% below the volumes observed in those countries in 1995. Overall, the model predicted the conifer sawnwood demand in each region under investigation within a close range. For ASIA-S and the ROW, estimates were within 5.7% and 2.9% above the proxies used in the model.

As for prices of conifer sawnwood, the model gave reliable estimates within 15% of the actual data for all the Mercosur countries, higher to Southern Brazil and RBZ, Argentina, and ROM (3.7%, 2.8%, 8.6% and 2.4% respectively) and lower for Chile (-3.8%). Equilibrium prices varied from as low as US\$122.7/m^3 in Argentina up to

US$137.3/m^3 in RBZ (as compared to US$125.7/m^3 in Southern Brazil). Prices of US$132.9/m^3 were estimated for Chile and US$124.0/m^3 in ROM. Estimates of the import conifer sawnwood prices from the bloc were US$192.2/m^3 for the ASIA-S countries and US$178.0/m^3 for the ROW, respectively 14.1% and 9.2% lower than the proxies used in the model (Figure 4.5).

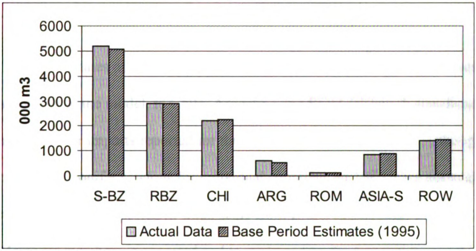


Figure 4. 4. Conifer sawnwood demand by region for base period and published data

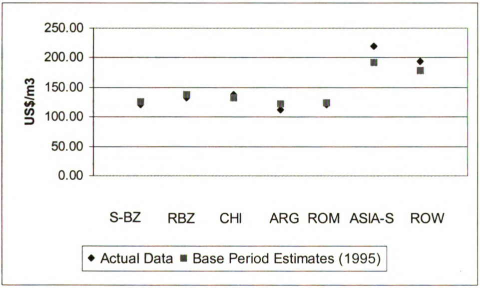


Figure 4. 5. Conifer sawnwood prices by region for base period and published data

Estimates of the total supply of conifer sawnwood (both domestic and exported/imported) can be derived from the estimates of the sawnwood demand by adding the net volume traded (exports and imports) following the material balance formulation (values not shown).

- Directions of Trade – Conifer Sawlogs and Sawnwood

Estimates of trade of conifer sawlogs in Mercosur for 1995 was restricted, according to the model, to Chile, Argentina and ROM (although significantly low), with no exports or imports reported for the other members (Table 4.4). Although actual data on trade of conifer sawlogs for individual countries for 1995 were not available, *Pinus* roundwood was exported in small scale from Brazil in that year. The lack of trade among Mercosur members is expected and is explained by the fact that its countries are mostly net exporters of forest products, with their own source of roundwood, and importing sawlogs may not be economically justifiable.

Table 4. 4. Estimates of conifer sawlog trade in Mercosur countries in 1995

To ⇒	REGIONS							TOTAL
From ⇓	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		0	0	0	0	0	0	**0**
RBZ	0		0	0	0	0	0	**0**
CHI	0	0		0	0	1145	327	**1472**
ARG	0	0	0		0	0	43	**43**
ROM	0	0	0	0		0	7	**7**
TOTAL	**0**	**0**	**0**	**0**	**0**	**1145**	**377**	**1521**

Note: values in thousand m^3

The estimates of conifer sawlogs exports from Chile were expected, since this country has intensively pursued exports of forest products (including sawlogs) in the past decades. The estimates of total volume exported by Chile in 1995 (1,15 million m^3), is in accordance with the actual data used in the model, although below the total reported by INFOR (2000). Chile exported 1.66 million m^3 and 1.39 million m^3 of radiata pine sawlogs in 1995 and 1996 respectively (INFOR, 2000). On the other hand, the 1994 Commodity Trade Statistics (UN, 1995) reports 1.12 million m^3 and 87 thousand m^3 of rough conifer untreated wood exported from Chile to ASIA-S countries and ROW, respectively. Traditionally Chile has aimed at exporting to the Pacific Rim countries, making the Asia-S countries its major group of conifer sawlog importers. The UN study also reported as much as 394 thousand m^3 of rough conifer untreated wood exported from Brazil (all to ROW) and 25.5 thousand m^3 from Argentina (almost all to ASIA-S countries). Considering that the definition of rough conifer untreated wood may not be the same as conifer sawlogs, and the data are 1994 volumes, the results from this study cannot be readily compared with the Commodity Trade Statistics data.

For conifer sawnwood, the results indicate a total of 2.5 million m^3 exported from the bloc in 1995, mostly to the ROW (1.46 million m^3) and to ASIA-S countries (892 thousand m^3) (Table 4.5). As expected, Brazil leads the conifer sawnwood exports to the ROW (traditionally to the US and to some EU countries), with estimated 1.0 million m^3 (although part refers to domestic trade), and Chile (with 1.1 million m^3 total) is the sole exporter to the Asia-S countries (estimated 892 thousand m^3). Minor exports come from Argentina and the ROM. The result also shows the internal trade of 162 thousand m^3 of conifer sawnwood from Southern Brazil to the RBZ. This magnitude of trade is a result of the assumption made that about 35% of the production from the Southern region go to the RBZ. Since this percentage could not be verified due to data unavailability, trade estimate between both regions may be either over- or underestimated, subject to future validation as data become available.

Table 4. 5. Estimates of conifer sawnwood trade among Mercosur countries in 1995

To ⇒ From ⇓	REGIONS							TOTAL
	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		162	0	0	0	0	1016	**1178**
RBZ	0		0	0	0	0	0	**0**
CHI	0	0		0	0	892	223	**1115**
ARG	0	0	0		0	0	197	**197**
ROM	0	0	0	0		0	24	**24**
TOTAL	**0**	**162**	**0**	**0**	**0**	**892**	**1459**	**2513**

Note: values in thousand m^3

Trade data from the 1994 Commodity Trade Statistics (UN, 1995) and from the 1995 International Trade Statistics Yearbook (UN, 1996) indicate conflicting trade statistics for conifer sawnwood from/to Mercosur countries. The 1994 Commodity Trade Statistics reports only 195 thousand m^3 of 'conifer wood, sawn' exported from Brazil in that year (90% to the ROW, and the remaining 10% to Argentina, ROM, and the ASIA-S countries), and only 484 thousand m^3 from Chile (66% to the ROW, 32% to ASIA-S countries, and 1.5% to Argentina). On the other hand, the 1995 International Trade Statistics Yearbook reports only 195 thousand m^3 of 'conifer shaped (sawn and planned) lumber' exported from Brazil and 720 m^3 from Chile in 1995. INFOR (2000) reports a total of 1.2 million m^3 of radiata pine sawnwood exported in 1995, about 67% above the total reported by the International Trade Statistics Yearbook and 7.7% above the findings from this study (Table 4.5). In addition, FAO (2000) reported 1997 trade statistics indicating that Brazil exported 649 thousand m^3 of conifer sawnwood (94% to the ROW), Chile exported 1.56 million m^3 (53% to ASIA-S countries and 47% to the ROW), with the combined Mercosur countries exporting 2.3 million m^3. The statistics over the period 1994-97 from both studies are highly variable.

Overall, the results from this study are not closely matched by the trade statistics, particularly for Brazil, which could be explained by lack of consistent definitions for the products reported by different sources, data discrepancy, or a higher domestic consumption of conifer sawnwood than initially assumed for the RBZ (resulting in a larger internal trade from S-BZ to the RBZ). The model, however, confirms the pattern of sawnwood trade for Brazil and Chile, the dominant net exporters within the bloc.

Even though the Mercosur countries started their economic integration in 1991, the findings of this study suggest that the creation of the bloc had (as far as 1995) none or a small impact on trade among the members, in part as a result of being net exporters and self-sufficient, to an extent, in raw material for sawmills. However, other indirect benefits have been in the form of direct investments from one country in another country's forest sector (e.g. Chile investing in Argentina), and increases in overall trade and consumption of goods and services, which may indirectly impact the conifer lumber market.

Increased trade of conifer sawlogs and sawnwood within the bloc in the future still remains a possibility. The perspective of roundwood shortage in Southern Brazil in the coming years, and increasing demand for forest products, changes in plantation rate in some countries, and the possibility of Chile and Bolivia becoming full members in the near future, with all countries benefiting from tariff reduction are considerations that can impact trade of conifer lumber. Some of these variables were considered in the dynamic forecast of the base scenario and in the sensitivity analysis.

4.6.1.2. Dynamic Forecast

The dynamic forecast predicts the possible changes occurring over time. A simulation taking into account the most likely scenario (base scenario) as well as changes in some of the major variables of the model was carried out. In this study the dynamic phase was modeled with exogenous changes in the growth rate of the GDP (as a demand shift variable), the growth rate of the upper bound on the conifer sawlogs in each region, and the change in import ad-valorem tax rate for Chile, assuming this country could become a full member of Mercosur by 2005 (Appendix 21).

Results of the dynamic simulation of the base scenario indicates that the demand for conifer sawnwood is expected to increase steadily for most of the Mercosur countries, except for Chile, between 1995-2010 (Figure 4.6). Such a decrease in domestic demand in Chile may be the result of increasing exports of conifer lumber over the period, rather than domestic processing. Other causes could be related to its relatively small population and consequently low domestic demand for lumber, and government policies targeting exports. For ASIA-S import demand for conifer sawnwood from Mercosur is expected to increase, although for the ROW it could decrease. This decrease could be the result of reduced production in Southern Brazil caused by shortage of sawlogs (Figure 4.6).

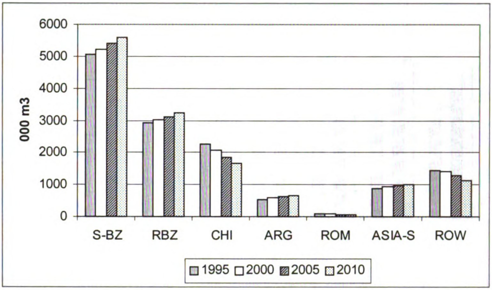


Figure 4. 6. Estimates of the demand for conifer sawnwood in the dynamic forecast – base scenario

Prices of conifer sawnwood are expected to increase across Mercosur, given the increasing demand in most of the countries and relatively limited supply of the sawlogs in some countries. The state of the forests in the region is not well known, nor is the magnitude and timing of the future availability of the plantation forests. The price increase therefore represents an overall trend, although the range of values may vary both in magnitude and timing (Figure 4.7). Prices in the ASIA-S and in the ROW represent equilibrium prices of imports from Mercosur. Such price differences reflect adjustments in the transportation costs and in the existing taxes/tariffs. Estimates of the average prices in the ASIA-S tend to be higher than in the ROW as result of higher transportation costs to that region.

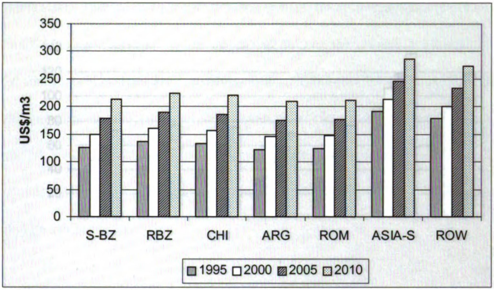


Figure 4. 7. Estimated conifer sawnwood prices in the dynamic forecast – base scenario

For sawlogs, the base scenario reveals a situation where an almost fixed volume is consumed by the manufacturing industry, except for Argentina and ROM, which may experience a slight increase in supply (not shown). Prices of conifer sawlogs show an increasing trend over the simulation period, with slightly higher prices in the RBZ and Chile (Figure 4.8). With respect to the exports, the model forecasts Chile as the sole exporter of conifer sawlogs to selected-Asian countries over the period. An average of 1110 thousand m^3 are forecast to be exported from Chile to Asian-S countries and 365 thousand m3 to the ROW for the period 2000-2010 (numbers not shown). Although some exports from countries such as Brazil, Uruguay, and Argentina, could be expected, the model does not account for such potential exports.

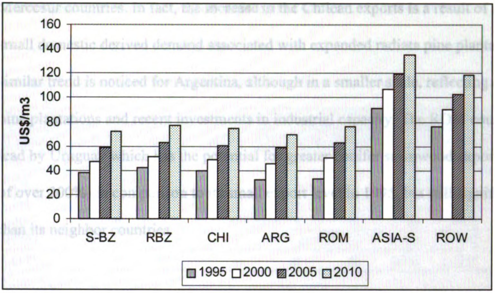


Figure 4. 8. Estimates of conifer sawlog prices in the dynamic forecast – base scenario

In terms of exports of conifer sawnwood, Chile and (Southern) Brazil may remain the regional leaders (Table 4.6). The steady reduction in potential lumber exports from Brazil during 1995-2010, however, can be attributed to the expected decrease in timber availability over the period. An opposite trend is predicted for Chile and Argentina, where the expansion of the forest resource base, and consequently the industrial capacity, is expected in the next decade. Under this scenario an increase in exports of conifer sawnwood of about 5% would be expected for Mercosur, from 2.51 million m^3 exported in 1995 to up to 2.63 million m^3 in 2010. Chile could experience an impressive increase of 52%, followed by Argentina with 14%, with Brazil suffering a decrease of about 47% over the period. This may represent a significant change in the pattern of the Brazilian exports of conifer lumber for a country that has solidly expanded its participation in the global market of pine lumber over the past two decades, due to a large extent to the use of pines. This base scenario takes into account an average decrease in the resource base for Brazil, and drives exports to the large domestic market as compared to the other

Mercosur countries. In fact, the increase in the Chilean exports is a result of a relatively small domestic derived demand associated with expanded radiata pine plantations. A similar trend is noticed for Argentina, although in a smaller scale, reflecting Argentinean pine plantations and recent investments in industrial capacity. The ROM countries are lead by Uruguay which has the potential for greater conifer sawnwood exports (increase of over 200%) in comparison to its small export level in 1995, but still significantly lower than its neighbor countries.

Table 4. 6. Potential exports of conifer sawnwood from Mercosur countries (1995-2010)

Region	YEAR			
	1995	2000	2005	2010
S-BZ	1178	1025	830	627
RBZ	0	0	0	0
CHI	1115	1315	1517	1699
ARG	197	203	214	225
ROM	24	54	69	76
TOTAL	**2513**	**2597**	**2629**	**2627**

Note: values in thousand m^3

For the direction of trade of conifer sawnwood for 2000 and 2010, (Southern) Brazil, Argentina, and Uruguay will likely continue exporting to the ROW countries, while Chile, given its geographic location, will keep its Asia-Pacific market, mostly the ASIA-S countries (Japan, China and Republic of Korea) (Tables 4.7 and 4.8).

Southern Brazil's major markets for conifer sawnwood will possibly remain the rest of Brazil (RBZ) and the ROW. In the mid-1990s, ROW exports have been lead by the US as Brazil has been the second largest exporter, following Canada (Flynn, 1999). For Southern Brazil, however, the decrease in exports between 2000 and 2010 may be even bigger as a result of an increase in regional pine sawnwood trade to the rest of the country, a major consumer region with expanded demand (Tables 4.7 and 4.8).

Table 4. 7. Potential directions of trade of conifer sawnwood for 2000 – base scenario

To ⇒ From ⇓	REGIONS							TOTAL
	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		250	0	0	0	0	775	**1025**
RBZ	0		0	0	0	0	0	**0**
CHI	0	0		0	0	937	378	**1315**
ARG	0	0	0		0	0	203	**203**
ROM	0	0	0	0		0	54	**54**
TOTAL	**0**	**250**	**0**	**0**	**0**	**937**	**1410**	**2597**

Note: values in thousand m^3

Table 4. 8. Potential directions of trade of conifer sawnwood for 2010 – base scenario

To ⇒ From ⇓	REGIONS							TOTAL
	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		486	0	0	0	0	141	**627**
RBZ	0		0	0	0	0	0	**0**
CHI	0	0		0	0	1005	694	**1699**
ARG	0	0	0		0	0	225	**225**
ROM	0	0	0	0		0	76	**76**
TOTAL	**0**	**486**	**0**	**0**	**0**	**1005**	**1136**	**2627**

Note: values in thousand m^3

For the base scenario during the period under investigation, the model predicts the possibility of Chile increasing its exports toward the ROW (694 thousand m^3 by 2010), compensating for the decrease in the exports from Brazil, if the ROW maintains its level of imports from the region. In fact, such an assumption may be the reason for the predicted decrease in domestic demand for pine sawnwood in Chile. Also Argentina and the ROM countries may likely face an increase of pine sawnwood exports to the ROW, although such volumes would not compromise their domestic demand for the commodity.

