Working Paper

Comparison of Two Models of the Austrian Forest Sector

Peter Schwarzbauer

WP-90-23
May 1990

IIASA

International Institute for Applied Systems Analysis □ A-2361 Laxenburg □ Austria

Telephone: (0 22 36) 715 21 * 0 □ Telex: 079 137 iiasa a □ Telefax: (0 22 36) 71313

Comparison of Two Models of the Austrian Forest Sector

Peter Schwarzbauer

WP-90-23
May 1990

Publication Number 104 of the Biosphere Dynamics Project

IIASA
International Institute for Applied Systems Analysis □ A-2361 Laxenburg □ Austria
Telephone: (0 22 36) 715 21 * 0 □ Telex: 079 137 iiasa a □ Telefax: (0 22 36) 71313

About the Author

Dr. Peter Schwarzbauer, forester, is University Assistant at the Institute of Forest Economy and Forest Policy of the University of Agriculture in Vienna, Austria. His basic research field is forest-products markets. Between 1981 and 1985, he was involved in the IIASA Forest Sector Project mainly as data collaborator but also in implementing a "Prototype Model" for Austrian purposes. From 1985 to 1988 he worked on an Austrian version of the IIASA Global Trade Model. During the same time he developed the Simulation Model of the Austrian Forest Sector (FOHOW) at the University of Agriculture in Vienna. His address is:

Institute of Forest Economy and Forest Policy
University of Agriculture
Gregor-Mendelstrasse 33
A-1180 Vienna
Austria

Foreword

Within IIASA's Environment Program, the Biosphere Dynamics Project seeks to clarify the policy implications of long-term, large-scale interactions between the world's economy and its environment. The project conducts its work through a variety of basic research efforts and applied case studies. One such case study, the Forest Study, has been underway since March 1986 and focuses on the forest decline problem in Europe. Objectives of the Forest Study are:

a) to gain an objective view of the future development of the European forest resources;

b) to illustrate the future development of forest decline attributed to air pollution and the effects of this decline on the forest sector, international trade and society in general;

c) to build a number of alternative and consistent scenarios about the future decline and its effects; and

d) to identify meaningful policy options, including institutional, technological and research/ monitoring responses, that should be pursued to deal with these effects.

In the framework of the Forest Study a whole series of working papers on forest decline attributed to air pollutants has been published. This paper presents two different modelling approaches for the entire Austrian forest sector. The objective of this study is to carry out an analysis of the forest sector on a global level, with the Austrian forest sector as the center. Several scenarios (including the effects of forest decline attributed to air pollutants) have been generated concerning the development of the forest sector up to the year 2030.

B.R. Döös
Leader
Environment Program

Acknowledgements

I am deeply indebted to several persons, without whom this work would not have been possible. Dr. Gabor Kornai of IIASA, now with the Institute for Economic and Market Research and Information in Budapest, devoted a lot of work in helping me implement the IIASA Global Trade Model for Austrian purposes. Prof. Lars Lönnstedt of IIASA, now of the Swedish University of Agricultural Sciences, was my teacher in using the system dynamics approach for forest-sector modelling purposes. I am also grateful to Prof. Peter Glück of the University of Agriculture in Vienna for giving me lots of scientific advice, reading the manuscripts and keeping my motivation alive to complete this study. My thanks also go to Serge Medow and Dennis Legault of the IIASA computer department for helping me use the IIASA computer. I am especially indebted to Prof. Sten Nilsson of the College of Forestry in Garpenberg (Sweden), currently also leader of the IIASA Forest Study, for getting my work published at IIASA. Special thanks go to Prof. Peter Duinker of Lakehead University (Canada) for reviewing and editing this paper.

Abstract

The paper presents two different modelling approaches for the Austrian forest sector. While the ATM (Austrian Trade Model) is a normative optimization model, based on the Global Trade Model developed at IIASA, the FOHOW (Simulation Model of the Austrian Forest Sector) is a descriptive simulation model, written in the Dynamo simulation language. ATM and FOHOW also differ in scope, with ATM being a global model covering the whole world (nine separate regions with Austria as the center) and FOHOW being basically a national model for Austria. Both models include the whole forest sector from timber growth to paper consumption. Thus the level of detail is naturally low. The ATM deals with fourteen, the FOHOW with nine different products ranging from raw materials (e.g. roundwood) to final products (e.g. paper). The models can be used mainly for long-term policy analysis ("what-if" questions) rather than for forecasting purposes. While an ATM-run starts at 1980, a FOHOW-run already begins in 1965; both end at 2030. Beside a base scenario, several scenarios were tested in parallel for both models under similar assumptions. The results of a selected number of scenario-runs are presented. The paper closes with a discussion of model strengths and weaknesses in terms of implementation, conceptual issues and potential for improvements.

Contents

Comparison of Two Models of the Austrian Forest Sector

Peter Schwarzbauer

1 Introduction

The German forest economist Heiner Ollmann recently called the wood market "a so far only superficially researched object" (Ollmann 1988, Translation P.S.[1]). One of the factors contributing to superficiality is the fact that "the so-called 'patterns' of activities in wood markets have not been sufficiently researched" (Ollmann 1988, T.P.S.). Science has dealt with forest-products markets mainly in the form of description and has failed "to achieve an insight into the underlying forces which affect markets" (Niesslein, introduction to Mantau 1981, T.P.S.).

Although economic figures on the Austrian forest sector in many respects exceed international averages (e.g. per capita production of forest products), the above statements, which were made for the situation in the Federal Republic of Germany, can be applied to Austria as well. Very few scientific publications deal with the factors influencing supply, demand and prices of forest products, and even fewer quantify these influences and try to draw conclusions on forest-market behavior based on these quantifications. Unlike in North America and Scandinavia, there is almost no tradition in forest-sector modelling in Central Europe and especially in Austria.

In this paper, the Austrian Forest Sector and its underlying forces are formulated in two separate macroeconomic computer models. One is a normative optimization model, based on the Global Trade Model (GTM) developed at IIASA; the other is a pure simulation model. They provide some insight into long-term developments of forest-products markets as well as how the forest sector reacts to assumptions on relevant future developments or specific policies. This work offers the possibility for decision-makers to evaluate, modify or develop strategies concerning the forest sector.

Both models take a rather comprehensive approach and try to cover the entire forest sector as an interacting system, from timber growth to paper consumption. Because of model complexity, the level of detail is naturally low, but one can experience simultaneity not to be found in much more detailed but less complex models.

The presented work is in large part based on achievements made during the Forest Sector Project of IIASA (1981–1985). Without this project and without the contacts to international scientists of that field, this study would not have been possible. IIASA has contributed to breaking Austria's isolation in forest sector modelling.

2 The Austrian Forest Sector and its Markets – A Survey

2.1 The position of the forest sector in the Austrian general economy

One aspect of the importance of the forest sector is its contribution to GDP (Table 1). The relative contribution of the entire forest sector to GDP has declined from 6.2% in 1966 to 4.1% in 1986. Forestry has lost more than the forest industries.

Excluding forest owners, 2% of the total labor force was working in the forest sector in 1986 (Table 2). While the total labor force has increased by 2% between 1966 and 1986, the

[1] All literally cited passages translated from German into English will hereafter be marked with "T.P.S." (Translation Peter Schwarzbauer).

Table 1: Forest-sector contribution to GDP in Austria. Data are percentages.

Sector	1966	1976	1986	Changes 1986–1966 in %
Forestry	1.2	1.0	0.5	– 58
Woodworking industry and sawmills	2.5	2.2	1.9	– 24
Paper industry[a]	2.5	2.0	1.7	– 32
Forest industries	5.0	4.2	3.6	– 28
Total forest sector	6.2	5.2	4.1	– 34
GDP in billion AS (nominal)	268.5	724.8	1432.5	+434

[a]Paper production, paper processing, printing and publishing
SOURCE: ÖstZA (1979b, 1987b)

Table 2: Labor force in the Austrian forest sector. Data are 1,000 persons and percentages of total labor force.

	1966		1976		1986		Changes 1986–1966
Sector	abs.	%	abs.	%	abs.	%	in %
Forestry	284.6	9.0	276.6	8.6	248.6	7.7	–13
Forest industries	67.1	2.1	60.6	1.9	47.1	1.5	–30
Total forest sector[a]	83.1	2.6	71.4	2.2	57.2	1.8	–31
Total forest sector[b]	351.7	11.1	337.2	10.5	295.8	9.2	–16
Total Austrian labor force	3159.6	100.0	3220.4	100.0	3226.3	100.0	+ 2

[a]Forest owners not counted
[b]Forest owners counted
SOURCES: Österreichischer Arbeiterkammertag (1988); BMLF (1972, 1982, 1987); ÖstZA (1965, 1977, 1983)

forest-sector labor force fell by 31%. The forest industries lost considerably more than forestry.

Unlike the total balance of trade in Austria, the trade balance for wood, wood products and paper products is positive. In 1986 6% of all imports were wood and paper products, while the share of exports was more than 11% (Table 3). The importance of the forest sector is declining, however. While the quotient of exports and imports (exports in % of imports) increased for all trade by 17% between 1966 and 1986, it fell by 60% for wood and wood products and by 33% for paper products. This development is caused by higher imports rather than lower exports.

2.2 Austrian forest resources

According to the Federal Austrian Forest Inventory, 3.86 million hectares, or 46% of the Austrian land base, are covered by forests. 53% belongs to private forest enterprises with less than 200 ha, 32% to enterprises with more than 200 ha, and 15% to the Austrian Federal Forests. 3.34 million hectares (87%) are timber-yielding forests, 71% of which is coniferous (FBVA 1986).

Growing stock in Austria's forests is currently about 908 million m^3 outside bark (o.b.) (only trees with a diameter at breast high of 10.5 cm are counted), 92% of which stands in commercial forests. Coniferous growing stock amounts to 82% of total growing stock (FBVA 1986). Gross annual increment in Austrian timber-yielding forests is slightly less than 20 million m^3 (o.b.) (FBVA 1985).

Since 1961, total forest area of Austria has increased by 4.5% and total growing stock by 20% (Table 4). Increment (between 1961/70 and 1971/80) has increased by 6%. While the forest-area

Table 3: Foreign trade of Austrian forest products.

Year	Commodity	Imports Bill. AS	Imports %	Exports Bill. AS	Exports %	Balance Bill. AS	Quotient[a] %
1966	Total	61.6	100.0	44.2	100.0	−17.4	71.8
	Wood, wood products	2.0	3.2	6.6	14.9	+4.6	330.0
	Paper products[b]	1.0	1.6	2.9	6.6	+1.9	290.0
1976	Total	208.1	100.0	152.6	100.0	−55.5	73.3
	Wood, wood products	5.3	2.5	10.6	6.9	+5.3	200.0
	Paper products[b]	5.0	2.4	10.1	6.6	+5.1	202.0
1986	Total	408.2	100.0	342.4	100.0	−65.9	83.9
	Wood, wood products	12.1	3.0	16.1	4.7	+4.0	133.1
	Paper products[b]	11.5	2.8	22.3	6.5	+10.8	193.9
Changes	Total	+562.7	–	+674.7	–	+278.7	+16.9
1986/1966	Wood, wood products	+505.0	−6.3	+143.9	−68.5	−13.0	−59.7
in %	Paper products[b]	+1050.0	+75.0	+669.0	−1.5	+468.4	−33.1

[a]Exports in % of imports
[b]Unprocessed and processed paper products
SOURCES: BHWR (1972, 1977, 1987)

Table 4: Changes in Austrian forest resources since 1961.

Variable	Data by Period 1961/70	1971/80	1981/85	Changes (81/85) – (61/70) in %
Total forest area (Mill. ha) of which:	3.69	3.75	3.86	+4.5
private < 200 ha	2.02	2.03	2.05	+1.3
private > 200 ha	1.12	1.14	1.22	+9.5
federal	0.55	0.58	0.58	+5.8
Forest area in % of total area	44.0	44.8	46.0	+4.5
Growing stock in timber-yielding forests				
Mill. m^3 (o.b.)	757	803	908	+19.9
m^3/ha	(234)	(254)	(272)	(+16.2)
Increment in timber-yielding forest				
Mill. m^3 (o.b.)	18.5	19.6	n.a.	+6.0[a]
m^3/ha	(5.7)	(6.2)	n.a.	(+8.8)[a]

[a]Changes (71/80) – (61/70) in %
SOURCES: FBVA (1973, 1985, 1986)

increase can partly be explained by afforestation, higher growing stock mainly is the result of harvests below net increment. In terms of growing stock and increment, forest enterprises with less than 200 ha are better off than the other ownership categories because they are usually managed by farmers located in climatically better areas.

2.3 Austrian domestic timber supply

According to the Austrian Agricultural Census, 228,000 forest-owning enterprises existed in 1980 (only those with a land holding larger than 1 ha are counted). An additional 10,000 enterprises have the permanent right to harvest in forests which they do not own (enterprises with "theoretical" forests) (ÖstZA 1983). The average size of a forest holding is 14 ha. More

Table 5: Changes in Austrian forest ownership.

Ownership Category	1970 1000	%	1980 1000	%	Changes 1980–1970 in %
Total forest owners (actual + "theoretical")	258.29	–	238.56	–	−7.6
Total forest owners (actual)	242.24	100.0	227.77	100.0	−6.0
of which:					
< 5 ha	167.81	69.3	153.11	67.2	−8.8
< 200 ha	240.88	99.4	226.45	99.4	−6.0
> 200 ha	1.36	0.6	1.32	0.6	−2.9

SOURCES: ÖstZA (1965, 1977, 1983)

Table 6: Changes in Austrian annual timber harvests.

Variable	Data by Period 62/71	71/80	78/87	Changes (78/87) – (62/71) in %
Total harvests (Mill. m^3 (u.b.))	10.22	10.84	11.86	+16.1
of which:				
private < 200 ha	5.07	4.07	5.39	+6.4
private > 200 ha	3.54	3.76	4.42	+25.0
federal	1.61	1.77	2.05	+26.9
Coniferous	8.58	9.12	9.83	+14.5
Non-coniferous	1.64	1.72	2.03	+24.3
Final cuts	8.89	9.21	9.59	+7.8
Thinnings	1.33	1.63	2.28	+71.1
Industrial roundwood	7.97	9.40	9.56	+19.9
Fuelwood	2.49	1.80	2.30	+12.3

SOURCES: BMLF (1972, 1981, 1988)

than 99% of the enterprises are smaller than 200 ha.

Between 1970 and 1980, the number of actual forest owners declined by 6% and the number of all forest owners (actual and "theoretical") by 7.6% (Table 5). In the last decade, about 12 million m^3 under bark (u.b.) of timber were harvested annually from the Austrian forests, of which 10 million m^3 were coniferous. Final cuts and industrial roundwood production were on about the same level as coniferous harvests. Non-coniferous harvests, thinnings and fuelwood each amounted to ca. 2 million m^3.

Between 1962/71 and 1978/87, the total harvest increased by 16%, but only 6.4% in the private forests smaller than 200 ha (Table 6). This is caused by the fact that the bulk of the harvest increase came through thinnings (+71%), which were mainly undertaken by the bigger-forest owners.

Roundwood prices are strongly related to the development of final product prices or prices of other roundwood products. Log prices follow sawnwood prices, and pulpwood prices depend on log prices, fuelwood prices and prices of final products. Because of the oil crisis in the mid 1970s, fuelwood prices rose much more than any other roundwood price between 1966 and 1986 in nominal terms (Table 7). Non-coniferous prices show higher increases than the corresponding coniferous prices.

Table 7: Changes in Austrian roundwood prices (AS/m^3 (nominal) and %).

Roundwood Product	1966	1976	1986	Changes 1986–1966 in %
Coniferous logs:				
spruce/fir, 2b,B	495	897	992	+100
Non-coniferous logs:				
beech B	330[a]	540	967	+190
Coniferous pulpwood:				
spruce/fir, 1b (u.b.)	361	562	600	+66
Non-coniferous pulpwood:				
beech long (o.b.)	231	263	462	+100
Non-coniferous fuelwood	170	263	719	+323
Coniferous fuelwood	190	259	570	+200

[a]1968
SOURCES: BMLF (1972, 1981, 1988)

Table 8: Structural changes in the Austrian forest industries (1964–1983).

	Number of Mills			
Sector	1964	1976	1983	Changes 1983–1964 in %
Saw mills	3,282	2,078	2,228	−32
Paper industry	95	67	48	−49
Panel industry	33	38	31	−6

SOURCES: ÖstZA (1979a, 1986)

2.4 Production of technological products and consumption of roundwood

In 1983 Austria's forest industries consisted of ca. 2,200 sawmills and several dozens of papermills and panel-producing plants (Table 8). Forest industries have undergone a dramatic concentration process in the last decades, mainly caused by technical innovation (BHWR 1980). The sawmill sector has lost the majority of small mills, while the big ones increased their market share. In 1986 1% of the sawmills produced one-third of the sawnwood. The situation in the panel industry is somewhat different, because its main product in Austria, particleboard, faced an enormous growth in demand and production, which led to a slight increase in the number of panel-producing plants in the 1970s.