4.6.2. Sensitivity Analysis

In any modeling project, the primary interest of potential users converges to the usefulness of the model for analyzing policy issues. In order to test the ability of the Mercosur model to serve as an acceptable representation of the conifer lumber sector and to show its capability for analyzing policy changes, alternative scenarios were studied.

The base scenario presented in the previous session may represent the most likely scenario for the period 1995-2010. However, given the large number of variables involved and the model assumptions, the magnitude of some variables could change, consequently changing the results both in the static and in the dynamic forecasts. Sensitivity analysis of the model considers potential changes in the magnitude of some key variables associated with the demand and supply of the commodities. The results from the sensitivity analysis presented below are results from changes in individual variables for each time. This section examines changes in (1) the growth of supply of conifer sawlogs in Brazil, (2) the growth of GDP in Brazil, and (3) the price elasticities of demand for conifer sawnwood in Brazil and Chile.

4.6.2.1. Change in the Growth of the Availability of Conifer Sawlogs in Brazil

An important objective of this study is to investigate the effect on the production, consumption, trade and prices from the expected shortage of pine sawlogs in Southern Brazil in the next decade. To investigate sensitivity of the model to changes in this variable, the following range of growth rates and timing of changes in the minimum availability of conifer sawlogs were considered in Brazil (Table 4.9).

Table 4. 9. Percentage change in the minimum availability of conifer sawlogs in Brazil

REGION	SCENARIOS (stock growth)	PERIOD		
		1996-2000	2001-2005	2006-2010
S-BZ	High	5.0%	2.0%	0.0%
	Medium *	2.0%	0.0%	-2.0%
	Low	0.0%	-2.0%	-5.0%
	Lower	0.0%	-5.0%	-10.0%
RBZ	High	5.0%	2.0%	0.0%
	Medium *	2.0%	0.0%	-2.0%
	Low	0.0%	-2.0%	-5.0%
	Lower	0.0%	-5.0%	-10.0%
CHI	Base scenario	2.0%	3.7%	3.7%
ARG	Base scenario	1.0%	1.0%	1.0%
ROM	Base scenario	1.0%	1.0%	1.0%

(*) Medium scenario represents the base scenario (section 4.6.1.)

Most of the changes in the outcomes from changes in the growth in supply were noticed by 2010, considering the cumulative effect of the decrease in timber availability. Negligible changes were observed in the prices and quantities (consumed, produced and traded) between the high and medium-value scenarios. With a more drastic reduction in sawlog availability (low-growth scenario), however, prices may increase for both sawlogs and sawnwood (not shown).

As result of the price-quantity interaction, the direction of trade changed significantly when comparing the high and low-value scenarios (Tables 4.10 to 4.12 as compared with Table 4.8 – base scenario). With a drastic decrease of timber availability (low scenario), Southern Brazil could eliminate its exports, supplying the domestic market exclusively. Higher prices, and lower distances (transportation costs) to the RBZ, could justify trade within Brazil only (Table 4.10). Extending the simulation to 2015, Brazil could face imports by that year (results not shown).

Table 4. 10. Potential directions of trade of conifer sawnwood for 2010 – Low-growth scenario for the supply of conifer sawlogs

To ⇒ From ⇓	REGIONS							TOTAL
	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		1308	0	0	0	0	0	**1308**
RBZ	0		0	0	0	0	0	**0**
CHI	0	0		0	0	877	822	**1699**
ARG	0	0	0		0	0	225	**225**
ROM	0	0	0	0		0	76	**76**
TOTAL	**0**	**1308**	**0**	**0**	**0**	**877**	**1123**	**3308**

Note: values in thousand m^3

In a more drastic scenario, considering 0%, 5% and 10% decrease in the resource base growth between 1995-2000, 2001-05, 2006-10 could potentially make Brazil (RBZ) to face imports of conifer sawnwood, more likely from Chile, considering their forest sector profiles and both countries' membership in Mercosur (Table 4.11). The country, a traditional net exporter and leader producer of pine lumber within the bloc, could become importer potentially creating an impact in the domestic industry and the forest operations. This scenario, however, may not occur if changes in the forest products markets take place. These changes could include regulation of the production and consumption of sawlogs and sawnwood, species and product substitutability, forest regulation and management towards sustainable yield, technological changes, and more investment in forest plantations. Each factor, to varying extents, could play a role in this scenario. Investments in plantations, although a possible medium- to long-term solution, need to be made soon to generate long-term results.

In the event of a considerably smaller decrease in pine timber availability (high-scenario), the prospect for Brazil exporting pine sawnwood instead of importing still exists. Exports, however, would be kept at a minimum level, considering that Southern

Brazil would supply mostly its own market (Table 4.12). In this scenario, the other Mercosur countries would export slightly less than in the low-value scenario, although in quite significant volumes, particularly from Chile to both the ROW and the ASIA-S countries.

Table 4. 11. Potential directions of trade of conifer sawnwood for 2010 – Lower-growth scenario for the supply of conifer sawlogs

To ⇒ From ⇓	REGIONS							TOTAL
	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		615	0	0	0	0	0	**615**
RBZ	0		0	0	0	0	0	0
CHI	0	865		0	0	825	531	**2221**
ARG	0	0	0		0	0	448	**448**
ROM	0	0	0	0		0	76	**76**
TOTAL	0	**1480**	0	0	0	**825**	**1056**	**3361**

Note: values in thousand m^3

Table 4. 12. Potential directions of trade of conifer sawnwood for 2010 – High-growth scenario for the supply of conifer sawlogs

To ⇒ From ⇓	REGIONS							TOTAL
	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		480	0	0	0	0	147	**627**
RBZ	0		0	0	0	0	0	0
CHI	0	0		0	0	1011	688	**1699**
ARG	0	0	0		0	0	225	**225**
ROM	0	0	0	0		0	76	**76**
TOTAL	0	**480**	0	0	0	**1011**	**1136**	**2627**

Note: values in thousand m^3

4.6.2.2. Change in the Growth of GDP in Brazil

Another possible change is the GDP growth rate in certain regions, which is expected to affect the demand for forest products, changing consequently the equilibrium prices and quantities. To investigate the model sensitivity to this change in Southern

Brazil, different scenarios were considered (Table 4.13).

Table 4. 13. Change in the Growth of GDP in Brazil

Scenarios	Specification
High	5% growth of GDP in Southern Brazil (S-BZ) and RBZ – 2000-2010
Medium *	4% growth of GDP in Southern Brazil (S-BZ) and RBZ – 2000-2010
Low	3% growth of GDP in Southern Brazil (S-BZ) and RBZ – 2000-2010

(*) Medium scenario represents the base scenario (session 4.6.1.)

Results indicate that the model is not very sensitive to a small change in this variable (between 3% to 5%). The scenarios held similar outcomes for sawnwood equilibrium prices (Figure 4.12) and quantities demanded for conifer sawnwood. Difference in prices was only within 1.7% range between the high and low growth scenarios, with lower prices estimated for the low GDP growth rate scenario. Similar results were observed for conifer sawlog prices (within 2% range between both scenarios).

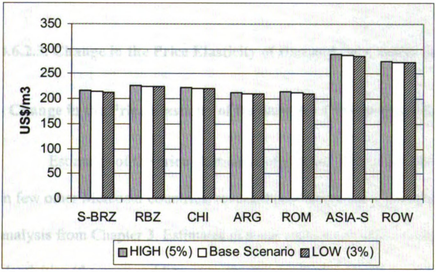


Figure 4. 9. Estimates of conifer sawnwood prices in the sensitivity analysis for change in GDP growth rate between 2000-2010 (prices in 2010)

For exports of conifer sawnwood, however, the effect of this simulation is more noticeable, mostly by 2010. A higher economic growth, represented by a sustained 5% GDP growth rate would likely reduce the sawnwood exports faster than with a 3% growth rate. Indirectly a higher rate could increase the domestic consumption. Considering that a significant percentage of the total trade for S-BZ represents domestic trade to RBZ, the estimated exports are even lower (Table 4.14).

Table 4. 14. Estimates of conifer sawnwood exports in the sensitivity analysis for change in GDP growth rate between 2000-2010

Exports	HIGH (5%)			MEDIUM (4%)			LOW (3%)		
	2000	2005	2010	2000	2005	2010	2000	2005	2010
S-BZ *	1015 (296)	792 (398)	553 (553)	1025 (250)	830 (363)	627 (486)	1035 (245)	887 (330)	736 (423)
RBZ	0	0	0	0	0	0	0	0	0
CHI	1315	1517	1699	1315	1517	1699	1315	1517	1699
ARG	203	214	225	203	214	225	203	214	225
ROM	54	69	76	54	69	76	54	69	76
TOTAL	2588	2592	2553	2597	2629	2627	2607	2687	2736

Note: values in thousand m^3

* numbers in parenthesis are the estimates of the domestic trade to RBZ

4.6.2.3. Change in the Price Elasticity of Demand for Conifer Sawnwood

- Change in the Price Elasticity of Demand for Conifer Sawnwood in Brazil

Estimates of the price elasticities of demand for conifer sawnwood in Brazil, and in few other Mercosur countries, revealed heterogeneous results through the regression analysis from Chapter 3. Estimates in some cases were within a range of highly variable elasticities (from around 0 to over –1). Such variability may be influenced by the data available and used in this study. In addition, extremely low elasticities for conifer sawnwood in Southern Brazil reflect the characteristics of the timber market during the period of the analysis (1980s through mid-1990s), which may differ from the period covered by the spatial equilibrium analysis (1995-2010). Sensitivity analysis focusing on the change of the price elasticity of demand for conifer sawnwood in Brazil (Southern Brazil and RBZ) considered a range of elasticities varying between –0.05 (low), -0.40 (medium – base scenario) to –1.00 (high). This range was set based on the results found for the elasticities in Brazil in Chapter 3.

This sensitivity analysis indicated that both elasticities between –0.05 and –0.40 held similar results in terms of prices of conifer sawlogs and sawnwood in all regions and relatively similar quantities demanded of conifer sawnwood. A higher elasticity of -1.00 gave overall lower equilibrium conifer sawnwood prices (Figure 4.10) and sawlog prices across the regions.

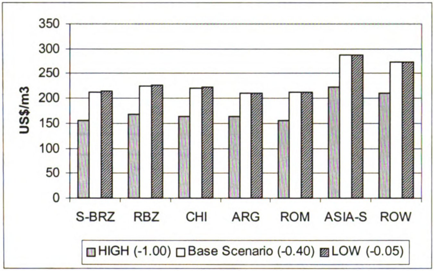


Figure 4. 10. Estimates of conifer sawnwood prices in the sensitivity analysis for price elasticity of demand (2010)

In terms of trade, the low and the medium elasticities held similar results suggesting that a range of relatively low price elasticities (between –0.05 to –0.40) would not affect the overall export estimates as well (Table 4.15 for elasticity of –0.05). A higher elasticity gave overall higher conifer sawnwood exports from Mercosur, particularly for Brazil, considering that Chilean exports changed slightly (Table 4.15).

Table 4. 15. Potential directions of trade of conifer sawnwood for 2010 with price elasticity of domestic demand in Brazil of -0.05

To ⇒	REGIONS							TOTAL
From ⇓	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		486	0	0	0	0	127	**612**
RBZ	0		0	0	0	0	0	0
CHI	0	0		0	0	1001	698	**1699**
ARG	0	0	0		0	0	226	**226**
ROM	0	0	0	0		0	76	**76**
TOTAL	**0**	**486**	**0**	**0**	**0**	**1001**	**1127**	**2613**

Note: values in thousand m^3

Table 4. 16. Potential directions of trade of conifer sawnwood for 2010 with price elasticity of domestic demand in Brazil of -1.00

To ⇒	REGIONS							TOTAL
From ⇓	S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
S-BZ		389	0	0	0	0	1025	**1414**
RBZ	0		0	0	0	0	0	0
CHI	0	0		0	0	1022	575	**1597**
ARG	0	0	0		0	0	0	0
ROM	0	0	0	57		0	19	**76**
TOTAL	0	**389**	0	**57**	0	**1022**	**1620**	**3087**

Note: values in thousand m^3

- Change in the Price Elasticity of Demand for Conifer Sawnwood in Chile

Chile is a major regional producer and exporter of conifer sawlogs and sawnwood and possible change in its elasticity of demand for sawnwood would likely change the regional equilibrium of prices and quantities. A sensitivity analysis focusing on the change of the price elasticity of demand for conifer sawnwood in Chile was carried out.

Two elasticities were considered: -1.5 (high) and – 0.40 (low), as compared with the base scenario elasticity (1.081) (Table 4.2.).

The sensitivity analysis for a range of price elasticities of conifer sawnwood demand in Chile indicates opposite results for domestic demand depending on the magnitude of the elasticity (Figure 4.11). For higher elasticities (between –1.20 and –1.50) the decreasing trend in domestic consumption is forecasted. This decrease in domestic consumption is compensated by an increase in exports (Table 4.17). For an elasticity as low as –0.40, an increase in domestic demand is expected over time, causing a direct decrease in exports. This result suggests a high sensitivity of the Chilean market to a change in the price elasticity of the demand for conifer sawnwood. Prices change as well with higher prices observed with the lower elasticity (about 3.6% higher than the base scenario - not shown).

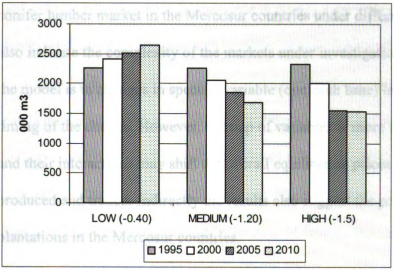


Figure 4. 11. Demand for conifer sawnwood in Chile in the sensitivity analysis for price elasticity of demand

As for exports, an opposite trend is observed, as expected, in comparison with the domestic demand trend (Table 4.17). The Southern Brazil could increase its exports to the ROW as result of the decrease in exports from Chile under a scenario with a lower elasticity of demand in the Chilean market, all other variables constant.

Table 4. 17. Estimates of conifer sawnwood exports from 1995-2010 in the sensitivity analysis for change in the price elasticity of conifer sawnwood in Chile

Exports	HIGH (-1.50)				MEDIUM (-1.20)				LOW (-0.40)			
	1995	**2000**	**2005**	**2010**	**1995**	**2000**	**2005**	**2010**	**1995**	**2000**	**2005**	**2010**
S-BRZ	1244 (162)	1092 (250)	897 (363)	732 (486)	1178 (162)	1025 (250)	830 (363)	627 (486)	1178 (162)	1215 (250)	1223 (363)	1223 (486)
RBZ	0	0	0	0	0	0	0	0	0	0	0	0
CHILE	1049	1372	1820	1839	1115	1315	1517	1699	1115	985	874	747
ARG	197	143	61	65	197	203	214	225	197	227	239	251
ROM	24	46	65	76	24	54	69	76	24	59	69	76
TOTAL	**2513**	**2653**	**2843**	**2712**	**2513**	**2597**	**2629**	**2627**	**2513**	**2486**	**2404**	**2297**

Note: values in thousand m^3
* numbers in parenthesis are the estimates of the domestic trade to RBZ

Overall these sensitivity analyses indicate the ability of the model to represent the conifer lumber market in the Mercosur countries under different scenarios. The results also indicate the complexity of the markets under investigation and reveals how sensitive the model is to changes in specific variable (one each time) in terms of the magnitude and timing of the change. However, a group of variables is more likely to change each time and their interactions may shift the overall equilibrium prices and quantities consumed, produced and traded. Indirectly the results also suggest the possible allocation of forest plantations in the Mercosur countries.

4.6.2.4. Summary of the Sensitivity Analyses

Sensitivity analyses were performed for scenarios that represent change in the timber availability in Brazil, growth in GDP in Brazil, and price elasticities of demand for conifer sawnwood in Brazil and Chile (Tables 4.9 and 4.13, and p. 181-182).