With the exception of solidwood panels, production of all technological products increased significantly in the last decades (Table 9). Growth rates of sawnwoods were much lower, however, than those for reconstituted panels and paper. Pulp production grew considerable slower than paper production because of recycled paper substitution.

Between 1966 and 1986 nominal non-coniferous sawnwood prices have increased most of all products, followed by coniferous sawnwood (Table 10). Reconstituted panels faced price reductions, while other paper and paperboard prices grew only moderately. Prices compared with production demonstrate that production grew especially for those products whose prices fell or grew only moderately. This seems to be in contradiction with supply theory. Because of price-data problems for panels and paper (average unit value), quality changes in production cannot be dealt with. The price decline (real) for reconstituted panels and other paper and paperboard is partly affected by higher supply, but partly also by the shift of production to lower qualities with lower prices.

Forest-industry roundwood consumption (including residues) increased by 46% between

Table 9: Annual production of technological products and residues in Austria.

Product	Data by Period in 1000 m^3 or tons 62/71	71/80	78/87	1987	Changes (78/87) – (62/71) in %
Coniferous sawnwood	4,764	5,630	5,907	5,686	+24.0
Non-coniferous sawnwood	288	378	329	223	+14.2
Residues	1,532	1,954	2,086	2,088	+36.2
Solidwood panels (veneer, plywood)	37	28	26	35	-29.7
Reconstituted panels (particle- and fiberboard)	398	1,091	1,300	1,416	+226.6
Chemical pulp	598	847	1,034	1,141	+72.9
Mechanical pulp	191	207	201	192	+5.2
Newsprint, printing and writing paper	438	727	930	1,234	+112.3
Other paper and board	361	643	907	1,123	+151.2

SOURCES: BHWR (1972, 1982, 1987); BMLF (1966, 1972, 1982, 1988); FAO (1975, 1988); Vereinigung österreichischer Papierindustrieller (1965–1988)

Table 10: Changes in nominal prices of some technological products in AS/m^3.

Product	1966	1976	1986	Changes 1986–1966 in %
Coniferous sawnwood: spruce/fir O/III	1,138	2,013	2,340	+105.6
Non-coniferous sawnwood: beech I/II	985	1,665	2,925	+197.0
Reconstituted panels (particle- and fiberboard)[a]	2,386	1,837	2,296	– 3.8
Newsprint, printing and writing paper[a]	5,774	9,607	11,847	+105.2
Other paper and board[a]	5,914	7,488	8,026	+ 35.7

[a]Average unit value: gross income divided through production quantities
SOURCES: BMLF (1972, 1982, 1988); ÖstZA (1967, 1978, 1987a)

1962/71 and 1978/87, but with different rates for each sector (Table 11). Panel-industry consumption grew most of all sectors, followed by the paper industry. Thus pulpwood consumption increased with a much higher rate than log consumption. Table 11 shows that residue consumption growth (as a part of pulpwood consumption) is much higher than the growth of pulpwood from the forests. Pulpwood consumption in the paper industry increased much less than paper production (+58% and +100%, respectively) because of a growing recycled paper input (+382%).

2.5 Domestic consumption of technical forest products in Austria

In terms of quantity, coniferous sawnwood is the most important product of Austria's domestic final-product consumption (Table 12). With a growth of more than 50% in the last two decades,

Table 11: Annual roundwood consumption of Austrian forest industries.

Sector/Roundwood Product	Data by Period in 1000 m^3 or tons 62/71	71/80	78/87	1987	Changes (78/87) – (62/71) in %
Sawmills:					
coniferous logs	6,930	8,338	8,960	8,730	+29.3
non-coniferous logs	384	534	493	349	+28.4
Panel industry:					
coniferous pulpwood	471	1,166	1,409[a]	1,487	+199.2
of which: residues	315	989	1,290[a]	1,320	+309.5
non-coniferous pulpwood	271	727	480[a]	657	+77.1
Paper industry:					
coniferous pulpwood	2,475	3,279	4,259	4,609	+68.0
of which: residues	837	1,250	1,737	2,024	+107.5
non-coniferous pulpwood	776	1,027	904	921	+16.5
Total	11,307	15,071	16,505	16,753	+46.0

[a]Estimated for period 1983/87
SOURCES: Fachverband der Säge-Industrie Österreichs (1984, 1988); BMLF (1972, 1981, 1988); BHWR (1980); Österreichischer Agrarverlag (1987, 1989); author's own calculations

Table 12: Annual domestic consumption of technological products in Austria.

Product	Data by Period in 1000 m^3 or tons 62/71	71/80	78/87	1987	Changes (78/87) – (62/71) in %
Coniferous sawnwood	1,665	2,137	2,505	2,762	+50.5
Non-coniferous sawnwood	239	401	360	267	+50.6
Solidwood panels (veneer and plywood)	39	37	44	70	+12.8
Reconstituted panels (particle- and fiberboard)	287	600	676	675	+135.5
Newsprint, printing and writing paper	177	285	395	490	+123.2
Other paper and board	235	413	461	512	+96.3
Fuelwood[a]	2,057	1,861	2,490	2,886	+20.1

[a]Excluding residues
SOURCES: BMLF (1972, 1982, 1988); Vereinigung österreichischer Papierindustrieller (1965–1988)

which is twice as high as production growth (+ 24%), the domestic market became increasingly important for coniferous sawnwood producers. In terms of consumption growth rates, reconstituted panels are leading, followed by newsprint, printing and writing paper. Solidwood panels and fuelwood show the slowest growth. Between the 1960s and 1970s, fuelwood consumption declined significantly, to rise again thereafter because of the energy crisis.

2.6 Foreign trade with forest products in Austria

Austria's forest sector is export oriented. More than two-thirds of the coniferous sawnwood production, more than half of the reconstituted panels, and between 60% and 70% of the paper

Table 13: Annual foreign trade with roundwood products in Austria (X=export; M=import; N=net export(+) or net import(−)).

Roundwood Product		Data by Period in 1000 m³ 62/71	71/80	77/86	1986	Changes (77/86) – (62/71) in %
Coniferous logs	X	128	222	194	169	+51.6
	M	66	688	1,120	1,092	+1,597.0
	N	+62	−466	−926	−923	–
Non-coniferous logs	X	49	132	171	127	+249.0
	M	82	43	22	18	−73.2
	N	−33	+89	+149	+109	–
Coniferous pulpwood	X	86	190	281	371	+226.7
+ non-conif. pulpwood	M	699	1,203	1,535	2,416	+119.6
(incl. residues)	N	−613	−1,013	−1,254	−2,045	+104.6
Fuelwood	X	19	21	25	6	+31.6
(excl. residues)	M	26	81	147	338	+465.4
	N	−7	−60	−122	−332	+1,642.9
Total roundwood	X	282	565	671	673	+138.7
	M	873	2,015	2,824	3,864	+223.5
	N	−591	−1,450	−2,153	−3,191	+264.3

SOURCES: BMLF (1972, 1982, 1988); FAO (1963, 1975, 1988)

is exported. In monetary values, exports amount to only 50% of total production for the whole industry. Roundwood exports are very low. Currently only 5% of the Austrian roundwood production is not used in Austria itself.

Although an overall exporter, Austria has become a net importer in roundwood products with increasing pace in the last decades. The import share of the Austrian roundwood consumption has grown from 8% to 18% since 1962/71 with coniferous pulpwood growing most (+34% 1977/86 as compared to 1962/71). Also, sawnwood imports have risen significantly from almost zero to about 20% of consumption. In 1977/86 Austria imported ca. 3 million m³ roundwood annually, while only about 0.6 million was exported (Table 13).

The most important suppliers for Austrian roundwood imports are FRG (54% of coniferous logs imported), CSFR (60% of non-coniferous pulpwood, 53% of sawmill residues) and the rest of Eastern Europe and the USSR (20% of coniferous logs, 80% of coniferous pulpwood, 28% of non-conferous pulpwood).

Although Austria is a net exporter for most products, imports have grown significantly faster than imports for sawnwood and solidwood panels, and exports have grown faster for reconstituted panels and paper products (Table 14). The most important Austrian forest product in terms of quantity, coniferous sawnwood, shows a stagnation in net exports in the last decade. This corresponds with the fact that domestic consumption grew more than production.

More than three-fourths of the exported coniferous sawnwood, reconstituted panels and paper products go to EC-markets. The most important trading partners for Austria are Italy and FRG. Two-thirds of Austrian coniferous sawnwood exports are imported by Italy, 54% of reconstituted panels and 33% of paper exports are imported by the FRG.

Table 14: Annual foreign trade with final products in Austria (X = export; M = import; N = net export (+) or net import (−)).