Overall the results of these sensitivity analyses indicate the ability of the model to represent the conifer lumber market in the Mercosur countries under different scenarios. The results also indicate the complexity of the markets under investigation and reveal how sensitive the model is to changes in specific variables (one at a time) in terms of the magnitude and timing. However, a group of variables is more likely to change each time and their interactions may shift the equilibrium prices and quantities consumed, produced and traded. Indirectly the results also suggest the possible allocation of forest plantations.

A summary of the sensitivity of the model to the changes in the key variables, with respect to the percentage change in exports of conifer sawnwood for the regions under investigation is shown in Table 4.18 and 4.19 (sensitivity analyses 1, 2, 3 and 4). Although the changes can be significant in relative terms in some other countries, their total volume may be small or negligible in terms of the total exports from the bloc. It is important to consider that the Southern Brazil and Chile are the major regional exports.

As for a change in the growth of the availability of conifer sawlogs in Brazil, the results are expressed in terms of the percentage change in trade of conifer sawnwood in 2010 as compared with the base scenario (Table 4.18 – sensitivity analysis 1). As expected, a faster decrease in timber availability reduces the exports from Southern Brazil, and increases the imports in the Rest of Brazil, representing either imports from other countries or intra-trade from Southern Brazil. The first two scenarios suggest a minor impact on conifer lumber exports of the other Mercosur countries, with a major impact predicted for Chile and Argentina as a more drastic reduction of the timber availability occurs.

The model seems to be less affected by a change in GDP growth rate in Brazil than by changes in the availability of supply in Brazil and in the price elasticities of demand for conifer sawnwood in both Brazil and Chile (Table 4.18 – sensitivity analysis 2, 3, and 4). For a change in the price elasticity of demand in Brazil, the model indicates an increase in exports from Southern Brazil with a price elasticity of –1.0, and a significant decrease in exports over 45% with lower elasticities (-0.40 and –0.05) between 2000-10 (Table 4.19 – sensitivity analysis 3). The same trend is predicted for Chile, with a significant increase in exports with higher elasticities (respectively 34% and 52% for elasticities of -1.5 and –1.2) and a significant decrease of over 30% in conifer sawnwood exports for a price elasticity of –0.40 (sensitivity analysis 4).

Table 4. 18. Summary of the results of the sensitivity analysis for a change in timber availability in Brazil

SENSITIVITY ANALYSES								
1 - Change in the Growth of the Availability of Conifer Sawlogs in Brazil (S-BZ - RBZ)								
– Change in Trade of Conifer Sawnwood for 2010 as compared with the Base Scenario in percent								
Scenario	**S-BZ**	**RBZ**	**CHI**	**ARG**	**ROM**	**ASIA-S**	**ROW**	**Total**
5% **2%** **0%**	0	-1 imports	0	0	0	0.5 imports	0	0
0% **-2%** **-5%**	109 exports	-12 imports	0	0	0	6 imports	6 imports	26 overall trade
0% **-5%** **-10%**	- 2 exports	205 imports	31 exports	99 exports	0	-18 imports	- 7 imports	28 overall trade

Table 4. 19. Summary of the results for the sensitivity analysis of changes in the GDP growth in Brazil and price elasticities of demand for conifer sawnwood in Brazil and Chile

SENSITIVITY ANALYSES								
2 - Change in the Growth of GDP in Brazil – % Change in Conifer Sawnwood Exports (2000-2010)								
Scenario	**S-BZ**	**RBZ * Imports**	**CHI**	**ARG**	**ROM**	**ASIA-S**	**ROW**	**Total**
5%	-46	86						-1
4% (BS)	-39	94	29	11	41	na	na	1
3%	-29	73						5
3 - Change in the Price Elasticity of Demand for Conifer Sawnwood in Brazil – % Change in Conifer Sawnwood Exports (2000-2010)								
Scenario	**S-BZ**	**RBZ * Imports**	**CHI**	**ARG**	**ROM**	**ASIA-S**	**ROW**	**Total**
e = -1.0	11	143	34	-100	65			17
e = -0.4 (BS)	-47	200	52	14	217	na	na	5
e = -0.05	-48	200	52	15	223			4
4 - Change in the Price Elasticity of Demand for Conifer Sawnwood in Chile – % Change in Conifer Sawnwood Exports (2000-2010)								
Scenario	**S-BZ**	**RBZ * Imports**	**CHI**	**ARG**	**ROM**	**ASIA-S**	**ROW**	**Total**
e = -1.5	-33	94	**34**	-55	65			2
e = -1.2 (BS)	-47	200	**52**	14	217	na	na	4
e = -0.4	4	200	**-33**	27	217			-9

* imports of conifer sawnwood from Southern Brazil (S-BZ)
BS – Base Scenario
na – not applicable

4.7 Conclusions

In this chapter, a spatial equilibrium model to analyze the consumption, production and trade of conifer timber markets in Mercosur was developed. Overall, the model behaves well under different scenarios and predicts within an acceptable range the results for changes in some of the most important variables under investigation. The model captures mostly changes in the sawnwood market, with the results for the market of sawlogs (production, consumption, and trade) subject to less variability. That may be a consequence of well-defined demand and supply markets, with the conifer sawmilling industry already established in countries such as Brazil and Chile.

The results of the static phase (in the base scenario) serve to calibrate the model and to outline the pattern of production, consumption, and trade among the regions, or which the dynamic forecast is based. The results from the sensitivity analyses indicate the many possibilities for changing key variables related to the demand and supply of the commodities under investigation. Different scenarios revealed the possibility of expanding or reducing exports, primarily in Southern Brazil, given the expected shortage of conifer timber in this decade.

A spatial equilibrium analysis is data intensive, and given the data limitation in this study some results should be viewed as trends of possible outcomes. It is important to note that the timing and the magnitude of the results may change as some assumptions change. As more specific data are collected and become available, the model could be improved and the results and trends tested over time.

This study concentrated on the economic aspects only. However, political, social and environmental aspects of related to the domestic supply, demand, and trade of forest products are also important and may be addressed properly as they become relevant issues to the model.

The model can be used, to a certain extent, as a flexible tool for policy simulation of the conifer lumber markets in the Mercosur countries. The usefulness of the model is attested by a range of possible applications, most noteworthy the simulation of alternative scenarios not contemplated in this study, such as a change in one variable or a group of variables each time. Minor changes in the model could accommodate other likely scenarios such as the advent of the Free Trade Agreement of the Americas (FTAA), the inclusion of other members to the bloc, and bilateral bloc trade negotiations (such as the possible Mercosur-EU agreement).

CHAPTER 5

CONCLUSIONS

This study was the first attempt to integrate the econometric results with secondary data in developing a partial equilibrium analysis to investigate forest products markets in Southern Brazil, and to a large extent, in the Mercosur countries. As a result, a workable and useful model to analyze the consumption, production and trade of conifer timber markets in the region was developed and tested.

Chapter 2 investigated qualitatively and quantitatively the forest resources and the lumber industry in Mercosur, with focus on the Southern Brazilian market for conifer sawlogs and sawnwood. It provided a critical view of the regional conifer lumber market, its opportunities and shortcomings in the region under unvestigation, helping to define the setting for the economic analysis that followed.

The econometric analysis for Brazil, Chile and Argentina in Chapter 3 provided a better understanding about the relationship between demand, supply and prices of conifer sawlogs and sawnwood in those countries. The evaluation also revealed the magnitude and range of price elasticities of the demand for and supply of the commodities under investigation, also identifying other major explanatory macroeconomic variables affecting them. Price and GDP elasticities were used in building the trade model in Chapter 4.

A spatial equilibrium model was developed in Chapter 4, which simulates the optimal trade pattern, consumption, production, and capacity that satisfy the price and the supply/demand quantity relationship. Sensitivity analyses indicated the possible changes in the outcome as a result of changing one key variable each time. The future pattern of production, consumption and trade of conifer lumber in Southern Brazil is likely to be highly influenced by the magnitude of changes in the availability of pine sawlogs from plantations. A sensitivity analysis with respect to changes in this variable indicated that the pine lumber market in Southern Brazil could face a significant reduction in its production and consequent exports, even becoming a net importer, if a drastic decrease in availability of pine sawlogs occurs. Such a scenario, however, will be positively or negatively influenced by the interaction with other major macroeconomic variables and the expansion of the resource base, both in Brazil and in some of the other Mercosur countries.

This study confirmed the need for industries and government agencies in those countries to address important policy issues such as the future availability of pine sawlogs from plantations, the level of forest and industrial investments, and the need for industrial modernization of the sawmilling sector in terms of competitiveness, and cost and technology efficiency. Particularly for Brazil, the future shortage of conifer sawlogs requires that effective actions be taken by the interested sectors (private and public) to expand the pine plantation base, guaranteeing the sustainable production of pine sawlogs. The effectiveness of these actions may be related to important ongoing forest debates at national and regional levels. Those include the direction to be taken by the recently created National Program for Forests, (decree 3.420, 2000), which aims at creating incentives for the sustainable use of natural and planted forests across the nation. Another important debate regards the existing Forest Legislation, which if effective, will likely influence the land use patterns and the consequent allocation of reforestation projects across the country by both private and public investments.

Continuous foreign investments in plantations and in the forest-based industries in Argentina and in Uruguay towards pines may expand their resource base and their industrial capacity, creating incentives for increased domestic consumption and exports of solidwood products. Likewise, continuous expansion of the radiata pine base in Chile, associated with intensified forest management practices (e.g. pruning and pre-commercial and selective harvesting), will expand the future production and exports of both high-grade pine sawlogs and sawnwood. These issues to varying extents may influence the market equilibrium for pine timber within the trade bloc.

In terms of policy-related issues, the dynamic model in this study can be used to analyze future policy scenarios. The model can be used as a starting point to address the impact on the lumber markets from changes in national policies and aggregated private investments in pine plantations, changes in the installed capacity and in the industrial technology, and also in terms of species substitution (e.g. *Eucalyptus* for pines).

Policy related issues with a global scope that may influence the markets under investigation and, to a certain extent, could be accommodated in the model are the Free Trade Area of the Americas (FTAA), bilateral trade bloc agreements (e.g. Mercosur-EU), the Kyoto Protocol on global climate change, and forest certification. Other developments and macropolicies at stake in the Mercosur countries that could influence the pine lumber markets include the extent of full integration of its members into the bloc, the inclusion of other regional countries as members, the ongoing discussion on trade issues among the current members, the dollarization and currency policies in some countries, and possible economic crises. In addition, the evolution of Mercosur and the full integration of its members (in terms of free trade and in other socio-economic areas) can create direct and indirect incentives for the benefit of the forest sector in each country.

Overall, the study contributes to a better understanding of the conifer timber markets in the Southern Brazil and in the other Mercosur countries. Although it accomplished its objectives, it is important to consider the limitations of the available data from different regions used in the development of the models. Future data as it becomes available may be used to refine and to confirm some of the findings of this study.

- Recommendations

As a recommendation, the disaggregation of the commodities (sawlogs and sawnwood) into different grades, species and price ranges would be useful as data become available. It would also be of interest to explore the substitutability between groups of species including hardwoods from natural forests and from plantations (such as the *Eucalyptus*, which only in recent years entered the lumber market). *Eucalyptus* is not a substitute species for pines in the manufacturing industries and its market niche is still being developed. However, considering the likely shortage of pine sawlogs in Brazil and that key forested countries in Mercosur have extensive *Eucalyptus* plantations, this species can play a future role in regional timber markets.

With the respect to improving and expanding the model, it is important to consider that some sawmills operate under an integrated process, adding value to their products, before exporting or commercializing them. For instance, some mills also make mouldings, frames and other lumber-related products, and therefore part of the lumber production may have not been accounted for in the process. The inclusion of these products and markets into the model would give a better representation of the sector as a whole. Further expansion of the model could also include trade inertia considering possible trade linkages between pairs of regions. Expanding the model to incorporate other countries or regions requires changing the geographic boundaries of the study. This would be interesting when simulating the possible expansion of Mercosur, either in terms of new members or new bloc integration (FTAA).

In addition, national agencies and institutes in Mercosur should develop standard procedures for data collection, either in terms of product standardization, as well as location (producer and consumer markets), and periodicity. As additional data and information is collected, further analysis may provide a better indication whether or not the future scenarios and the respective results will hold.

LITERATURE CITED

ABIMCI - Associação Brasileira de Indústria de Madeira Processada Mecanicamente (author unspecified). 1999. *Mechanically Processed Timber. Sectorial Study*. IV International Plywood and Tropical Wood Congress, Oct, 1999 Brazil. 54 p.

ABPM - Associação Brasileira de Produtores de Madeira (author unspecified) 1994. Datasource from Revista da Madeira. 1994. Bons negócios em casa [Good business at home]. 3 (16): 4-5.

Adams, D.M. 1985. A spatial equilibrium model of African-European trade in tropical logs and sawnwood. *Forest Ecology and Management*, 13: 265-287.

Adams, D. M. 1987. Issues in trade modeling: global and regional models. In: *Forest Sector and Trade Models: Theory and Applications*, UW. 105-110.

Adams, D.M. and R.W. Haynes. 1980. The 1980 softwood timber assessment market model: structure, projections, and policy simulations. *Forest Science*, Monograph 22. 63 p.

Adams, D.M and R.W. Haynes. 1987. Interregional modeling. In: *The Global Forest Sector: An Analytical Perspective*. (editors) Kallio, M; D. Dykstra and C.S. Binkley. IIASA. John Wiley & Sons. 391-413.

Andersson, A.E., M. Kallio and R. Seppala, 1986. Systems analysis for the forest sector. In: *Systems Analysis in Forestry and Forest Industries - Studies in the Management Sciences*. Editors. Kallio, M. Andersson, A.E., Seppala, R. and Morgan, A. (ed.) Elsevier Science Publishers. Volume 21. p.1-26.

ANFPC – Associação Nacional de Fabricantes de Papel e Celulose (author unspecified). 1994. *Relatório Estatístico* [Statistic Report]. Section: "Reflorestamento". ANFPC (current BRACELPA). São Paulo, Brazil. Section 6.

Angelo, H. 1998. *As Exportações Brasileiras de Madeiras Tropicais*. [The Brazilian Exports of Tropical Timber]. Dissertation. Universidade Federal do Paraná [Federal University of Paraná]. 131 p.

Apland, J. 1986. The approximation of non-linear programming problems using linear programming. *Staff-Pap-P-Univ-Minn-Dep-Agric-Appl-Econ*. St. Paul : Department of Agricultural and Applied Economics, University of Minnesota. Jan (86-2) 23 p.

Avogrado, E.G. 2000. *Argentina: Uma Síntese - Cálculo de custo de importacion* [Argentina: A Synthesis - Calculation of Import Costs]. http://www.artrade.com/esp/info/sintrans.htm#costo

Azeredo, N.R.S. 1993. *Desafios e oportunidades para o desenvolvimento florestal dos países Latino-americanos para o ano 2000* [Challenges and opportunities for the forest development of Latin-American countries for 2000]. Speech in: Feira Internacional de Exposicion y Demonstracion de Maquinaria Florestal 39. 18 p.

Bacha, C.J.C. 2000. Evolução da Produção Brasileira de Madeira: Haverá Escassez? [Evolution of the Brazilian Wood Production: Will there be scarcity*?]. Preços Agrícolas*, July 2000. 13-16.

Bergh, J.C.J.M. van den, P. Nijkamp and P. Rietveld. 1996. Spatial equilibrium models: a survey with special emphasis on transportation. In: Recent advances in spatial equilibrium modeling - Methodology and Applications. Bergh, J.C.J.M. van den, P. Nijkamp and P. Rietveld. (editors). *Advances in Spatial Sciences.* Springer-Verlag, 48-76.

Bigsby, H.R. 1993. An econometric model of the sawtimber market in Australia. Aust. For. 56 (1):61-67.

Bishop, P.M., J.E. Pratt and A.M. Novakovic. 1993. Analyzing the impacts of the proposed North American Free Trade Agreement on European-North American dairy trade using a joint-input, multi-product approach., Cornell-Agric-Econ-Staff-Pap. Ithaca, N.Y. Cornell University, Sept. (93-17) 17 p.

Blatner, K. 1987. Approaches to bilateral trade modeling, In: *Forest Sector and Trade Models: Theory and Applications*, UW. 157-163.