Product		Data by Period in 1000 m³ or tons 62/71	71/80	78/87	1987	Changes (78/87) − (62/71) in %
Coniferous sawnwood	X	3,079	3,626	3,932	3,690	+27.7
	M	11	158	521	655	+5,854.5
	N	+3,068	+3,468	+3,411	+3,035	+11.2
Non-conif. sawnwood	X	69	106	101	85	+23.2
	M	41	128	134	127	+209.8
	N	+28	−22	−33	−42	−
Solidwood panels (veneer and plywood)	X	8	10	21	26	+125.0
	M	9	18	39	60	+566.6
	N	−1	−8	−18	−34	+1,700.0
Reconstituted panels (particle- and fiberboard)	X	110	519	697	860	+681.8
	M	79	28	60	101	+27.8
	N	+31	+491	+637	+759	+1,954.8
Newsprint, printing and writing paper	X	280	460	658	971	+135.0
	M	97	32	133	226	+37.1
	N	+183	+428	+525	+745	+186.9
Other paper and board	X	137	335	558	747	+307.3
	M	59	112	116	137	+96.6
	N	+78	+223	+442	+610	+466.7

SOURCES: BMLF (1972, 1982, 1988); FAO (1963, 1975); Vereinigung österreichischer Papierindustrieller (1965–1988)

3 A Forest Sector Optimization Model – Implementation of IIASA's "Global Model of Production, Consumption and Trade in Forest Products" for Austrian Purposes

Between 1981 and 1985, a global-forest-sector computer model was developed at IIASA by scientists of the Forest Sector Project. Beginning in 1985, work was started to implement the "Global Model of Production, Consumption and Trade in Forest Products" (commonly referred to as "Global Trade Model" and in the following called GTM) for Austrian purposes. This step was necessary because the original GTM was not suited as a tool for Austrian decision-makers, mainly due to its regional aggregation lumping most of Western Europe, including Austria, into one single region.

Assuming that the reader is already familiar with the GTM (see Kallio et al. 1987), the following mainly stresses the major differences between the GTM and the Austrian Trade Model (ATM).

3.1 Model structure

3.1.1 Regional and product aggregation

The ATM is also a global model, but it observes the world from an Austrian viewpoint. Austria, despite its marginal size from a global point of view, is treated as the "center of the world". The rest of the globe is divided according to the relative importance that countries/regions play in Austrian trade, either as partners or as competitors. Regions were defined considering conflicting needs: (i) to create as many regions as possible to represent accurately Austrian exports and imports, and (ii) to create as few regions as possible, to reduce analytical burden. Based on these considerations, the following nine regions were defined to represent the world in the ATM (m=major trading partner, c=competitor).

1 Austria
2 West Germany (m)
3 Italy (m)
4 Scandinavia (c)
5 Rest of Western Europe (m)
6 Czechoslovakia (m)
7 Rest of Eastern Europe & USSR (c)
8 North America (c)
9 Rest of the World

The ATM regions differ in size and weight more drastically than the GTM regions. This leads to a general problem: larger regions with less direct significance for Austria and perhaps even with weak data (e.g. Rest of the World) have a greater impact on the model results than do the smaller regions of specific interest.

Because of great difficulites in obtaining the necessary data to achieve a finer product disaggregation than the GTM, the modelled products are very similar to those of the original model. Indeed the number was reduced to 14 as follows (i=intermediate, f=final):

1 coniferous logs (i)
2 non-coniferous logs (i)
3 coniferous pulpwood (i)
4 non-coniferous pulpwood (i)
5 fuelwood (f)
6 mechanical pulp (i)
7 chemical pulp (i)
8 coniferous sawnwood (f)
9 non-coniferous sawnwood (f)
10 solidwood panel (f)
11 reconstituted panels (f)
12 newsprint, printing and writing paper (i)
13 other paper and paperboard (f)
14 recycled paper (i)

3.1.2 Timber supply

Timber supply in every region is technically modelled exactly like in the GTM. Price elasticities of supply have also been taken from the original GTM but have been changed during model calibration.

The necessary parameters for shifting the short-term supply curve over time were developed for Austria, based on calculations from yield tables, and taken from the original GTM for the other regions. The calculations for Austria turned out to be pretty much the same as for Western Europe (in the GTM).

To represent deforestation and new plantations in the Third World (Region Rest of the World in the ATM) several exogenous assumptions had to be implemented (Table 15). In Austria, forest area is assumed to increase annually by 5,000 hectares. This lies somewhat higher than afforestation in recent years (BMLF 1987) but should reflect the fact that in the future a significant amount of currently agriculturally used lands will be given up and afforested.

Table 15: Exogenous changes in timber supply in the region "Rest of the World" (yearly rates).

Variable	1990	2000	2030
Forest area (in Mill. ha)	−9.8	−9.5	−6.0
Non-coniferous growing stock (in Mill. m^3)	−966	−956	−625
Coniferous growing stock (in Mill. m^3)	+11.5	+11.5	+15.7

3.1.3 Final product demand

Final product demand is technically modelled the same way as in the GTM, the difference being the calculation and implementation of the demand-function parameters. The ATM does not use price elasticities estimated by IIASA (e.g. Wibe 1984), but incorporates results from a specific demand study (Schwarzbauer 1987, 1988). IIASA's approach was that of using pooled cross-section/time-series data, where countries were grouped into income categories for which the same behavior and the same elasticities were assumed. The Austrian results are based on pure time-series data for each country/region and product. These regional results could not directly be incorporated into the ATM because the software does not allow for regional characteristics in terms of elasticities. The ATM uses different income groups than the GTM.

The short-term demand function is shifted over time by the following equation:

$$\mathrm{DN} = \mathrm{a} * (\mathrm{BIPK}') + \mathrm{c} * 100 + \mathrm{BEV}' \tag{1}$$

where DN=shift of demand curve (%); a= income elasticity; BIPK'=per capita income growth (%); c * 100=technological trend (%); BEV'= population growth (%).

The original income elasticities and time-trend values again reflect that they are based on pooled cross-section/time-series data. The weight of cross-section data as compared to the length of the times series made it appear to Wibe (1984) that technological trends can be neglected, except for coniferous sawnwood in industrialized countries (negative trend). Thus the original GTM does not provide for the implementation of a technological trend in general, but uses the following simplified equation to shift the demand curve over time:

$$\mathrm{DN} = \mathrm{a} * (\mathrm{BIPK}') + \mathrm{BEV}' \tag{2}$$

The econometric estimations of technological trends based on time series alone turned out to be significant (Schwarzbauer 1987, 1988). A trick had to be found to incorporate them into the model, despite the fact that the software does not directly provide for it. The problem was solved by the calculation of a "reduced" income elasticity, incorporating both the estimated income elasticities and the estimated time trends. The original shifting function (1) was reformulated:

$$\mathrm{DN} = \mathrm{a} * (\mathrm{BIPK}') + \{\mathrm{c} * 100 * (\mathrm{BIPK}')/\mathrm{BIPK}'\} + \mathrm{BEV}' \tag{3}$$

and

$$\mathrm{DN} = (\mathrm{a} + \mathrm{c} * 100/\mathrm{BIPK}') * \mathrm{BIPK}' + \mathrm{BEV}' \tag{4}$$

The term $(\mathrm{a} + \mathrm{c} * 100/\mathrm{BIPK}')$ now is the reduced income elasticity a' which can be put into (2) instead of a.

This "reduced" or "long-run" income elasticity is also a function of economic growth. Thus, for each assumption on economic growth a new set of income elasticities has to be calculated. The calculations for the base scenario are based on the assumptions that any trend will become nil in 2030 and thus only half the value of c has to be taken for calculating a'. The other consideration is economic growth which, given a certain starting value, is also changing over time in relation to the absolute level of per capita income. BIPK' goes down over time with increasing BIPK. For getting the reduced income elasticities, BIPK' was taken as the average between the starting value in 1980 and the value it has in 2030.

3.1.4 Production costs and production capacity

The cost data for the ATM were largely taken from the original GTM, with some additional information from Austrian sources (e.g. for sawnwood, see Deringer 1986). The figures were used as a "starting point" and changed later during the calibration process. The ATM implements only two types of capacities: "existing" and "new". Information on production levels and capacities was obtained primarily from various international statistics (e.g. ECE/FAO 1984, 1985, 1987b; FAO 1981).

3.1.5 Technological coefficients

Conversion factors for 1980 were taken from various published sources (Institut für Forst- und Holzwirtschaftspolitik 1970; ECE/FAO 1982, 1987a) and, especially for paper and pulp, from the original GTM. Again these data served as starting points and were changed during calibration.

3.1.6 Transportation costs

Beside other distances due to different regional aggregation, few differences in transportation costs exist between the ATM and the GTM. For both models the same transportation cost functions (Wisdom 1987) are used. Reflecting differences in product aggregation between the two models, the GTM parameters for white pulp are used in the ATM for chemical and mechanical pulp, and the ATM parameters of the two paper products are averages of the four original paper products.

3.1.7 Trade flows

Significant differences exist between the GTM and the ATM in the handling of trade flows. The GTM expresses international trade (or rather "interregional trade" (see Kornai 1987)) through bilateral trade flows. The formulation of these trade flows is based on the theory of perfect competition and on totally homogeneous products. Under these assumptions, one of two bilateral trade flows must be automatically unprofitable. One possibility to avoid this problem is to net out bilateral trade flows and let only unilateral trade flows represent trade in the model (see e.g. Bigsby and Kornai 1987; Kornai and Schwarzbauer 1987; Weeks 1987). Beyond that, the problem of indirect trade flows still exists.

The ATM has a netting procedure using simple subroutines. Concerning a certain product, a region is either a net importer or a net exporter. The number of original trade flows could be reduced by 75% from 650 to 166. Matrix density fell from 57% to 15%. To prevent total isolation of regions, in cases where there would not be any import or export flow after netting, some artificial trade channels (with quantity zero in the base year) have been introduced. These artificial zero-trade-flows are allowed to develop into actual trade flows over time.

As in the GTM, fuelwood is treated as a non-traded product in the ATM. Thus, only 13 of the 14 products appear in the trade matrix. The trade flow dynamics in the ATM are handled similar to the GTM. In all regions the lower bounds have been set to 0.8 of the existing or previous trade flow, the upper bounds to 1.4. To allow proper reactions to the comparatively large population and income growth in the region "Rest of the World", the upper bounds have been set to 2.0. Tariffs have been implemented the same way as in the original GTM.

3.1.8 Centrally planned economies

Structurally, there is no difference in the centrally planned economies (CPE) as compared to the GTM. The ATM deviates from the GTM in the number of CPE-regions and in some data. The international trade in forest products between market economies has a large share in world trade. A special situation exists for Austria in that Czechoslovakia is the most important eastern trade partner in forest products. The ATM recognizes two CPE-regions: the CSFR and the "Rest of Eastern Europe & USSR". The marginal size of Czechoslovakia created severe implementation problems. While "Rest of Eastern Europe & USSR" is defined analogous to the USSR of the GTM, the CSFR is treated as a regular market economy in the ATM. The dynamics of the CPE-region were handled exactly the same way as for the USSR in the GTM, but the data were somewhat different.

Table 16: Gross income of the forest sector in 1980 and 2030 in Mill. US $ (1980 values) by regions in the base scenario.

Region	1980	Forest Industry Share, in %	2030	Forest Industry Share, in %	Changes 2030–1980 in %
Austria	4,012	(73)	9,262	(76)	+ 131
West Germany	12,002	(78)	18,630	(83)	+ 55
Italy	6,027	(90)	8,509	(90)	+ 41
Scandinavia	27,473	(72)	48,848	(75)	+ 78
Rest of Western Europe	30,175	(73)	43,898	(84)	+ 45
Western Europe Total	79,689	(75)	129,147	(80)	+ 62
Austrian share (%)	5.0		7.2		+ 42
Czechoslovakia	3,276	(68)	7,985	(74)	+ 141
Rest of Eastern Europe & USSR	55,819	(69)	108,531	(68)	+ 94
North America	138,547	(74)	241,333	(79)	+ 74
Rest of the World	134,456	(63)	490,389	(74)	+ 265
World total	411,787	(70)	977,385	(76)	+ 137
Austrian share (%)	1.0		0.9		– 2.7

3.2 The base scenario

Assumptions on model dynamics are analogous to those of the GTM, but differences occur due to aggregation and calibration processes. In addition, the substitution of coniferous with non-coniferous materials in processes using both has not been implemented in the base scenario.

Any ATM run provides a large amount of results, more than 6,000 different numbers, only a small part of which can be presented here. The presentation is divided into global developments and specific Austrian features. Because of the importance of the base scenario as a standard setter, the base scenario results will be given more space than the results of scenario variations.

3.2.1 Forest product production and consumption

General and global trends

Worldwide gross income increases by 137% between 1980 and 2030. The regions with the highest growth are "Rest of the World", CSFR and Austria. The growth of the sector in the other developed regions is much lower. Within the forest sector, the share of the forest industry increases from 70% (1980) to 76% (2030) worldwide, in the "Rest of the World" from 63% to 74%. "Rest of the World" becomes the "driving region" in terms of increases (Table 16). The main reasons for this development lie in the specific features of that region: high growth rates for population and income, high income elasticities, plantations of coniferous forests.

Production and consumption of non-coniferous pulpwood grows most of all roundwoods, while non-coniferous logs show the lowest increase (Table 17). This reflects two different developments. The increase in pulpwood is a reaction to the increased demand for that product in the forest industries due to relatively high income elasticities of pulpwood-based products as compared to the income elasticities of products based on non-coniferous logs. On the other hand, there is a decrease of non-coniferous log supply in the "Rest of the World" because of deforestation. Negative income elasticities for fuelwood and the loss of considerable portions of the tropical rainforest result in a decrease of production and consumption of this product. Recycled paper shows the highest increase of all products.

Table 17: Production of forest products in Austria and World in the base scenario. Data are 2030 figures as percentage changes to 1980 data.

	Production	
Product	World	Austria
Coniferous logs	+ 42	+ 20
Non-coniferous logs	+ 16	+ 12
Coniferous pulpwood	+ 42	+ 55
Non-coniferous pulpwood	+ 88	+ 5
Fuelwood	− 23	− 41
Recycled paper	+ 217	+ 91
Mechanical pulp	+ 41	+ 97
Chemical pulp	+ 50	+ 45
Coniferous sawnwood	+ 59	+ 5
Non-coniferous sawnwood	+ 4	− 28
Solidwood panels (veneer and plywood)	+ 77	± 0
Reconstituted panels (particle- and fiberboard)	+ 165	+ 199
Newsprint, printing and writing paper	+ 187	+ 64
Other paper and board	+ 98	+ 216

Among the final products, the growth rates for both sawnwoods are lower than the others. The main reason that there is at all an increase for coniferous sawnwood is the increased demand and supply in the "Rest of the World", while other regions even face declines. Again these developments, along with those for solidwood panels, reflect the relatively low income elasticities. The big increase for reconstituted panels and the paper products is partly a response to higher income elasticities, partly due to a higher supply of raw materials (pulpwood for the panels, recycled paper for the paper products).

Austrian trends

While production of coniferous sawnwood and solidwood panels is very stable over time, fuelwood and non-coniferous sawnwood undergo a substantial reduction. Production of all other final products increases considerably. Due to demand growth in the region "Rest of the World", Austrian production of most products increases more than domestic consumption.

The reactions of intermediate products do not always reflect the development of the corresponding final products. This is partly a result of changing foreign trade patterns as well as changes in technological development. Coniferous log production, for example, increases much more than that of coniferous sawnwood because imports decline over time and the technological development (conversion factor) requires more sawlogs for sawnwood production. Recycled paper production is not exeeding pulp production so much as in the world average, which is partly a result of the abundance of pulpwood. However, non-coniferous pulpwood is increasingly imported, but production remains at the level of 1980.

3.2.2 Forest product prices

General and global trends

Growing demand in the region "Rest of the World" leads to significant price increases in this region for almost all products. Because this region is a net importer and by its demand is affecting world trade, most product prices in most other regions increase accordingly. The model allows for some insight into the main reasons for price increases:

(1) Demand is increasing faster than supply (restriction by forest resource and timber supply curves). In technical terms, demand curves are shifted more to the right than supply curves, which results in a higher price.

(2) Demand of most forest products is formulated as being inelastic to price changes (price elasticity). A "steep" (inelastic) demand curve, shifted by a certain percentage to the right, always results in a higher product price than a "flat" (elastic) demand curve, shifted by the same percentage.

Generally, price increases of non-coniferous pulpwood are the highest of all products. This reflects declining supply (deforestation) and also production growth of products, which are at least partly based on non-coniferous pulpwood (chemical pulp, reconstituted panels). The price decrease for coniferous pulpwood in "Rest of the World" gives an insight into how the inter-relationships of forest products are handled in the model. Fuelwood consumption in that region goes down much less than in the other regions (due to variations in income elasticities, and income and population growth). A considerable amount of coniferous pulpwood is used as fuelwood (in such a case the model applies the same price to coniferous pulpwood as to fuelwood). Thus, the price for coniferous pulpwood declines. On the other hand, it is much more profitable to use non-coniferous pulpwood (as such) in producing final goods than to use it as fuelwood, so the price increases. Most developed countries experience stronger price increases for pulpwood than for logs, which again reflects the fact that final products based on pulpwood have a higher income elasticity than those based on logs.