BNDES - Banco Nacional de Desenvolvimento (author unspecified). 1995. Produtos Florestais - Panorama 1980/1992 [Forest Products - 1980/1992 Panorama]. BNDES, *Relatos Setoriais*, 41 p. http://www.bndes.gov.br/publica/relato.htm (electronically acquired material downloaded in 01/05/1999)

Brannlund, R.; P.O. Johansson; and K.G Lofgren. 1985. An econometric analysis of aggregate sawtimber and pulpwood supply in Sweden. Forest Science. 31 (3): 595-606.

BRDE - Banco Regional de Desenvolvimento do Extremo Sul (author unspecified). 1995. *Programa para Implantação de Reflorestamentos de Múltiplo Uso na Região Sul do Brasil - Versão preliminar* [Program for Establishing Multiple-use Plantation Forest in Southern Brazil – Preliminary Version]. Superintendência de Planejamento/Departamento de Desenvolvimento de Programas. 70 p.

Brooks, D.J. 1987. Issues in trade modeling: aggregation of products, In*: Forest Sector and Trade Models: Theory and Applications*, UW. 111-120.

Brooks, D.J. and J. Kincaid. 1987.REACTT : an algorithm for solving spatial equilibrium problems. *General Technical Report PNW* ; 204. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, 37 p.

Brooks, D., A. Baudin and P. Schwarzbauer. 1995. *Modeling Forest Products Demand, Supply and Trade*. UN-ECE/FAO Timber and Forest Discussion Papers. ETTS V Working paper. United Nations. 39 p.

Brown, C. 2000. The global outlook for future wood supply from forest plantations. *Working Paper No: GFPOS/WP/03*, FAO, Rome. 164 p.

Buongiorno, J. 1986 A Model for international trade in pulp and paper. In: *Systems Analysis in Forestry and Forest Industries - Studies in the Management Sciences. Editors.* Kallio, M. Andersson, A.E., Seppala, R. and Morgan, A. (ed.) Elsevier Science Publishers. Volume 21. p.41-54.

Buongiorno, J. 1996. Forest sector modeling: A synthesis of econometrics, mathematical programming, and system dynamics methods. *International Journal of Forecasting* 1: 329-343.

Buongiorno, J.; D. Zhang, A. Rytkonen, Y. Zhang and S. Zhu. 1997. Modeling global timber trends in forest products production, consumption and trade. In: System Analysis in Forest Resources. USDA, *Gen. Tech. Rep.* NC-205, pp. 397-403.

Buongiorno, J, N.H.H. Svanqvist and P. Wiroatmodjo. 1981. Forestry sector development planning: A model for Indonesia. *Agricultural Systems*. 7: 113-135.

Buongiorno, J. and H.S. Chang. 1986. Effect of the energy crisis on the elasticities of demand for forest products in OECD countries. *Can. J. For. Res.* 16: 968-974.

Buongiorno, J., P. Harou, A.C. Omoluabi and L. Ogundare. 1994. Timber demand and supply in Nigeria: models and forecasts to 2010. *Journal of World Forest Resource Management*, 7 : 101-127.

Cardellichio, P.A., D. Adams and R.W. Haynes. 1987. *Forest Sector and Trade Models: Theory and Applications.* Proceedings of an International Symposium. CINTRAFOR, University of Washington, Seattle, WA. 298 p.

Cerda, I.V. 1996. "Trayectoria del sector forestal Chileno: Sus logros y desafios". [Trajectory of the Chilean Forest Sector]. Instituto Forestal - *Informe Tecnico* 140. Chapter VI: Precios de los Productos Forestales. p. 67-75.

Chen, N-J, C.W. Ames and A.L. Hammett. 1988. Implications of a tariff on imported Canadian softwood lumber. *Canadian Journal of Agrivcultutal Economics*. 36: 69-81.

CIA – Central Intelligency Agency (author unspecified). 2000. The World Factbook 2000. Central Intelligence Agency. USA. http://www.odci.gov/cia/publications/factbook/ (downloaded in 06/12/2000)

Corinaldesi, L.; L. LaRosa, S. Brandan, D. Pinasco, C. Frisa. 1999. *Sector Forestal. Ano 1998*. SAGPyA, Buenos Aires. Direccion de Forestaccion.

Cottle, L.E., Schreuder, G.F. and A.A.A. Barros, 1990. *Brazil: A Country Profile of the Forests and Forest Industries.* Working Paper 27. CINTRAFOR, University of Washington. Seattle, WA. 116 pp.

DNER - Departamento Nacional de Estradas e Rodagem (author unspecified). 2000. Departamento Nacional de Estradas e Rodagem [National Road Department]. 2000. Brazil. http://www.dner.gov.br/search/distancia2.asp (downloaded in 6/28/2000)

Donnely, R. and Suchek, V. 1996. Oportunidades de Expansão para o Setor Madeireiro [Expansion Opportunities for the Wood Sector]. *Revista da Madeira*, 32 (6): 04-08.

Dos Santos, F.L.C. 1995. Perspectivas do Mercado Nacional de Madeiras Serradas [Domestic Sawnwood Market Perspectives]. *Revista da Madeira*, 5 (31): 12-22.

Dos Santos, F.L.C. 1996. "Perspectivas do Mercado Nacional de Madeiras Serradas Oriundas de Florestas Plantadas". [Perspectives of the Domestic Market of the Sawtimber from Plantation Forests]. In: *VI Simposio IPEF*. Proceedings, 4.: 31-52.

Draper, N.R. and Smith, H. 1966. *Applied Regression Analysis*. John Wiley & Sons, Inc. USA. 405 p.

Duerr, W.A. 1993. *Introduction to Forest Resource Economics*. Chapter 13: Consumer Demand for Forest Resources. p 86-94. McGraw-Hill. 485 p.

ECLAC – Comisión Económica para a América Latina y el Caribe (author unspecified). 2000. *Salario Real Industrial Normal* [Data on regular real industrial wage]. Argentina, Comisión Económica para América Latina. http://www.eclac.cl/espanol/investigacion/buenosaires/cuadros99/CUADRO16.htm (downloaded in 08/08/2000).

EViews. 1998a. *EViews 3 - User's Guide*. Quantitative Micro Software. 2nd edition. Irvine, CA. 656 p.

EViews. 1998b. *EViews 3 – Command and Programming Reference*. Quantitative Micro Software. 2nd edition. Irvine, CA. 416 p.

FAO - Food and Agriculture Organization (author unspecified). 1996. *Forest Products Yearbook.* Commodity names and definition, page xi. FAO Series no 29 – 1994. Rome, Italy. 377 p.

FAO - Food and Agriculture Organization (author unspecified). 2000a. *Directions of Trade - Bilateral Trade Matrices.* FAOSTAT Forestry database. http://www.fao.org/forestry/include/frames/english.asp?section=http://apps.fao.org/page/collections?subset=forestry (downloaded in 06/12/2000)

FAO - Food and Agriculture Organization (author unspecified). 2000b. *Forest Yearbook: Roundwood, Sawnwood, Wood-Based Panels.* FAOSTAT Forestry database. http://www.fao.org/forestry/include/frames/english.asp?section=http://apps.fao.org/page/collections?subset=forestry (downloaded in 09/14/2000)

FF - Fundação Florestal. 1998. Fundação Florestal [Forest Foundation], São Paulo, Brazil. Dataset at http://www.fflorestal.sp.gov.br/ (downloaded in 02/05/1998)

FGV- Fundação Getúlio Vargas (author unspecified). 1998. *Conjuntura Econômica.* Fundação Getúlio Vargas FGV, São Paulo, Brazil. Downloadable document at http://www.fgv.com.br/ (printed copy of electronically acquired material) (downloaded in 05/12/1998) 18 p.

Flynn, R. 1996. Southern Cone forest industry: comparative analysis of Brazil, Argentina, Chile and Uruguay. In: *World Forest Institute Conference - "Brazil's Forest Industry: Resources, Trade, Investment, Environment".* November 6 & 7, 1996. Portland, Oregón. http://www.latco.org/flynn/brazil.htm (downloaded in 05/07/1998)

Flynn, R. 1998. *South American Sawtimber Potentials.* Presentation at the World Wood Summit, Chicago, Aug 31 to Sep 2, 1998. http://www.latco.org/flynn/sawtimber.htm (downloaded in 07/14/1999)

Flynn, R., Donnelly R. and S. Ahrens, 1998. The U.S. Lumber Market: Outlook for Brazilian Products, http://www.latco.org/flynn/brazil98.htm (downloaded in 07/14/1999)

Flynn, R. 1999a. *Mercosur: Outlook for Solidwood Products from Pine and Eucalyptus Plantations.* Presentation in Rotorua, New Zealand April 14-15, 1999. http://www.latco.org/flynn/zealand.htm (downloaded in 07/14/1999)

Flynn. R. 1999b. South America: Impact on Global Softwood Lumber Markets. 1st Annual North American Softwood Conference. May 4-5, 1999. Quebec, Canada http://www.latco.org/flynn/quebec.htm (downloaded in 07/14/1999)

Flynn, R. 1999c. *Update on South American Forest Products Industry.* Presented to "16th Annual International Forest Products Marketing Conference", Nov 4-5, 1999. Seattle. http://www.latco.org/flynn/cintrfor/index.htm (downloaded in 10/07 /2000)

Forestworld - (2000). Forest Industry Unit Conversions. http://search2.forestworld.com/converx/cu_frame.html (downloaded in 01/10/ /2000)

Fowler, K.S. and J.C. Nautiyal. 1986. A model for land use planning. In: *Systems analysis in forestry and forest industries.* M. Kallio et al. (editors). North-Holland: Elsevier Science Publishers, p. 257-267.

Garlipp, R.C. 1997. Incentivos Fiscais: *O Brasil Parando no Tempo* [Fiscal Incentives: Brazil]. Silvicultura, ano XVIII (72): 24-28.

Gilless, J. K. and J. Buongiorno. 1985. *PAPYRUS: A Model of the North American Pulp and Paper Industry.* College of Agriculture and Life Sciences, University of Wisconsin, Madison. 20 p.

Graça, L.R.; V.A. Hoeflich, and M. Haliski. 1988. Diagnóstico setorial da madeira no Sul do Brasil: consumo, utilização e destino da produção [Sectoral diagnosis of timber in Southern Brazil: consumption, utilization, and destination of the production]. In: "*I Encontro Brasileiro de Economia Florestal*". CNPF/Embrapa. Curitiba, Proceedings - 2nd volume.

Greber, B.J. and H.W. Wisdom. 1985. A timber market model for analyzing roundwood product interdependencies. *Forest Science*, 31 (1): 164-179.

Gregory, G.R. 1972. *Forest Resource Economics.* Part III - Timber Production Economics, Chapter 16 - Timber Demand, Supply, and Price (pg. 327-357). The Ronald Press Company, New York, 548 p.

Gregory, R.G. 1987. *Resource Economics for Foresters.* Chapter 3: Forest Products Demand, and Chapter 4: Production and Supply Profit and Rent. John Wiley & Sons, Inc. 477 p.

Gujarati, D.N. 1992. *Basic Econometrics.* McGraw-Hill, 2nd edition. International edition. McGraw-Hill.838 p.

Haeri, M.H. 1987. *Interregional Competition in the Wood Products Industry: An Econometric Spatial Equilibrium Approach.* Dissertation. Portland State University. 126 p.

Hardwood Review Export. 1997. *Container Freight Rates.* 9 (1-12). http://www.hardwoodreview.com/ (printed copy of electronic material)

Harou, P. 1992. Minimal review of the forestry sector. In: *Forestry Sector Analysis for Developing Countries.* Proceeding of the working groups S6.12-03 and S6.11-00. 10th Forestry World Congress. Paris, France. College of Forest Resource, University of Washington, Seattle. CINTRAFOR. SP10. 3-15.

Haynes, R.W. 1993. Forestry Sector Analysis for Developing Countries: Issues and Methods. USDA, Forest Service. Pacific Northwest Research Station. *General Technical Report.* Oct, 1993. 47 p.

Haynes, R.W. and A.P. Harou, 1993. Forestry Sector Analysis for Developing Countries: A Summary of the Discussions. In: *Forest Sector Analysis for Developing Countries: Issues and Methods.* Gen. Tech. Rep. PNW-GTR-314, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. p. 233-241.

Hetemaki, L., and J. Kuuluvainen. 1992. Incorporating data and theory in roundwood supply and demand estimation. *American Journal of Agricultural Economics*, 74 (4): 1010-1018.

Higushi, N. 1985. *Perspectives and Technological Opportunities - Uso (Abuso?) dos Recursos Naturais da Amazônia*. [Perspectives and Technological Opportunities – Use (Abuse?) of Natural Resource from Amazon]. Banco de Dados Tropical, Biodiversity. http://www.bdt.org.br/ (downloaded in 07/09/1998)

Hillier, F.S. and and G.J. Lieberman, 1974. Operations Research. San Francisco, Holden-Day. 2nd. edition. 800 p.

Hseu, J-S and J. Buongiorno. 1993. Price elasticities of substitution between species in the demand of U.S. softwood lumber imports from Canada. Can. J. of For. Res. 23: 591-597.

IADB - Inter-American Development Bank (author unspecified) 2000. *Research and Statistics/Economic*, trade and social database. http://www.iadb.org/exr/english/index_english.htm (downloaded in 07/25/2000).

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (author unspecified). 1996. *Balança Comercial de Produtos Florestais 1989-1993* [Commercial Balance of Forest Products 1989-1993]. IBAMA, Brasilia, 57p.

IBGE - Instituto Nacional de Geografia e Estatística (author unspecified). 1996-2000. Quantidade produzida na silvicultura [Quantity produced in Silviculture]. http://www.sidra.ibge.gov.br/ or http://www.sidra.ibge.gov.br/cgi-bin/tprvaqt/6/25/142 (downloaded between 1996-2000).

IBGE - Instituto Nacional de Geografia e Estatística (author unspecified). 1980-1995. Anuário Estatístico do Brasil [Brazilian Statistics Yearbook]. Ministério da Agricultura, Indústria e Commércio, Directoria Geral de Estatística.

INFOR - Instituto Forestal de Chile (author unspecified) 1998-2000. Exportaciones, Estadísticas Forestales, Precios y Inventarios Forestales [Exports and Forest Statistics, Prices and Inventories]. http://www.infor.cl/webinfor/producyserv/inforestad/estadisticas.htm (downloaded between 1998-2000).

IPEA - Instituto de Pesquisa Econômica Aplicada (author unspecified). 1998 Taxas de câmbio [Exchange rates]. IPEA database. http://www.ipea.com.br/ (downloaded in 04/29/1998).

Jélvez, A., and K.A. Blatner, R.L. Govett, and P.H. Steinhagen. 1989. Chile's evolving forest products industry. Part 1: Its role in international markets. *Forest Products Journal*. 39 (10):63-67.

Kallio, M., D.P. Dykstra and C. Binkley (editors) 1987. *The Global Forest Sector: An Analytical Perspective.* IIASA. John Wiley & Sons. 703 p.

Kallio, M., A. Propoi, A. and R. Seppala. 1986. A model for the forest sector. In: *Systems Analysis in Forestry and Forest Industries - Studies in the Management Sciences.* Editors. Kallio, M., A.E. Andersson, R. Seppala and Morgan, A. (ed.) Elsevier Science Publishers. Volume 21. p.89-112.

Kant, S.; W Al-Ameen, and J.C. Nautiyal. 1996. The Canadian forest product sector: A sectoral econometric model. *Can. J. For. Res.* 26: 1122-1134.

Kengen, S. 1987. The Future Trends of Forestry Sector and Forest Policy in Brazil. In: Proceedings. Symposium on Cooperation of Forestry Between Finland and Brazil. Aug. 10-11, 1987. Parviainen, J. (ed.) Metsantutkimuslaitoksen Tiedonantoja 273, Helsinki. p. 65-91.

Kengen, S. and L.R. Graça. 1998. Forest Policies in Brazil. Regional Forum. In: *World Forest, Society and Environment.* M. Palo and J. Uusivuori (editors). P. 256-265.

Kennedy, P. 1992. *A Guide to Econometrics*. III Edition. The MIT Press, Cambridge, Massachusetts. 410 p.

Klemperer, W.D. 1996. *Forest Resource Economics and Finance*. McGraw-Hill, New York. 551 p.