Austrian trends

Over time Austria loses competitiveness of its exports, especially as compared to Eastern Europe. Austria gains some competitiveness concerning exports of coniferous sawnwood and other paper and paperboard in relation to the region "Rest of the World".

3.2.3 International trade in forest products

General and global trends

The changes in international trade over time are much more drastic than those of production (Table 18). The main reason for that development is again the demand growth in "Rest of the World", which leads to increasing trade flows from "developed regions" into the "developing region". Trade flows of products, in which "Rest of the World" is a net exporter (non-coniferous products) do not change much or undergo a substantial decline. This is a reaction both to the increased regional demand (it is more profitable to sell the product in the region than to export it) as well as to deforestation in that region. Most of the big trade flows have their origin in North America, and those of coniferous sawnwood and reconstituted panels also in Scandinavia and "Rest of Eastern Europe & USSR".

Excluding the region "Rest of World" and thus concentrating on the trade between "developed countries", an interesting pattern can be observed. Trade flows of "low-cost" products like roundwood and coniferous sawnwood decline over time, while those of "high-cost" products like panels, paper, and recycled paper increase substantially. This development partly reflects the fact that high transportation costs relative to product prices reduce profitability of trade.

Austrian trends

Austrian trade in forest products shows a differentiated development. Log products and final products based on logs (sawnwood and solidwood panels) undergo a decline or only a slight increase, while pulpwood and products based on pulpwood as well as recycled paper are increasingly traded. Especially important for Austrian trade in final products is the increasing share

Table 18: World trade of forest products in the base scenario. Data are Mill. m^3 or tons and changes are 2030–1980 in %.

Product	Volumes Traded 1980	2000	2030	2030–1980 (%)
Coniferous logs	17.5	23.0	59.9	+ 241
Non-coniferous logs	4.9	1.9	0.7	– 85
Coniferous pulpwood	12.5	6.5	5.1	– 59
Non-coniferous pulpwood	8.2	10.8	24.8	+ 202
Recycled paper	3.0	6.5	13.0	+ 335
Mechanical pulp	0.6	4.5	7.1	+ 1144
Chemical pulp	10.4	13.3	17.1	+ 64
Coniferous sawnwood	28.1	48.7	91.5	+ 226
Non-coniferous sawnwood	3.2	3.9	3.5	+ 9
Solidwood panels (veneer and plywood)	2.3	1.7	2.2	– 4
Reconstituted panels (particle- and fiberboard)	2.0	7.4	21.1	+ 965
Newsprint, printing and writing paper	8.6	6.5	8.4	– 3
Other paper and board	7.5	6.2	19.2	+ 157

of exports to the "Rest of the World". In the case of coniferous sawnwood, reconstituted panels and other paper and paperboard, the profitability to trade with this region becomes so high that domestic consumption has to go down in order to cover the exports. Increases in production of pulpwood-based products in connection with the inelastic supply from Austrian forests lead to substantial increases in pulpwood imports. For the same reason, exports of chemical pulp decrease to fulfil the domestic need for paper production.

3.2.4 Timber removals and forest resources

General and global trends

World removals go up by 6% between 1980 and 2030 (Table 19). It is interesting to differentiate removals by "developed" and "developing" regions and by "coniferous" and "non-coniferous". Harvests in industrialized countries increase by 22%, while Third World harvests decline by 8%. Due to assumed investments in coniferous plantations in "Rest of World" and to deforestation affecting only non-coniferous resources, worldwide coniferous removals go up by 43% and non-coniferous down by 19%.

Compared to the changes in production and consumption, a global increase in removals of 6% is not very much. The main reasons for this moderate rate, besides deforestation in the tropical rainforests, are:

(1) Technological development (target conversion factors), which leads to a more efficient use of rawmaterials;
(2) Increased use of recycled paper instead of pulp; and
(3) Decrease of fuelwood consumption.

The development of forest resources is similar to that of removals. Mainly through deforestation, growing stock goes down worldwide by 23%. It has increased, though, in most "developed" regions. Coniferous plantations have especially contributed to the increase of coniferous growing stock by 10%. The worldwide reduction of forest area by 18% is the result of deforestation only.

Table 19: Timber harvests by region in the base scenario. Data are Mill. m^3 and changes are 2030–1980 in %.

	1980			2030			2030–1980 (%)		
Region	conif.	non-conif.	total	conif.	non-conif.	total	conif.	non-conif.	total
Austria	12	2	14	17	3	20	+ 42	+50	+43
West Germany	21	9	30	24	10	34	+ 14	+11	+13
Italy	1	6	7	1	8	9	± 0	+33	+29
Scandinavia	89	18	107	103	25	128	+ 16	+39	+20
Rest of Western Europe	57	51	108	64	53	117	+ 12	+ 4	+ 8
Czechoslovakia	13	5	18	18	7	25	+ 38	+40	+39
Rest of Eastern Europe & USSR	317	91	408	374	131	505	+ 18	+44	+24
North America	390	161	551	427	255	682	+ 9	+58	+24
Rest of the World	218	1,307	1,525	567	842	1,409	+160	−36	− 8
World	1,118	1,650	2,768	1,595	1,334	2,929	+ 43	−19	+ 6
World (excluding Rest of the World)	900	343	1,243	1,028	492	1,520	+ 14	+43	+22

Austrian trends

Austrian removals increase by 43% between 1980 and 2030 with similar rates for coniferous and non-coniferous harvests. The moderate increase in production of log-based products leads to a comparatively moderate increase of final cuts (+18%), while thinnings more than double due to the pulpwood demand of the panel and paper industries.

Austrian growth rates in removals are higher than in most other regions. This is a result of increasing growing stock (shift of the supply curve to the right), which is also – unlike in other regions – affected by the exogenous assumption of substantial afforestation. In 2030 the Austrian forest area has grown by 250,000 hectares or 8% as compared to 1980.

3.3 Scenario variations

The main interest in scenario runs lies in the deviations from the base scenario, not so much in absolute numbers. The following variations are all based on the change of one parameter or one group of related parameters to sort out the specific impacts of these assumptions.

3.3.1 Economic growth variations

In the low-growth scenario, economic growth rates (starting values) were set 50% lower than in the base scenario. In the high-growth scenario, all starting values were doubled.

General and global developments

Regional differences in forest-sector incomes are bigger for the high-growth scenario than for the low-growth scenario (Table 20). "Rest of the World" reacts strongest of all regions in both directions of variations. The main reasons are:

(1) By doubling the starting values for economic growth, the disparity between these growth rates increases.

Table 20: Gross income of the forest sector in 2030 by region for high and low economic growth rates. Data are percentage differences between the growth rate scenarios and the base scenario.

Region	Changes in % to Base Scenario High	Low
Austria	+ 95	−27
West Germany	+159	−26
Italy	+ 86	−33
Scandinavia	+ 99	−30
Rest of Western Europe	+ 98	−20
Czechoslovakia	+ 98	−38
Rest of Eastern Europe & USSR	+ 60	−18
North America	+120	−25
Rest of the World	+201	−37
World	+152	−30
Austrian share	− 64.3%	+11.0%

(2) The regions with higher growth rates are lower income regions (in absolute terms) with higher income elasticities.

World production changes for most products are lower than those for gross income in both directions. Because of inelastic income elasticities, demand and supply do not fully follow the income development. Demand curves are shifted (due to income changes) more than supply curves, thus resulting in price changes. Price changes have more impact on the gross income than do production changes.

The results demonstrate the advantage of using the ATM over less-complex models, namely the interrelationships between products. In simple one-product one-equation forecasts, a higher economic growth rate would never result in a consumption decline, which is the case with sawnwood products. Because of higher income elasticities for products based on pulpwood, a significant amount of logs is converted to pulpwood to cover the demand for that raw material. Fewer logs are available for producing sawnwood. Coniferous logs worldwide increase only by 10% in the high-growth scenario.

International trade follows a similar pattern as production in that the high-growth scenario leads to bigger trade volumes (a significant amount is trade into the "Rest of the World"), whereas low growth results in a decline. A special case is world trade of coniferous sawnwood which goes up by 2% in the low-growth scenario. Again, product conversion is involved. In "Rest of the World", demand for pulpwood makes it necessary to convert logs partly into pulpwood. Demand for coniferous roundwood cannot be met anymore, sawnwood production goes down, and imports go up.

Both growth variations show an increase in removals compared to the base scenario. In the case of the high-growth scenario, this is a result of a higher demand for industrial roundwood, whereas in the low-growth scenario, it is a result of a higher demand for fuelwood (negative income elasticity).

Austrian trends

Austria's responses to variations in income growth are more moderate than worldwide reactions which are heavily affected by the "Third World" developments. While gross income is higher with the high-growth scenario and lower with the low-growth scenario, Austria's share of worldwide profits declines in the first case and increases in the second.