Korosi, G; L Matyas and I .P. Szekely. 1992. *Practical Econometrics*. Avebury, England, 319 p.

Luppold, W.G. 1984. An econometric study of the hardwood lumber market. Forest Science, 30 (4): 1027-1038.

Macedo, A.R.P.; Roque, C.A.L. and E. T. Leite, 1995.Produtos Sólidos de Madeira [Solidwood Products]. BNDES, *BNDES Setorial*. Edição Especial - Balança Comercial Brasileira (Nov/97). 17pp. http://www.bndes.gov.br/publica/setorial.htm (downloaded in 04/07/1998)

Macedo, A.R.P.; Roque, C.A.L. and E. T. Leite, 1996. Tendências das exportações brasileiras de madeira [Trends of Brazilian Exports of Wood Products]. *Revista da Madeira*, 6 (35): pp 11-16.

Manurung, E.G.T. and J. Buongiorno. 1997. Effects of the ban on tropical log exports on the forestry sector of Indonesia. *Journal of World Forest Resource Management.* 8: 21-49.

Magellan (1992) South America map. http://www.maps.com/cgi-bin/magellan/Maps___South_America (downloaded in 02/27/1998)

Martin, L.J. 1981. Quadratic single and multi-commodity models of spatial equilibrium: a simplified exposition. *Can-J-Agric-Econ.* Ottawa, Canadian Agricultural Economics Society. v. 29: 21-48.

McKillop, W. and G. Liu. 1990. Modelling disaggregated lumber demand and supply by constrained estimation techniques. *Can. J. For. Res.* 20: 781-789.

MECON - Ministério de Economia (author unspecified) 1996. *Forestry - Economic Analysis.* Ministry of Economy and Public Works and Services of Argentina http://www.mecon.gov.ar/econom.htm (downloaded in 1996).

Meister, A.D., C.C. Chen, and E.O. Heady. 1978. *Quadratic Programming Models Applied to Agricultural Policies.* Iowa State University Press, Ames. 109 p.

Merrifield, D.E. and R.W. Haynes. 1983. Production function analysis and market adjustments: an application to the Pacific Northwest forest products industry. *Forest Science.* 29 (4): 813-822.

MGAP - Ministério de Ganaderia, Agricultura y Pesca (author unspecified). 1997. *Uruguay Forestal – Antecendentes, Legislación y Política, Desarrollo Actual y Perspectivas.* Dirección General de Recursos Naturales Renovables – Division Forestal. Montevídeo, Uruguay, 38 p.

MMA - Ministério do Meio Ambiente (author unspecified) 2000. *Programa Nacional de Florestas* [National Forest Program]. http://www.mma.gov.br/florestas/ (downloaded in 12/07/2000)

Nautiyal, J.C. 1988. *Forest Economics: Principles and Applications.* Chapter 4: The concept of demand. Pp. 91-136. Canadian Scholars' Press, Toronto. 581 p.

Newman, D.H. 1987. An econometric analysis of the Southern softwood stumpage market: 1950-1980. *Forest Science.* 33 (4): 932-945.

Ochoa, M.A.F. 1996. *Análise dos Efeitos da Criação do Mercosul na Indústria de Compensados do Paraná - Brasil e de Misiones - Argentina: Uma Abordagem Tarifária.* [Analysis of the Effect of the Creation of Mercosur on the Plywood Industry in Paraná - Brazil, and Misiones - Argentina: A Tariff Approach]. Thesis. Federal University of Paraná. Curitiba, Brazil. (electronic copy received from L.R. Graça in 1996)

Prestemon, J.P. and J. Buongiorno. 1996. The impacts of NAFTA on the U.S. and Canadian forest product exports to Mexico. *Can. J. For. Res.* 26: 794-809

Ramos, A.A. 1993. Perspectivas Qualitativas e Econômicas da Produção Florestal em Sucessivas Rotações. [Qualitative and Economic Perspectives of Forest Production in Successive Rotations] In: *Anais do 7o Congresso Florestal* Brasileiro. Vol 2. SBS-SBEF, Curitiba, p. 177-189.

Revista Construir. 1999. Costo de la Construcción [1982-1995 Construction Costs]. *Construir*. http://www.construir.com/Econsult/00/document/101002.htm (downloaded in 04/26/1999).

Revista da Madeira (author unspecified). 1993. País Ocupa a 5a Posição no Cenário Mundial [The Country Ranks 5th Worldwide]. *Revista da Madeira*, 7: 6-8.

Revista da Madeira (author unspecified). 1995a. O Gigante Ainda Não Acordou [The Giant Has Not Awaked Yet]. Curitiba, Brazil. *Revista da Madeira*, 4 (22): 4-10.

Revista da Madeira (author unspecified). 1995b. Vocação Inquestionável [Unquestionable Vocation]. Curitiba, Brazil. *Revista da Madeira*, 4 (22): 18-20.

Revista da Madeira (author unspecified). 1996. Usos da Madeira de *Pinus* [Uses of Pine Wood]. Curitiba, Brazil. *Revista da Madeira.* 5 (29): 10-12.

RISI - Resource Information Systems, Inc. (author unspecified). 1997. *Timber Review*. Resource Information System, Inc. 167p.

Rockel, M.L. and J. Buongiorno. 1982. Derived demand for wood and other inputs in residential construction: A cost function approach. *Forest Science*, 28 (2): 207-219.

Samuelson, P.A. 1952. Spatial price equilibrium and linear programming. *The American Economic Review*. 42: 282-303.

SAGPyA - Secretaria de Agricultura, Ganadería, Pesca y Alimentación.. 1996-1999. Suplemento Precios. Argentina. *SAGPyA Forestal 1*. December, 1996 to March 1999. 25p.

SAGPyA - Secretaria de Agricultura, Ganadería, Pesca y Alimentación. apparently 1999. Argentine Forestry Guide. 2nd edition. SAGPyA. 118 p + appendices (document received by mail in 8/25/1999)

SAGPyA-INDEC - Secretaria de Agricultura, Ganadería, Pesca y Alimentación. (author unspecified). 1999 Estadísticas de Extracción de bosques implantados [Statistics of Harvesting of Plantation Forests]. Argentina. http://siiap.sagyp.mecon.ar/forestal/indice.htm (downloaded in 07/26/1999)

Sarkar, A. 1991. Optimal resource allocation in timber production. *Resource Management and Optimization.* 9 (1): 55-69.

Shim, K.J. 1985. A spatial equilibrium analysis of Southern pine lumber pricing and allocation. *The Annals of Regional Science*. 19 (1): 61-76.

SIFRECA - Sistema de Informações de Fretes para Cargas Agrícolas (author unspecified). 2000. *Fretes – Madeira* [Transportation Cost – Timber] http://www.agrocast.com.br/agrotaxas/sifreca/sifreca.php3?tabela_1=madeira%25 (downloaded from 07/1998 to 02/2001)

Siqueira, J.P. 1995. *Diagnóstico e Avaliação do Setor Florestal Brasileiro - Relatório da Região Sul.* [Diagnosis and Appraisal of the Brazilian Forest Sector]. *Executive Summary.* ITTO project no ITTO/167/91 (M). ITTO/IBAMA/FUNATURA - STCP. 2-71. (partial document obtained as an electronic copy from CEDEFOR/Brazil in 1998; personal communication).

Sobrinho, V.F. 1996. Evolução do mercado madeireiro no Brasil [Evolution of the Brazilian solidwood market]. *Revista da Madeira*: 32 (6): 10-14.

Sperandio, J. 1989. *Estudo Econométrico de Demanda e Oferta de Compensado para o Estado do Paraná.* [Econometric Study of the Supply of and Demand for Plywood in the State of Paraná]. Federal University of Parana. Dissertation. 147p.

STCP - STCF-Engenharia de Projetos Ltda (author unspecified). Price and Quantity Data. STCP Databank – STCP Engenharia e Projetos, Curitiba, Brazil (unpublished; electronic file received in 06/19/2000)

Suchek,V.I. 1991. The role of the planted forest in the pulp and paper industry in Brazil. *For-Chron.* 67 (6): 636-648.

Styrman, M. and S. Wibe. 1986. Wood resources and availability as determinants of the supply of timber. *Canadian Journal of Forest Research.* 16: 256-259.

Takayama , T. and G. Judge. 1964a. *Spatial Equilibrium and Quadratic Programming.* American Farm Economic Association, Menasha, WI. p. 67-93.

Takayama , T. and G. Judge. 1964b. Equilibrium among spatially separated markets: a reformulation. *Econometrica.* 32: 510-24.

Takayama , T. and G. Judge. 1971. *Spatial and Temporal Price and Allocation Models.* North -Holland Publishing Company. 528 p.

Takayama, T. 1996 Third years with spatial and intertemporal economics. In: Recent advances in spatial equilibrium modeling - Methodology and Applications. Bergh, J.C.J.M. van den, P. Nijkamp and P. Rietveld. (editors). *Advances in Spatial Sciences.* Springer-Verlag, 3-47.

Tomaselli, I. 1998. *Forestry Industry Opportunities in Brazil.* STCP Engenharia de Projetos. A speech presented in Santiago, Chile, May 1998 (unpublished, photocopy).

Trade and Investment Guide – Chile. 1999. *Forestry, Pulp & Paper, Wood Products.* http://journal.chilnet.cl/ind_FR.htm. (downloaded in 08/15/99)

USDC – US Department of Commerce (author non-specified). 1991. *Developing Competitive Markets in Forest Products: Brazil.* United States Department of Commerce – International Trade Organization. Washington, D.C. 45 p.

UN – United Nations (author unspecified). 1995. *Commodity Trade Statistics 1994.* Statistical Papers. Department for Economic and Social Information and Policy Analysis. Statistic Division, United Nations. 1109 p.

UN – United Nations (author unspecified). 1996. *1995 International Trade Statistics Yearbook.* Volume I. Trade by country. Department for Economic and Social Information and Policy Analysis. Statistic Division, United Nations.

Valverde, S.R.; E.A.V. Zauza and M.L. da Silva. 1999. Impactos dos diferentes acordos de liberalização do comércio internacional no setor florestal brasileiro [Impacts of the different international agreements on the Brazilian forest economy]. *Scientia Forestalis.* 55: 117-128.

Vincent, J.R. 1992. A simple, non-spatial modeling approach for analyzing a country's forest-products trade policies. In Haynes R., Harou P. and Mikowski J (eds) Forestry Sector Analysis for Developing Countries: 43-54. University of Washington, Seattle.

Waquil, P.D. and T.L. Cox. 1995. Spatial equilibrium with intermediate products: Implementation and Validation in the MERCOSUL. *Staff paper series No 388.* University of Wisconsin-Madison. 31 p.

Webb, S. H.; C.K. Halbrent, R. Gana and F. Tuan. 1994. An application of a spatial equilibrium model to analyze the impact on China's trade of a policy change. *Spec. Circ.* Ohio Agriculture Research Development Center. # 144, July/94. p. 33-44.

WFI - World Forest Institute (author unspecified). 1995. *Brazil: Forestry and the Wood Products Industry.* World Forestry Center, Portland, OR. 52 pp.

WFI - World Forest Institute (author unspecified). 1996. *Brazil's Forest Industry.* World Forest Institute Conference, Nov, 1996, Portland, OR. 50 pp.

Wiecheteck, M. and J.A. Stevens, 1996. *Modeling Demand and Supply of Pulpwood in Brazil.* Department of Forestry, Michigan State University (unpublished paper).

Wiecheteck, M. and K. Tella, 1997. *Trade of Forest Products in Mercosur.* Department of Forestry, Michigan State University (unpublished paper).

Willet, K. 1983. Single- and Multi-Commodity Models of Spatial Equilibrium in a Linear Programming Framework. *Canadian Journal of Agriculture Economics.* 31: 205-222.

Wisdom, H.W. 1987. The transportation cost model. In: The Global Forest sector : An Analytical Perspective (Kallio, M; Dykstra, D.P. and Binkley, C.S. – editors) Chichester p. 579-591.

World Bank, The (author unspecified). 1995.*The World Tables.* Baltimore, Johns Hopkins University Press. 610p.

World Port (author unspecified). *World Port Distances* 2000. http://www.distances.com/ and http://www.ports.com/ (downloaded in 04/12/2000).

Youn, Y.C. 1988. *An Econometric Analysis of the Korean Pulp and Paper Industry.* Dissertation. University of Washington. 245 p.

Zhang, D. and J. Buongiorno, 1994. Training material for forest sector modeling. *Staff Paper Series 44.* Department of Forestry, University of Wisconsin, Madison. 64p.

Zhang, D., J. Buongiorno, and P. Ince. 1993. PELPS III - A microcomputer price endogenous linear programming system for economic modeling . Version 1.0. USDA/USFS - Forest Products Laboratory - *Research Paper FPL-RP-526,* 43 p.

Zhang, D., J. Buongiorno, and S. Zhu. 1997. *Trends and Outlook for Forest Products Consumption, Production, and Trade in the Asia-Pacific Region.* Working Paper No APFSOS/WP/12. Forestry Policy and Planning Division, Rome, Regional Office for Asia and the Pacific, Bangkok. 161 p.

APPENDICES

Appendix 1 – Conversion factors

Weight & Measures	Unit		Conversion Factors
Volume[1]	m^3	cubic meter	1 m^3 sawnwood = 423.77 board feet of sawnwood 1 m^3 roundwood = 0.00348 board feet of roundwood 1 m^3 roundwood = 0.004525 board feet of lumber equivalent
Area[2]	ha	hectare	1 ha = 2.471 acres 1 ha = 10,000 square meters
	km^2	square kilometer	1 km^2 = 100 ha 1 km^2 = 0.3861 square miles
Distance[2]	km	kilometer	1 km = 1,000 m = 0.621371 mile
	m	meter	1 m = 3.281 feet
Volume to Weight[3]	mT	metric ton	1 m^3 = 1.43 mT (sawlogs and veneer logs) 1 m^3 = 1.82 mT (sawnwood)
Currency	-	-	R$ - Brazilian Real (Brazil) A$ - Argentinean Peso P$ - Chilean Peso US$ - U.S. dollar (USA)

Sources:
[1] Forestworld (2001) http://search2.forestworld.com/converx/cu_frame.html
[2] Conversion Calculator (2001): http://www.cyberstation.net/~jweesner/conv.html
[3] FAO (1996)

Appendix 2 – Conifer sawnwood data for the regression analysis in Brazil

YEAR	Conifer Sawnwood Demand (D)	Conifer Sawnwood Supply (S)	Lagged Conifer Sawnwood Demand (D(-1))	Lagged Conifer Sawnwood Supply (S(-1))	Conifer Sawnwood Price (P)	Dummy Variable (D1)	Conifer Sawlog Price (M)	Interest Rate (IR)	GDP (G)	Real Minimum Wage (W)
	m^3	m^3	m^3	m^3	1995R$/$m^3$	-	1995R$/$m^3$	rate	1995R$	index 1990
1982	7639700	7766000	7317600	7475000	87.69	0	44.70	2.19	6.1341E+11	250.40
1983	7996200	8110000	7639700	7766000	79.94	0	36.86	3.00	7.2201E+11	222.58
1984	8303800	8384000	7996200	8110000	79.51	0	25.17	3.56	7.0950E+11	204.87
1985	8312500	8384000	8303800	8384000	90.06	0	34.84	3.77	7.1064E+11	212.46
1986	8303500	8384000	8312500	8384000	226.12	1	44.50	1.69	7.5210E+11	207.40
1987	8317400	8384000	8303500	8384000	71.90	0	45.29	4.58	8.1956E+11	164.40
1988	8265400	8384000	8317400	8384000	97.44	0	41.47	11.68	8.1810E+11	159.34
1989	8269900	8384000	8265400	8384000	72.66	0	38.00	27.17	7.2314E+11	174.52
1990	7843000	7923000	8269900	8384000	57.34	0	34.53	15.12	7.0492E+11	100.00
1991	8471000	8591000	7843000	7923000	42.91	0	25.75	6.59	8.9739E+11	114.90
1992	8344444	8591000	8471000	8591000	62.34	0	26.04	16.51	8.6918E+11	120.99
1993	8241373	8591000	8344444	8591000	95.17	0	22.82	31.83	7.7173E+11	119.25
1994	8100034	8591000	8241373	8591000	105.42	0	29.45	14.86	8.6130E+11	100.17
1995	8105600	8591000	8100034	8591000	111.04	0	20.15	1.53	9.0866E+11	108.92
Source	FAO (2000)	FAO (2000)	FAO (2000)	FAO (2000)	RM (1995)	-	IBGE (1999)	IADB (2000)	UN (1995)	IADB (2000)