With the exception of reconstituted panels and newsprint, printing and writing papers in the low-growth case, Austrian production of final products reacts much less to income changes than world averages. An interesting phenomenon is that despite lower economic growth, production of non-coniferous roundwood increases. This is the result of the tremendous rise in fuelwood production, which mostly affects non-coniferous cuts.

3.3.2 Forest decline scenario

This scenario is based on the same concepts as the "Acid Rain" scenario of Dykstra and Kallio (1987). Some minor modifications were made concerning affected regions, shift of the supply curves and the starting point for forest decline:

(1) Only North America and "Rest of the World" were treated as non-affected.

(2) Between 1990 and 2000, removals increase due to sanitation fellings. This is done in the model by shifting the timber-supply curves in the affected regions to the right by 40%. Sanitation fellings result in a reduction of "normal" fellings. It is assumed that by 2000 the period of sanitation fellings is over. The supply curve is exogenously shifted back and is shifted only endogenously after 2000.

(3) Starting with 1990, annual forest growth is decreased by one-third in the affected regions. Thus growing stock is declining as compared to the base scenario, shifting the supply curves to the left.

"Rest of Eastern Europe & USSR" removals are treated differently and exogenously. Timber harvests increase by 4% in 1990 and gradually go back to the level of 1980 by 2030.

General and global trends

Affected regions, with the exception of "Rest of Eastern Europe & USSR", react with higher removals in 1995 (Table 21). Eastern Europe already shows a decline (due to an exogenous formulation), thus resulting in an overall increase in all affected regions of only 1%. Non-affected regions reduce timber harvests slightly by 1%. By 2030 all affected regions experience a reduction. North America and "Rest of the World" slightly increase their removals, so that total world removals in 2030 are only 5% below the base scenario.

World growing stock in 2030 is 8% below the base scenario, growing stock in affected regions is 22% below, and in non-affected regions 1% lower. The latter is the result of removal increases in order to compensate the loss in the affected regions.

The development of gross income shows that forest decline does not necessarily mean a loss in profits (Table 22). In 2030, worldwide gross income is 3% higher than in the base scenario. Especially high profits have affected regions with an important forest sector, like Austria, Scandinavia and CSFR. The main explanation for higher profits despite considerably lower production can be given with the price elasticities of final products. Forest-product demand reacts inelastically to price changes. Shifts of the timber-supply curves to the left result in price increases. Because of the steep demand curves (inelastic), prices go up much more than production goes down. Thus, the forest sectors in affected regions do produce less than in the base scenario but at considerably higher prices. Forest decline has an impact on world markets in that non-affected regions produce more timber. Because they can only compensate part of the production loss in the affected regions, the prices in non-affected regions do not go down (despite higher supply) but remain within the same range as in the base scenario. More production at the same price levels means higher profits for non-affected regions too (+10%).

Roundwood prices react stronger to forest decline than prices of final products because roundwood is only a part of the costs in final products. By 2030 the share of forestry in the gross income of the entire forest sector is higher than in the base scenario.

Reconstituted panels face the highest worldwide reduction of all products (–10%), the reason being that non-affected regions have a relatively small market share in that product (Table 23). Trade increases occur through expanding trade flows from non-affected to affected regions. Trade reductions happen for products where affected regions have an important market share; trade declines because production goes down. Because of raw-material scarcity in important forest

Table 21: Removals by region for the forest-decline scenario. Data are percentage differences between the forest-decline and the base scenario.

Region	1995	2030
Austria	+21	−20
West Germany	+ 6	−38
Italy	+13	−33
Scandinavia	+14	−30
Rest of Western Europe	+10	−40
Czechoslovakia	+11	− 4
Rest of Eastern Europe & USSR	− 7	−21
North America	− 2	+ 9
Rest of the World	± 0	+ 1
World	± 0	− 5
Affected regions	+ 1	−25
Non-affected regions	− 1	+ 4

Table 22: Gross income of the forest sector in 2030 by regions for the forest-decline scenario. Data are percentage differences between the forest-decline and the base scenario.

Region	Changes in % to Base Scenario
Austria	+12
West Germany	+ 1
Italy	− 5
Scandinavia	+14
Rest of Western Europe	− 4
Czechoslovakia	+20
Rest of Eastern Europe & USSR	− 4
North America	+10
Rest of the World	+ 2
World	+ 3
Austrian share	+11
Affected regions	+ 1
Non-affected regions	+ 4

sector regions and because of almost unchanged consumption patterns for final products, trade volumes for roundwood increase significantly more than trade volumes for final products. Scandinavia plays an interesting part in paper products. After a period of lower production, this region starts importing high quantities of pulpwood and mechanical pulp, reduces its chemical pulp exports, and increases paper production again.

Austrian trends

Because Austrian removals are reduced less than increment goes down, growing stock in 2030 is 42% below the base scenario. Sanitation fellings cause removals to go up 21% above the base scenario in 1995. After that they fall gradually to 20% below the base values in 2030. During the period of excess supply of roundwood, imports go down. In the period of raw-material scarcity, log imports especially show a dramatic increase. These imports have their origin in North America and partly in Eastern Europe. Because of the high pulpwood imports in Scandinavia, Austrian imports either go down or increase only slightly. With the exception

Table 23: World production/consumption and trade by products in 2030 for the forest-decline scenario. Data are percentage differences between the forest-decline and the base scenario.

Product	Production	Trade
Coniferous logs	– 5	+ 12
Non-coniferous logs	– 3	+ 505
Coniferous pulpwood	– 4	+ 286
Non-coniferous pulpwood	– 2	+ 16
Fuelwood	– 2	–
Mechanical pulp	– 1	– 29
Chemical pulp	± 0	+ 3
Coniferous sawnwood	– 5	– 16
Non-coniferous sawnwood	– 5	+ 60
Solidwood panels (veneer and plywood)	– 2	– 42
Reconstituted panels (particle- and fiberboard)	– 10	± 0
Newsprint, printing and writing paper	– 1	+ 30
Other paper and board	± 0	± 0

of solidwood panels and newsprint, and printing and writing paper, reductions in production of final products are less than for roundwood.

With the exception of recycled paper, all products face a price reduction in the period of excess supply, and the reductions of roundwood prices are higher than those for final products. Prices do not react so homogeneously in the period of raw-material scarcity. Austrian prices follow world market prices. For non-coniferous logs and sawnwood as well as solidwood panels, where the non-affected regions have a big market share, prices fall or increase only slightly. Because of restructuring paper production (based on the import of raw materials), Scandinavia can stabilize and partly increase paper production and thus reduce prices.

Because the range of price changes is larger than that of production, Austrian-forest-sector gross income mainly follows the price development. In the period of excess supply, income is lower, and in times of scarcity higher, than that of the base scenario.

3.3.3 Exchange rate variations

Although trade is a fundamental part of the ATM, and exchange rates play a vital role in international trade (which would make this type of model an excellent tool for testing the impact of relative currency changes), exchange-rate variations could not be implemented successfully because of a specification problem. Therefore, it is necessary to discuss the modelling technology for handling exchange rates and its underlying assumptions.

Exchange rate variations in the model are based on the theory of spatial equilibrium (see e.g. Takayama and Labys 1986). If, for example, the currency in region 2 (Figure 1) gets stronger relative to the currency in region 1, the supply and demand curves of region 1 will be shifted down along the price axis. The new equilibrium point is at the same quantity (x1), but at a lower price (p1′). The curves of region 2 with the stronger currency will remain in position. Thus the profitability of exports from region 1 to region 2 will increase.

Although interrelationships of 9 regions and 13 traded products make the ATM more complicated, the situation should be basically the same as in Figure 1. Exporters generally profit from strong currencies in importing regions.