Equation (from EViews©):

D=c(1)+c(2)*p+c(3)*d1+c(4)*ir+c(5)*g+c(6)*w+c(7)*d(-1)

S=c(11)+c(12)*p+c(13)*m+c(14)*s(-1)

INST d1 ir g w d(-1) m s(-1)

Appendix 3 – Conifer sawlog data for the regression analysis in Brazil

YEAR	Conifer Sawlog Demand (D)	Conifer Sawlog Supply (S)	Lagged Conifer Sawlog Supply (S(-1))	Conifer Sawlog Price (P)	Conifer Sawnwood Price (M)	Interest Rate (IR)	Total Real Wage Index (W)	Time (T)	Non-conifer Sawlog Price (S1)
	m^3	m^3	m^3	1995 R$/$m^3$	1995 R$/$m^3$	rate	Index 1994	unit	1995 R$/$m^3$
1983	980033.6	6173733	6720568	36.86	79.94	3.00	60.83	4	69.53
1984	1456562.6	4006772	6173733	25.17	79.51	3.56	62.65	5	54.33
1985	1932174.9	4898000	4006772	34.84	90.06	3.77	76.94	6	55.56
1986	2335525.1	6706399	4898000	44.50	226.12	1.69	96.33	7	63.04
1987	3138748.0	7341173	6706399	45.29	71.90	4.58	91.51	8	97.21
1988	4152044.6	7456353	7341173	41.47	97.44	11.68	97.27	9	105.06
1989	5165341.1	6720510	7456353	38.00	72.66	27.17	105.93	10	89.74
1990	6155755.8	6592761	6720510	34.53	57.34	15.12	91.21	11	74.42
1991	8983066.3	7430201	6592761	25.75	42.91	6.59	80.17	12	49.67
1992	10924461.6	7500343	7430201	26.04	62.34	16.51	86.74	13	35.53
1993	12770350.5	8878732	7500343	22.82	95.17	31.83	92.64	14	71.23
1994	14680822.4	11841305	8878732	29.45	105.42	14.86	98.48	15	54.75
1995	12247778.7	13419656	11841305	20.15	111.04	1.53	105.50	16	33.47
1996	14495433.6	12207745	13419656	15.92	86.75	1.27	101.60	17	27.88
Source	FAO (2000)	FAO (2000)	FAO (2000)	IBGE (1999)	RM (1996)	IADB (2000)	FGV (1998)	-	IBGE (1999)

Equation (from EViews©):

D=C(1)+C(2)*p+c(3)*m+c(4)*ir+c(6)*w+c(7)*s1

S=C(11)+C(12)*p+C(13)*t+C(14)*s(-1)

INST m t s(-1) ir w s1

Appendix 4 – Conifer sawnwood data for the regression analysis in Chile

YEAR	Conifer Sawnwood Demand (CO)	Conifer Sawnwood Supply (P)	Conifer Sawnwood Price (P3)	Conifer Sawlog Price (M1)	Construction Index (CC)	Interest Rate (IR)	Exchange Rate (nominal) (EX)	Lagged Sawnwood Exports (E(-1))	Real Minimum Wage (W)
	m^3	m^3	1995 P$/$m^3$	1995 P$/$m^3$	index	rate	P$/US$	m^3	Index 1990
1980	695250	1954500	35863.04	8416.2	2316.8	37.7	39.0	1040450	137.6
1981	606650	1455500	28807.88	7032.0	2216.6	40.9	39.0	1259250	136.2
1982	409200	1014500	18740.08	5908.2	2121.0	48.7	50.9	848850	133.4
1983	685500	1424500	18444.78	5519.9	1838.4	28.0	78.8	605300	107.3
1984	849000	1711500	18149.48	6887.0	1823.7	27.6	98.7	739000	92.2
1985	1185700	1877500	25689.06	8668.0	1717.1	32.0	160.9	862500	88.0
1986	900900	1734000	24326.16	8312.8	1681.2	19.0	192.9	691800	83.9
1987	1318100	2308000	28216.71	8974.5	1752.2	25.2	219.4	833100	78.8
1988	1288000	2336000	33820.10	13256.9	1794.0	15.0	245.0	989900	83.5
1989	1268500	2324500	33020.24	13910.0	1870.0	27.5	267.0	1048000	88.1
1990	1693000	2889000	31820.62	13641.0	1888.9	39.8	304.9	1056000	100.0
1991	1589000	2751000	36317.90	15640.4	1860.2	22.0	349.2	1196000	108.9
1992	1767139	2565000	45014.46	16443.2	1905.4	18.1	362.6	1162000	110.2
1993	1959366	2663000	44422.61	17561.6	1943.8	18.0	404.2	799000	116.1
1994	2003200	2927000	41220.68	17049.7	1897.6	15.1	420.2	707000	120.1
1995	2199500	3394000	39427.00	16083.0	1894.5	13.7	396.8	931400	124.7
1996	2688000	3744000	39330.09	16499.6	1877.0	13.5	412.3	1201800	129.6
1997	3056000	4274000	36881.07	15342.4	1998.4	12.0	419.3	1062000	133.8
1998	3079000	4222000	34707.73	14959.1	1998.1	14.9	460.3	1218000	142.4
Source	FAO (2000)	FAO (2000)	INFOR (1999)	INFOR (1999)	-	IADB (2000)	IADB (2000)	FAO (2000)	IADB (2000)

Equation (from EViews©):
co=c(1)+c(2)*p3+c(3)*cc+c(6)*ir+c(5)*ex
p=c(11)+c(12)*p3+c(15)*p(-1)+c(14)*t+c(16)*w+c(17)*m
INST p(-1) cc ir ex t m w

Appendix 5 – Conifer sawlog data for the regression analysis in Chile

YEAR	Conifer Sawnwood Demand (D)	Conifer Sawnwood Supply (S)	Lagged Conifer Sawnwood Supply (S(-1))	Conifer Sawlog Price (P)	Conifer Sawnwood Price (M)	Interest Rate (IR)	Trend Variable (T)	Real Minimum Wage (W)
	m^3	m^3	m^3	1995 P$/$m^3$	1995 P$/$m^3$	rate	-	Index 1990
1980	3071200	4075000	4075000	8416.22	35863.04	37.7	1	137.6
1981	3000900	3360000	4075000	7032.00	28807.88	40.9	2	136.2
1982	1883600	2772000	3360000	5908.20	18740.08	48.7	3	133.4
1983	2177000	3200000	2772000	5519.93	18444.78	28.0	4	107.3
1984	2957800	3859000	3200000	6887.00	18149.48	27.6	5	92.2
1985	3146300	4417000	3859000	8667.97	25689.06	32.0	6	88.0
1986	3846100	5008000	4417000	8312.83	24326.16	19.0	7	83.9
1987	3528900	4800000	5008000	8974.52	28216.71	25.2	8	78.8
1988	3484300	4884000	4800000	13256.87	33820.10	15.0	9	83.5
1989	4441900	5303000	4884000	13909.98	33020.24	27.5	10	88.1
1990	6629000	6629000	5303000	13640.96	31820.62	39.8	11	100.0
1991	6629000	6629000	6629000	15640.36	36317.90	22.0	12	108.9
1992	7180000	7180000	6629000	16443.17	45014.46	18.1	13	110.2
1993	7923000	7923000	7180000	17561.62	44422.61	18.0	14	116.1
1994	8704000	8704000	7923000	17049.67	41220.68	15.1	15	120.1
1995	10125000	10125000	8704000	16083.00	39427.00	13.7	16	124.7
1996	9878000	9878000	10125000	16499.60	39330.09	13.5	17	129.6
1997	10982000	10982000	9878000	15342.40	36881.07	12.0	18	133.8
1998	9335000	9335000	10982000	14959.06	34707.73	14.9	19	142.4
Source	FAO (2000)	FAO (2000)	FAO (2000)	INFOR (1998-2000)	INFOR (1998-2000)	IADB (2000)	-	IADB (2000)

Equation (from EViews©):
D=c(1)+c(2)*p+c(4)*m+c(5)*ir+c(7)*t
S=c(11)+c(12)*p+c(14)*s(-1)+c(15)*w
INST m s(-1) t w ir

Appendix 6 – Conifer sawnwood data for the regression analysis in Argentina

YEAR	Conifer Sawnwood Demand (D)	Conifer Sawnwood Supply (S)	Export Conifer Sawnwood Price (P)	Construction Index (CC)	Conifer Sawlog Price (M)	Non-Conifer Sawnwood Price (S1)	GDP (G)
	m^3	m^3	1995 A$/$m^3$	index	1995 A$/$m^3$	1995 A$/$m^3$	1995 A$
1983	540200	305000	148.11	241.6	38.53	368.16	3.22540E+11
1984	443100	186000	134.78	248.4	40.17	341.28	3.28084E+11
1985	318300	164000	135.42	201.1	29.63	319.95	3.05265E+11
1986	367200	134000	129.92	191.2	33.28	360.55	3.28327E+11
1987	377000	156000	198.62	187.1	38.06	384.77	3.36237E+11
1988	262000	130000	231.35	197.3	25.47	361.25	3.29604E+11
1989	210000	130000	211.70	229.9	24.77	324.30	3.05747E+11
1990	146240	130000	167.78	163.3	23.36	275.79	3.01963E+11
1991	146200	130000	178.23	147.6	22.04	275.32	3.32747E+11
1992	364880	309000	206.41	144.8	26.78	261.55	3.66137E+11
1993	398000	360000	240.70	153.5	26.60	271.64	3.88618E+11
1994	286200	254000	267.39	154.4	24.62	277.79	4.11250E+11
1995	615900	625000	238.42	155.6	23.33	268.54	3.99067E+11
Source	FAO (2000)	FAO (2000)	FAO (2000)	Rev. Construir (1999)	SAGPyA (1999)	SAGPyA (1999)	IADB (2000)

Equation (from EViews®):
D=c(1)+c(2)*p+c(4)*cc+c(5)*g
S=c(11)+c(12)*p+c(13)*m+c(14)*s1
INST cc g m s1

Appendix 7 – Conifer sawlog data for the regression analysis in Argentina

YEAR	Conifer Sawlog Demand (D)	Conifer Sawlog Supply (S)	Lagged Conifer Sawlog Supply (S(-1))	Conifer Sawlog Price (P)	Real Minimum Wage (W)	Non-Conifer Sawlog Price (S1)	Conifer Sawnwood Price (M)	Trend Variable (T)
	m^3	m^3	m^3	1995 A$/$m^3$	Index 1990	1995 A$/$m^3$	1995 A$/$m^3$	-
1983	664000	664000	589000	38.53	115.0	28.12	81.04	2
1984	393000	393000	664000	40.17	143.2	22.59	79.71	3
1985	322000	322000	393000	29.63	134.1	16.77	92.02	4
1986	100000	100000	322000	33.28	133.6	22.65	214.68	5
1987	150000	150000	100000	38.06	120.6	21.59	76.78	6
1988	200000	200000	150000	25.47	116.6	16.70	101.62	7
1989	300000	300000	200000	24.77	94.3	15.30	80.06	8
1990	400000	400000	300000	23.36	98.7	15.56	67.21	9
1991	500000	500000	400000	22.04	100.0	16.90	57.62	10
1992	827000	827000	500000	26.78	101.4	21.76	78.40	11
1993	593000	593000	827000	26.60	100.0	25.78	105.66	12
1994	711000	711000	593000	24.62	100.7	23.54	112.08	13
1995	1443000	1443000	711000	23.33	99.6	23.00	114.87	14
Source	FAO (2000)	FAO (2000)	FAO (2000)	SAGPyA (1996-1999)	ECLAC (2000)	IBGE (1998) INFOR (1998-2000)	RM (1995)	-

Equation (from EViews©):

D=c(1)+c(2)*p+c(3)*w+c(4)*s1+c(5)*m

S=c(11)+c(12)*p+c(13)*w+c(14)*s(-1)+c(15)*t

INST s1 m w s(-1) t

Appendix 8 – Conifer sawlog data for the regression analysis in the AUPB countries

YEAR	Conifer Sawlog Demand (D)	Conifer Sawlog Supply (S)	Lagged Conifer Sawlog Supply (S(-1))	Conifer Sawlog Price (P)	Conifer Sawnwood Price (M)	Non-Conifer Sawlog Price (S1)	Real Minimum Wage (W)	Trend Variable (T)
	m^3	m^3	m^3	1995 A$/$m^3$	1995 A$/$m^3$	1995 A$/$m^3$	Index 1990	-
1983	675000	675000	626000	38.53	81.04	28.12	337.1	2
1984	435000	435000	675000	40.17	79.71	22.59	356.3	3
1985	363000	363000	435000	29.63	92.02	16.77	233.0	4
1986	223000	223000	363000	33.28	214.68	22.65	226.5	5
1987	328000	328000	223000	38.06	76.78	21.59	247.1	6
1988	391000	391000	328000	25.47	101.62	16.70	200.5	7
1989	515000	515000	391000	24.77	80.06	15.30	107.0	8
1990	645000	645000	515000	23.36	67.21	15.56	100.0	9
1991	715000	715000	645000	22.04	57.62	16.90	126.4	10
1992	1094000	1094000	715000	26.78	78.40	21.76	118.7	11
1993	860000	860000	1094000	26.60	105.66	25.78	166.5	12
1994	978000	978000	860000	24.62	112.08	23.54	190.1	13
1995	1710000	1710000	978000	23.33	114.87	23.00	185.0	14
Source	FAO (2000)	FAO (2000)	FAO (2000)	SAGPyA (1996-1999)	RM (1995)	IBGE INFOR	IADB (2000)	-

Equation (from EViews©):
D=c(1)+c(2)*p+c(3)*m+c(4)*s1
S=c(11)+c(12)*p+c(13)*w+c(14)*t+c(15)*S(-1)
INST w m s1 t s(-1)

Appendix 9 - Price Elasticities of Demand and Supply of Lumber – Literature

Authors	Region	Species/Product	Own-Price Elasticity Supply	Own-Price Elasticity Demand
Zhang, Buongiorno and Zhu (1997)	High GDP	Conifer Lumber	-	-0.13 (0.04)*
	Low GDP		-	-0.07 (0.04)*
	World		-	-0.08 (0.03)*
Kant et al. (1996)	Canada	Solidwood and manufacturing	0.15 to 0.32	-0.3 to -1.08 (av. = -0.47)
McKillop and Liu (1989)	Western US	Douglas-fir – clears	-	-0.88 to -0.95
		– commons	-	-2.83 to –2.91
		– all	-	-2.13 to –2.27
		Hemlock-fir – clears	0.39 to 0.68	-
		– commons	1.35 to 1.37	-
		– all	2.40 to 2.13	-
Chen et al. (1988)	USA	Softwood lumber (Douglas fir)	0.309 (t=5.77)**	-0.029 (t=-0.47)
Buongiorno and Chang (1986)	OEDC countries	Coniferous sawnwood	-	-0.24 (0.08)*
Merrifield and Haynes (1983)	PNW US	(All species) lumber and plywood products	-	-0.359 (t=-1.44)
Rockel and Buongiorno (1982)	USA	Softwood lumber in the residential construction	-	-0.91 (0.02)**
	Citation – different authors		-	0.00 to – 0.87
Adams and Haynes (1980) - TAMM –	NW – Northwest US	Softwood lumber	-	-0.30 (nr)
	SW – Southwest US		-	-0.34 (nr)
	RM – Rocky Mountains		0.35 (nr)	-0.40 (nr)
	NC – North Central US		-	-0.40 (nr)
	NE – Northeast US		-	-0.39 (nr)
	SO – South US		-	-0.34 (nr)
	PNWW – Pacific NW - West US		0.21 (nr)	-
	PNWE – Pacific NW – East US		0.60 (nr)	-
	PSW – Pacific Southeast		0.23 (nr)	-
	SC – South Central US		0.79 (nr)	-
	SE – Southeast US		0.31 (nr)	-
	Canada		0.47 (nr)	-

standard errors are in parenthesis.
nr - not reported
* 5% significance, ** 1% significance

Appendix 10 - Price Elasticities of Demand and Supply of Sawlogs – Literature

Authors	Region	Species/ Product	Own-Price Elasticity		
			Supply		Demand
			FI [1]	OP [1]	
Newman (1987)	Southern US (for either lumber or plywood)	Stumpage roundwood	0.55 (t=8.21)**		-0.57 (t=2.22)*
Haeri (1987)	Inland - Rocky Mountains	Stumpage	0.11		-
	Southwest		0.14		-
	Northwest		0.46		-
	South		0.49		-
Merrifield and Haynes (1983)	PNW – Pacific Northwest	Stumpage	0.7974 (t=1.02)		-
Adams and Haynes (1980) - TAMM - US	PNWW – W Pacific Northwest	Regional stumpage	0.26 (8.49)	0.06 (nr)	-
	PNWE – E Pacific Northwest		0.16 (4.69)	0.18 (nr)	-
	PSW – Pacific Southwest		0.26 (nr)	0.12 (nr)	-
	RM – Rocky Mountains		0.06 (nr)		-
	SC – South Central		0.47 (nr)	0.39 (3.36)	-
	SE – Southeast		0.47 (9.35)	0.30 (3.36)	-
	NC – North Central		0.99 (5.60)	0.31 (7.67)	-
	NE – Northeast		0.32 (5.10)	0.99 (nr)	-

standard errors are in parenthesis.

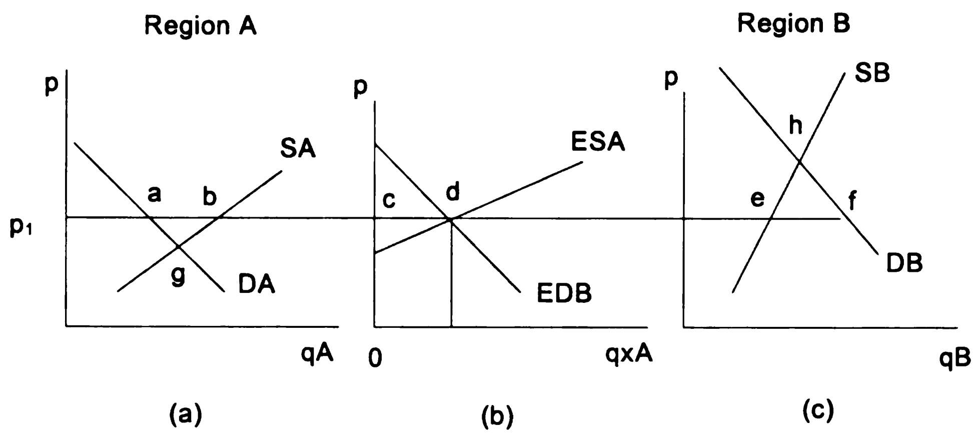
nr – not reported

*** 5% significance, ** 1% significance**

Appendix 11 - Samuelson's conceptual framework

In 1951, Enke[17] formulated the problem of competitive equilibrium among spatially separated markets, suggesting a solution in the case of linear market functions. Proceeding from the Enke formulation, Samuelson (1952), presented the theoretical foundations for computable spatial equilibrium modeling, showing how this purely descriptive problem in non-normative economics can be cast mathematically into a maximum problem, and related the Enke specification to a standard problem in linear programming, the so-called Koopmans-Hitchcook minimum-transport-cost problem. Samuelson established the desired formal equivalence between the equilibrium of interregional trade and a maximum problem, restricted to a single commodity (in numerous markets) and the objective function was the difference between the areas under the excess supply and demand curves for each market minus transportation cost. His argument was that given equilibrium quantities, the equilibrium pattern of trade minimizes total transportation costs (Meister et al., 1978).

Samuelson's formulation was developed in the context of a spatial equilibrium model in which market supply (S) and demand (D) are fixed and given exogenously (Meister et al., 1978; and Willet, 1983). On developing his study, he related his problem of finding the minimum total transportation costs to the Koopmans's linear programming problem, which anticipated the 'dual problem' theory, which states that "... every minimum problem in linear programming can be, so to speak, turned on its side and can be converted into a related maximum problem, and the answer for this maximum problem also gives the correct answer for the quantity that was to be minimized". Samuelson illustrated his concept by using two exports and two import regions, local prices and transport costs between and within regions (Figure 4.1). Using the primal approach, he showed that market equilibrium can be achieved through either the minimization of transportation costs or the maximization of the net social payoff function (Figure Appendix 11.1.).



Source : Adapted from Houck[18], 1992 (cited by Ochoa, 1996)

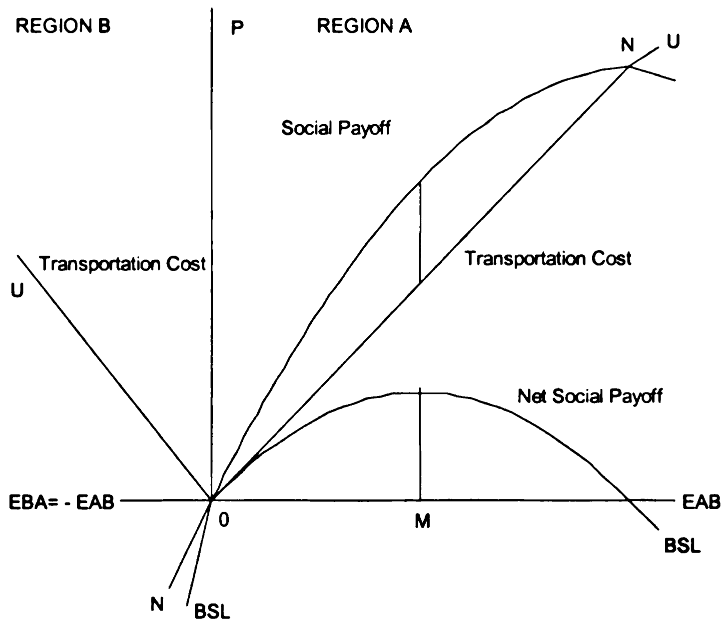
Figure Appendix 11. 1. Trade model between two regions

The trade model between two pairs of regions, can be represented as shown in Figure 4.1, stimulated by the price difference in each region as result of the respective domestic supply and demand functions (graphs "a" and "c"). Graph "b" indicates the equilibrium price and quantity given ESA and ESD, representing respectively the excess supply and excess demand functions derived from the relationship between the supply and demand functions in region A and B.

Figure Appendix 11.2 represents Samuelson's description of the so-called net

[17] Enke, S. 1951. Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue. *Econometrica* 19: 50-57.
[18] Houck, J.. *Elements of Agricultural Trade Policies*. USA : Waveland Press, Inc. 1992.

social payoff, derived by subtracting transportation costs from the social payoff (net surplus given by the area under the demand curve minus the area under the supply curve).



Source: Samuelson, 1952.

Figure Appendix 11. 2. Graphical representation of the Samuelson's Net Social Payoff (NSP)

Takayama and Judge (1964a, 1964b, 1971, 1996) extended Samuelson's concept to a multicommodity equilibrium among spatially separated markets using a quadratic programming formulation, assuming appropriate linear dependencies between regional supply, demand and price. Given this quadratic programming formulation a computational algorithm was specified to obtain directly and efficiently the competitive optimum solution for regional prices, quantities and regional flows. The authors represented manufacturing activities in a spatial equilibrium model by activity analysis, i.e., in terms of the inputs per unit of output, the unit cost of manufacturing net of these \inputs, and regional manufacturing capacities (Gilles and Buongiorno, 1985).

Appendix 12 – Kuhn-Tucker conditions for optimality

After substituting constraint (6) in the maximization problem (3), the corresponding Lagrangean function becomes:

$$L = \sum_i \{ \sum_n \int_o^{D_{n,i}} P_{ni}^d(D)dD - \sum_k \int_o^{S_{k,i}} P_{ki}^s(S)dS - \sum_n \int_o^{PF} CT_{ni} \}$$

$$- \sum_k \sum_i \sum_j TP_{nij} . XP_{kij} - \sum_n \sum_i \sum_j TF_{nij} . XF_{kij}$$

$$- \sum_i \sum_k \lambda_{ki} \cdot \left[S_{ki} - \sum_n XP_{kij}] \right] - \sum_i \sum_k \mu_{ki} \cdot \left[\sum_j XP_{kij} - \sum_n \alpha_{kni} . PF_{ni} \right]$$

$$- \sum_i \sum_n \eta_{ni} \cdot \left[S_{ni} - \sum_j XF_{nij} \right] - \sum_i \sum_n \tau_{ni} \cdot \left[\sum_j XF_{nji}] - D_{ni} \right] \quad (7)$$

where, $\lambda_{k,i}$, $\eta_{k,i}$, $\tau_{n,i}$ are the corresponding Lagrangean multipliers.

The Kuhn-Tucker conditions for optimality associated with the problem are both necessary and sufficient conditions for the optimal global maximum solution, provided that the suitable concavity and differentiability conditions of the objective function are satisfied in the presence of linear constraints (Hillier and Lieberman, 1974; and Sposito, 1975; Takayama, 1985, 1994, both cited by Waquil and Cox, 1995). The associated Kuhn-Tucker conditions are:

(a) $\delta L/\delta D_{ni} = P^d_{ni} - \tau_{ni} \le (=) 0$ if $D_{ni} = (\ge) 0$; $(\delta L/\delta D_{ni}).D_{ni} = 0$

(b) $\delta L/\delta S_{ki} = P^s_{ki} - \lambda_{ki} \le (=) 0$ if $S_{ni} = (\ge) 0$; $(\delta L/\delta S_{ki}).\ S_{ki} = 0$

(c) $\delta L/\delta PF_{ni} = - \Sigma_k \alpha_{kni} + \eta_{ni} \le (=) 0$ if $PF_{ni} = (\ge) 0$; $(\delta L/\delta\ PF_{ni}).\ PF_{ni} = 0$

(d) $\delta L/\delta XP_{kij} = - TP_{kij} - \lambda_{ki} + \mu_{ki} \le (=) 0$ if $XP_{kij} = (\ge) 0$; $(\delta L/\delta XP_{kij}).\ XP_{kij} = 0$

(e) $\delta L/\delta XF_{nij} = - TF_{nij} - \eta_{ni} + \tau_{ni} \leq (=) 0$ if $XF_{nij} = (\geq) 0$; $(\delta L/\delta XF_{nij}).\ XF_{nij} = 0$

(f) $\delta L/\delta\lambda_{ki} = S_{nki} - \Sigma_j XP_{kij} \leq (=) 0$ if $\lambda_{k,i} = (\geq) 0$; $(\delta L/\delta\lambda_{ki}).\ \lambda_{ki} = 0$

(g) $\delta L/\delta\mu_{ki} = \Sigma XP_{kij} - \Sigma_n \alpha_{kni} .PF_{ni} \leq (=) 0$ if $\mu_{ki} = (\geq) 0$; $(\delta L/\delta\mu_{ki}).\ \mu_{ki} = 0$

(h) $\delta L/\delta\eta_{ni} = PF_{ni} - \Sigma_j XF_{nij} \leq (=) 0$ if $\eta_{ni} = (\geq) 0$; $(\delta L/\delta\eta_{ni}).\ \eta_{ni} = 0$

(i) $\delta L/\delta\tau_{ni} = \Sigma XF_{nij} - D_{ni} \leq (=) 0$ if $\tau_{ni} = (\geq) 0$; $(\delta L/\delta\tau_{ni}).\ \tau_{ni} = 0$ (8)

which imply the following interpretation: (9)

$D_{ni} > 0$: $P^d{}_{ni} = \tau_{ni}$

$S_{ki} > 0$: $P^s{}_{ki} = \lambda_{ki}$

$PF_{ni} > 0$: $\Sigma_k \alpha_{kni}.\ \mu_{ki} = \eta_{ni}$

$XP_{kij} > 0$: $TP_{kij} = \mu_{ki} - \lambda_{ki}$

$XF_{nij} > 0$: $TF_{nij} = \tau_{n,i} - \eta_{ni}$

$\lambda_{ki} > 0$: $S_{ki} = \Sigma_j XP_{kij}$

$\mu_{ki} > 0$: $\Sigma_j XP_{kji} = \Sigma_k \alpha_{kni}.\ PF_{ni}$

$\eta_{ni} > 0$: $PF_{ni} = \Sigma_j XF_{nij}$

$\tau_{ni} > 0$: $\Sigma_j XF_{nji} = D_{ni}$

The Lagrangean multipliers are interpreted as *shadow prices* in competitive equilibrium.

Appendix 13 – Input data for the PELPS's demand

DEMAND

A : Region number (01 to 99, in ascending order)
B : Commodity number (01 to 99, in ascending order within each region)
C : Base period price in common currency
D : Base period quantity demanded at price C
E : Price elasticity (<0, enter 0.00 for horizontal demand)
F : Elasticity of demand with respect to the first shift variable (optional, enter 0.00 if omitted)
G : Elasticity of demand with respect to the second shift variable (optional, enter 0.00 if omitted)
H : Elasticity of demand with respect to the third shift variable (optional, enter 0.00 if omitted)
I : Elasticity of demand with respect to previous-period demand (optional, enter 0.00 if omitted)
J : Lower bound on the quantity demanded (optional, enter 0.00 if omitted)
K : Price of commodity in the period before the base period
L : Quantity demanded in the period before the base period
M : Minimum fraction of recycled content

A	B	C	D	E	F	G	H	I	J	K	L	M
reg	com	price	quant	p elast	shift 1	shift 2	shift 3	dem(-1)	low bnd	prv prc	q(-1)	recyc
01	03	121.00	5188.0	-0.400	0.189	0	0	0	3631.6	114.9	5184.0	0
02	03	133.50	2918.0	-0.400	0.189	0	0	0	2042.6	162.3	2916.0	0
03	03	137.95	2199.5	-1.081	0.160	0	0	0	1539.7	143.9	2003.2	0
04	03	112.07	615.9	-1.342	3.624	0	0	0	431.1	117.8	286.2	0
05	03	121.00	106.6	-1.342	0.160	0	0	0	74.6	140.3	107.0	0
06	02	115.9	1022.0	-0.500	0.150	0	0	0	715.4	112.7	882.0	0
06	03	219.3	841.3	-0.500	0.150	0	0	0	588.9	198.3	334.0	0
07	02	60.1	428.0	-0.500	0.160	0	0	0	299.6	58.4	369.0	0
07	03	194.3	1416.6	-0.500	0.160	0	0	0	991.6	175.8	1055.0	0

Note: Adapted from PELPS III (Zhang, Buongiorno, and Ince; 1993)

Appendix 14 – Input data for the PELPS's supply

SUPPLY

A : Region number (01 to 99, in ascending order)
B : Commodity Number (01 to 99, in ascending order within each region)
C : Resource commodity number (optional, leave blank if omitted)
D : Base period price in common currency
E : Base period quantity supplied at price C
F : Price elasticity (>0, enter 0.00 for horizontal supply)
G : Elasticity of supply with respect to the first shift variable (optional, enter 0.00 if omitted)
H : Elasticity of supply with respect to the second shift variable (optional, enter 0.00 if omitted)
I : Elasticity of supply with respect to the third shift variable (optional, enter 0.00 if omitted)
J : Elasticity of supply with respect to previous-period supply (optional, enter 0.00 if omitted)
K : Elasticity of supply with respect to resource stock (optional, enter 0.00 if omitted)
L : Lower bound on the quantity supplied (optional, enter 0.00 if omitted)
M : Upper bound on the quantity supplied
N : Price in the period before the base period
O : Quantity supplied in the period before the base period

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
reg	com	rcn	price	quantity	p elas	shift 1	shift 2	shift 3	pr sup	res sck	low bnd	upp bnd	prev price	q(-1)
01	02		28.54	14932.0	0.256	0	0	0	0	0	0	26000.0	32.10	14341.0
02	02		33.46	6847.0	0.256	0	0	0	0	0	0	7000.0	31.90	7438.0
03	02		40.50	10125.0	0.268	0	0	0	0	0	0	17000.0	43.00	8704.0
04	02		22.99	1443.0	0.993	0	0	0	0	0	0	1750.0	25.46	711.0
05	02		28.54	267.0	0.993	0	0	0	0	0	0	300.0	32.10	267.0

Note: Adapted from PELPS III (Zhang, Buongiorno, and Ince; 1993)

Appendix 15 – Input data for PELPS's manufacture activity (sawmilling)

MANUFACTURE

A : Record type (three types of records are used, M, P and B)
-> Record type M (manufacturing cost) :
B : Region number (01 to 99, in ascending order)
D : Commodity (primary) number (01 to 99, in ascending order within each region)
E : Commodity (secondary) number (01 to 99, in ascending order within each primary comm.; leave blank if not applicable)
F : Process number(01 to 99, in ascending order within each commodity)
G : Input mix number(1 to 9, in ascending order with each process)
H : Net manufacturing cost in common currency
-> Record type P (manufacturing coefficients) :
B : Region number (01 to 99, in ascending order)
D : Input commodity number (01 to 99, in ascending order within each output commodity)
E : Output commodity number (01 to 99, in ascending order within each region)
F : Process number(01 to 99, in ascending order within each commodity)
G : Input mix number(1 to 9, in ascending order with each process)
H : Amount of input commodity per unit of output commodity
-> Record type B (by-product coefficients) :
B : Region number (01 to 99, in ascending order)
D : Primary commodity number (01 to 99, in ascending order within each output commodity)
E : Secondary commodity number (01 to 99, in ascending order within each region)
F : Process number(01 to 99, in ascending order within each commodity)
G : Input mix number(1 to 9, in ascending order with each process)
H : Amount of secondary commodity per unit of primary commodity

A	B	C	D	E	F	G	H
M	01		03		02	2	29.80
M	01		03	04	02	2	0.00
M	02		03		02	2	29.80
M	02		03	04	02	2	0.00
M	03		03		02	2	31.00
M	03		03	04	02	2	0.00
M	04		03		02	2	40.00
M	04		03	04	02	2	0.00
M	05		03		02	2	31.00
M	05		03	04	02	2	0.00
P	01		02	03	02	2	2.54
P	02		02	03	02	2	2.54
P	03		02	03	02	2	2.56
P	04		02	03	02	2	2.31
P	05		02	03	02	2	2.31
B	01		03	04	02	2	1.54
B	02		03	04	02	2	1.54
B	03		03	04	02	2	1.56
B	04		03	04	02	2	1.31
B	05		03	04	02	2	1.31

Note: Adapted from PELPS III (Zhang, Buongiorno, and Ince; 1993)

Appendix 16 – Input data for PELPS's manufacturing costs and capacity (sawmilling)

CAPACITY - 2

A : Region number (in ascending order)
C : Commodity number (in ascending order in each region)
D: Process number(01 to 99, in ascending order within each commodity for overtime capacity; leave blank if not applicable)
E : Process number(01 to 99, in ascending order within each commodity)
F : Manufacturing capacity of base period
U,V,...,Y, Z : Manufacturing capacity one period, two periods, ..., five periods before the base period, respectively

A	B	C	D	E	F	U	V	X	Y	Z
						C(-1)	C(-2)	C(-3)	C(-4)	C(-5)
reg	=	com	otp	pro	cap.	=	=	=	=	=
01		03		02	9727	9629.7	9533.4	9438.1	9343.7	9250.3
02		03		02	3500	3465	3430.4	3396	3362.1	3328.5
03		03		02	4500	4455	4410.5	4366.3	4322.7	4279.5
04		03		02	739	731.6	724.3	717.1	709.9	702.8
05		03		02	127	125.7	124.5	123.2	122	120.8

Note: Adapted from PELPS III (Zhang, Buongiorno, and Ince; 1993)

Appendix 17 – Input data for PELPS's transportation costs

TRANSPORTATION COST AND TAX							
A : Origin region number (01 to 99) C : Destination region number (01 to 99, in ascending order within each origin) E : Commodity number (01 to 99, in ascending order within each origin-destination) F : Freight cost of shipping one unit of commodity from origin to destination G : Import ad-valorem tax rate H : Export ad-valorem tax rate							
A	B	C	D	E	F	G	H
01		02		02	13.00	0	0
01		02		03	11.62	0	0
01		03		02	37.54	0	0
01		03		03	28.70	0	0
01		04		02	61.91	0	0
01		04		03	22.30	0	0
01		05		02	72.42	0	0
01		05		03	22.15	0	0
01		06		02	59.18	0.108	0
01		06		03	46.50	0.108	0
01		07		02	38.13	0.108	0
01		07		03	31.34	0.108	0
02		01		02	13.00	0	0
02		01		03	11.79	0	0
02		03		02	38.20	0	0
02		03		03	28.66	0	0
02		04		02	66.54	0	0
02		04		03	22.84	0	0
02		05		02	79.05	0	0
02		05		03	22.68	0	0
02		06		02	59.13	0.108	0
02		06		03	46.46	0.108	0
02		07		02	38.08	0.108	0
02		07		03	29.92	0.108	0
03		01		02	37.54	0.100	0
03		01		03	29.36	0.100	0
03		02		02	38.20	0.100	0
03		02		03	29.62	0.100	0
03		04		02	87.99	0.100	0
03		04		03	27.82	0.100	0
03		05		02	35.98	0.100	0
03		05		03	27.93	0.100	0
03		06		02	47.59	0.100	0
03		06		03	37.39	0.100	0
03		07		02	32.66	0.100	0
03		07		03	25.66	0.100	0

... continued from Appendix 17

TRANSPORTATION COST AND TAX							
A	B	C	D	E	F	G	H
04		01		02	61.91	0	0
04		01		03	50.06	0	0
04		02		02	66.54	0	0
04		02		03	55.13	0	0
04		03		02	87.99	0.109	0
04		03		03	64.18	0.109	0
04		05		02	70.22	0	0
04		05		03	58.13	0	0
04		06		02	59.05	0.109	0
04		06		03	46.39	0.109	0
04		07		02	41.43	0.109	0
04		07		03	34.15	0.109	0
05		01		02	72.42	0	0
05		01		03	55.49	0	0
05		02		02	79.05	0	0
05		02		03	60.50	0	0
05		03		02	35.98	0.108	0
05		03		03	31.53	0.108	0
05		04		02	63.91	0	0
05		04		03	9.23	0	0
05		06		02	57.89	0.108	0
05		06		03	45.49	0.108	0
05		07		02	39.96	0.108	0
05		07		03	32.98	0.108	0
07		01		02	38.13	0.05	0
07		01		03	29.83	0.05	0
07		02		02	38.09	0.05	0
07		02		03	29.53	0.05	0
07		03		02	32.66	0.05	0
07		03		03	28.73	0.05	0
07		04		02	41.43	0.05	0
07		04		03	31.19	0.05	0
07		05		02	39.96	0.05	0
07		05		03	31.06	0.05	0

Note: Adapted from PELPS III (Zhang, Buongiorno, and Ince; 1993)

Appendix 18 – Input data for PELPS's exchange rate

EXCHANGE RATE	
A : region number (including demand, supply and production, 01 to 99) B : Exchange rate (expressed as the ratio of regional currency to U. S. dollar)	
A	B
01	1.00
02	1.00
03	1.00
04	1.00
05	1.00
06	1.00
07	1.00

Note: Adapted from PELPS III (Zhang, Buongiorno, and Ince; 1993)

Appendix 19 – Distance between the main centers in each region (sawlogs)

#	Sawlog Supply Region	Main Center	#	Sawlog Demand Region	Main Center	Distance (km)	TC[1] (US$/m3)
01	Southern Brazil	PontaGrossa	02	RBZ	Bauru	421	13.00
01	Southern Brazil	PontaGrossa	03	Chile	Concepcion	7858	37.54
01	Southern Brazil	PontaGrossa	04	Argentina	Posadas	673	61.91
01	Southern Brazil	PontaGrossa	05	ROM	Tacuarembo	1340	72.42
01	Southern Brazil	PontaGrossa	06	ASIA-S	Asia (Nagoya)	22867	59.18
01	Southern Brazil	PontaGrossa	07	ROW	USA (Atlantic)[2]	8270	38.13
02	RBZ	Bauru	01	Southern Brazil	PontaGrossa	421	13.00
02	RBZ	Bauru	03	Chile	Concepcion	8319	38.20
02	RBZ	Bauru	04	Argentina	Posadas	967	66.54
02	RBZ	Bauru	05	ROM	Tacuarembo	1761	79.05
02	RBZ	Bauru	06	ASIA-S	Asia (Nagoya)	22833	59.13
02	RBZ	Bauru	07	ROW	USA (Atlantic)[2]	8237	38.08
03	Chile	Concepcion	01	Southern Brazil	PontaGrossa	7858	37.54
03	Chile	Concepcion	02	RBZ	Bauru	8319	38.20
03	Chile	Concepcion	04	Argentina	Posadas	2328	87.99
03	Chile	Concepcion	05	ROM	Tacuarembo	6781	35.98
03	Chile	Concepcion	06	ASIA-S	Asia (Nagoya)	14830	47.59
03	Chile	Concepcion	07	ROW	USA (Atlantic)[2]	4476	32.66
04	Argentina	Posadas	01	Southern Brazil	PontaGrossa	673	61.91
04	Argentina	Posadas	02	RBZ	Bauru	967	66.54
04	Argentina	Posadas	03	Chile	Concepcion	2328	87.99
04	Argentina	Posadas	05	ROM	Tacuarembo	1200	70.22
04	Argentina	Posadas	06	ASIA-S	Asia (Nagoya)	22772	59.05
04	Argentina	Posadas	07	ROW	USA (Atlantic)[2]	10560	41.43
05	ROM	Tacuarembo[3]	01	Southern Brazil	PontaGrossa	1340	72.42
05	ROM	Tacuarembo[3]	02	RBZ	Bauru	1761	79.05
05	ROM	Tacuarembo[3]	03	Chile	Concepcion	6781	35.98
05	ROM	Tacuarembo[3]	04	Argentina	Posadas	800	63.91
05	ROM	Tacuarembo[3]	06	ASIA-S	Asia (Nagoya)	21973	57.89
05	ROM	Tacuarembo[3]	07	ROW	USA (Atlantic)[2]	9541	39.96
07	ROW	USA (Atlantic)[1]	01	Southern Brazil	PontaGrossa	8270	38.13
07	ROW	USA (Atlantic)[1]	02	RBZ	Bauru	8241	38.09
07	ROW	USA (Atlantic)[1]	03	Chile	Concepcion	4476	32.66
07	ROW	USA (Atlantic)[1]	04	Argentina	Posadas	10560	41.43
07	ROW	USA (Atlantic)[1]	05	ROM	Tacuarembo	9541	39.96

[1] Values also referred in Appendix 17
[2] Savannah/GA
[3] in Uruguay

Appendix 20 – Distance between the main centers in each region (sawnwood)

#	Sawnwood Supply Region	Main Center	#	Sawnwood Demand Region	Main Center	Distance (km)	TC[1] (US$/m3)
01	Southern Brazil	PontaGrossa	02	RBZ	São Paulo	523	11.62
01	Southern Brazil	PontaGrossa	03	Chile	Santiago	7160	28.70
01	Southern Brazil	PontaGrossa	04	Argentina	Buenos Aires	1512	22.30
01	Southern Brazil	PontaGrossa	05	ROM	Montevideo	1379	22.15
01	Southern Brazil	PontaGrossa	06	ASIA-S	Asia (Nagoya)	22867	46.50
01	Southern Brazil	PontaGrossa	07	ROW	USA (Atlantic)[2]	9486	31.34
02	RBZ	Bauru	01	Southern Brazil	Curitiba	535	11.79
02	RBZ	Bauru	03	Chile	Santiago	7126	28.66
02	RBZ	Bauru	04	Argentina	Buenos Aires	1983	22.84
02	RBZ	Bauru	05	ROM	Montevideo	1844	22.68
02	RBZ	Bauru	06	ASIA-S	Asia (Nagoya)	22833	46.46
02	RBZ	Bauru	07	ROW	USA (Atlantic)[2]	8237	29.92
03	Chile	Concepcion	01	Southern Brazil	Curitiba	7744	29.36
03	Chile	Concepcion	02	RBZ	São Paulo	7974	29.62
03	Chile	Concepcion	04	Argentina	Buenos Aires	6379	27.82
03	Chile	Concepcion	05	ROM	Montevideo	6481	27.93
03	Chile	Concepcion	06	ASIA-S	Asia (Nagoya)	14830	37.39
03	Chile	Concepcion	07	ROW	USA (Atlantic)[2]	4476	25.66
04	Argentina	Posadas	01	Southern Brazil	Curitiba	787	50.06
04	Argentina	Posadas	02	RBZ	São Paulo	1197	55.13
04	Argentina	Posadas	03	Chile	Santiago	1928	64.18
04	Argentina	Posadas	05	ROM	Montevideo	1439	58.13
04	Argentina	Posadas	06	ASIA-S	Asia (Nagoya)	22772	46.39
04	Argentina	Posadas	07	ROW	USA (Atlantic)[2]	11971	34.15
05	ROM	Tacuarembo[3]	01	Southern Brazil	Curitiba	1226	55.49
05	ROM	Tacuarembo[3]	02	RBZ	São Paulo	1631	60.50
05	ROM	Tacuarembo[3]	03	Chile	Santiago	9656	31.53
05	ROM	Tacuarembo[3]	04	Argentina	Buenos Aires	350	9.23
05	ROM	Tacuarembo[3]	06	ASIA-S	Asia (Nagoya)	21973	45.49
05	ROM	Tacuarembo[3]	07	ROW	USA (Atlantic)[2]	10934	32.98
07	ROW	USA (Atlantic)[2]	01	Southern Brazil	Curitiba	8156	29.83
07	ROW	USA (Atlantic)[2]	02	RBZ	São Paulo	7892	29.53
07	ROW	USA (Atlantic)[2]	03	Chile	Santiago	7189	28.73
07	ROW	USA (Atlantic)[2]	04	Argentina	Buenos Aires	9360	31.19
07	ROW	USA (Atlantic)[2]	05	ROM	Montevideo	9241	31.06

[1] Values also referred in Appendix 17
[2] Savannah/GA
[3] in Uruguay

Appendix 21 – Exogenous changes in PELPS

Periods	Years	Exogenous Change Variable	Table in PELPS (worksheet)	Regions and Changes (values)							Commodity
				S-BZ	RBZ	CHI	ARG	ROM	ASIA-S	ROW	
1 to 5	**1995-1999**	GDP growth	Demand	0.03	0.03	0.08	0.02	0.02	0.07	0.035	Sawnwood
		Upper-bound	Supply	0.02	0.02	0.02	0.01	0.01	-	-	Sawlogs
6 to 10	**2000-2004**	GDP growth	Demand	0.04	0.04	0.632	0.02	0.02	0.0592	0.038	Sawnwood
		Upper-bound	Supply	0.00	0.00	0.037	0.01	0.01	-	-	Sawlogs
		Import Tax	Transport.	-0.10	-0.10	-0.10	-0.10	-0.10	-	-	Sawnwood/ Sawlogs
11-15	**2005-2010**	GDP growth	Demand	0.04	0.04	0.632	0.02	0.02	0.592	0.038	Sawnwood
		Upper-bound	Supply	-0.02	-0.02	0.037	0.01	0.01	-	-	Sawlogs
		Import Tax	Transport.	-0.10	-0.10	-0.10	-0.10	-.010	-	-	Sawnwood/ Sawlogs

Appendix 22 – Summary statistics of Lindo® in the Base Scenario (1995)

SUMMARY STATISTICS FROM LINDO® – BASE SCENARIO - BASE YEAR (1995)
: : : NAME BASEYEAR CANDIDATE OBJECTIVE ROW(S) IS(ARE): OBJFUNC MAX OR MIN ? ? ROWS= 44 VARS= 220 NO. INTEGER VARS= 0 NONZEROES= 684 CONSTRAINT NONZ= 450(440 ARE +- 1) DENSITY=0.070 SMALLEST AND LARGEST ELEMENTS IN ABSOLUTE VALUE= 1.00000 26000.0 NO. < : 10 NO. =: 5 NO. > : 28, OBJ=MAX, GUBS <= 32 SINGLE COLS= 0 : LP OPTIMUM FOUND AT STEP 178
OBJECTIVE VALUE = 2970482.75