The core of the exchange-rate variations in the GTM and ATM is the shift of supply and demand curves in all regions relative to North America. North American curves remain in their

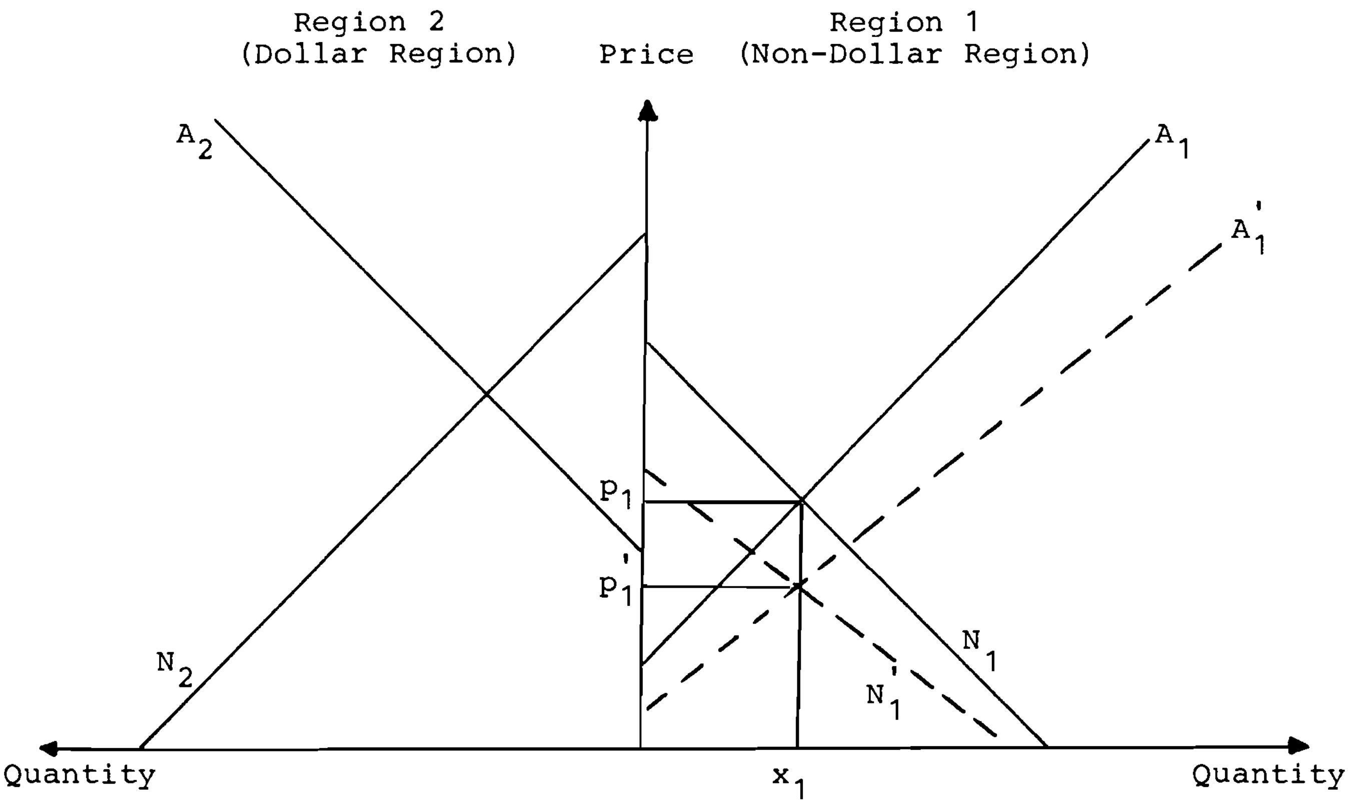

Figure 1: Shift of demand and supply curves in a "non-dollar" region (region 1) as a reaction to a stronger dollar in region 2.

position, because all prices are measured in real US $ (1980). Exchange-rate variations only affect "non-dollar" regions.

Two variations are tested with the ATM:

(1) *Strong Dollar*: This means a downward shift of supply and demand curves relative to the base scenario in all "non-dollar" regions, starting with 1990. The magnitude of the shift is the same as in the GTM.

(2) *Weak Dollar*: This means an upward shift of supply and demand curves relative to the base scenario in all "non-dollar" regions, starting with 1990.

Upward and downward shifts in the ATM do not follow the concept outlined in Figure 1, but are modelled as in Figure 2. Because the GTM/ATM software does not provide for the inclusion of transportation and investments costs – as a part of the supply side – in the shifting process (Kallio 1987; Wisdom 1987), demand curves react stronger (in both directions) than supply curves (Cardellichio and Adams 1988). Especially on trade routes with long distances, transportation costs constitute a large share of prices and thus cause the lesser shift of supply curves. As can be seen from Figure 2 the equilibrium point in region 1 is not shifted up and down along the price axis, but rather to the left and right. Higher profitabilty of region 1 in export with a strong dollar in region 2 is thus unintentionally compensated by lower production. A weaker dollar works the opposite way.

Selected results from ATM runs with the implemented assumption on exchange rates (Table 24) demonstrate that there is not only some compensation due to the different shifts of supply and demand curves, but sometimes overcompensation. The main reason for a "wrong" behavior is mainly a result of the fact that the relative changes to the US $ in the various regions have a different magnitude, thus creating a totally new spectrum of price relationships among "non-dollar" regions themselves (Dykstra and Kallio 1987). This argument is certainly correct. To check whether the "wrong" behavior in the ATM is mainly due to new price relationships between "non-dollar" regions or mainly due to different shifts of the demand and supply curves,

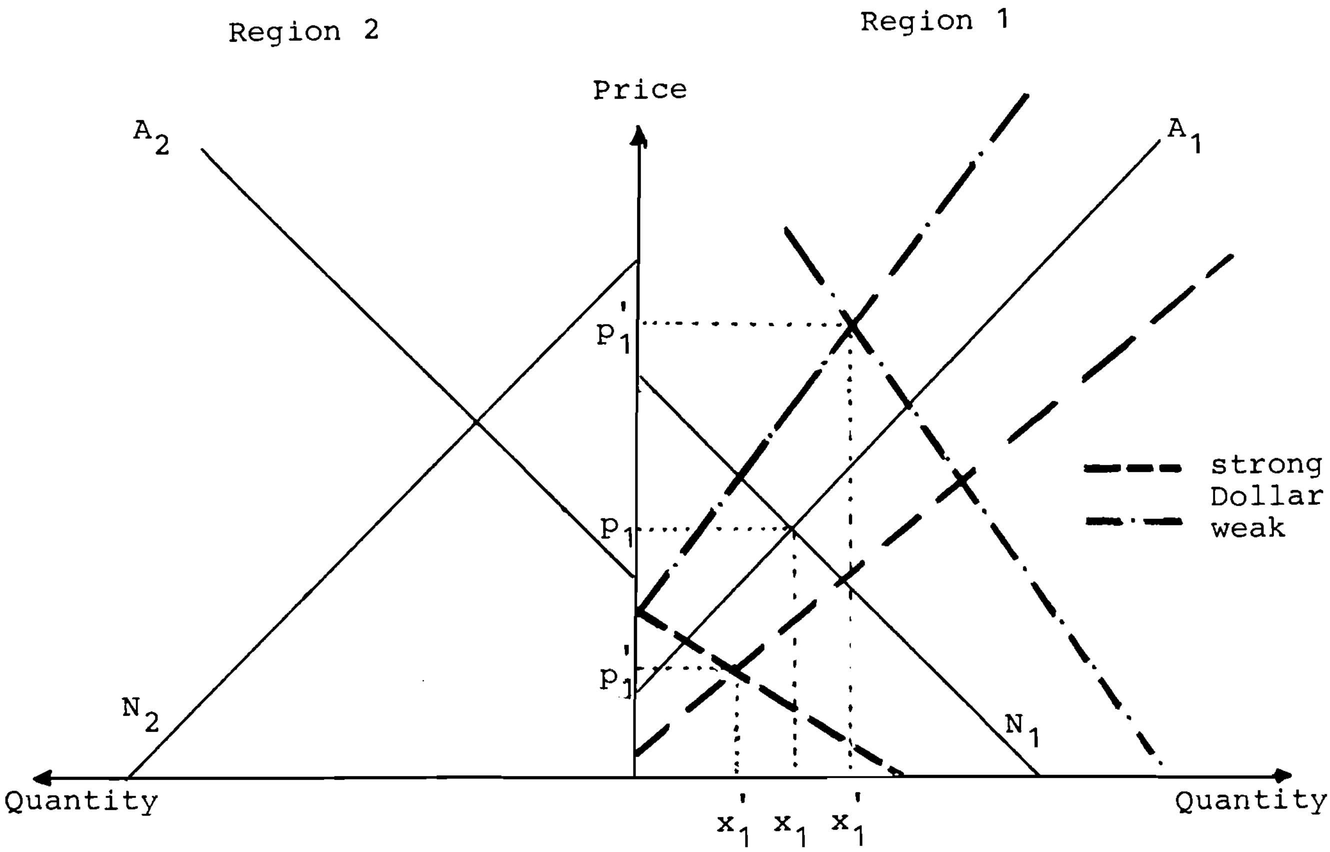

Figure 2: Shift of demand and supply curves in a "non-dollar" region (region 1) as a reaction to exchange-rate fluctuations as handled in the ATM.

Table 24: Selected results of runs with exchange-rate fluctuations in the exchange-rate scenario, variant 1. Data are percentage differences between exchange-rate scenarios and the base scenario.

	Strong Dollar		Weak Dollar	
Product	1990	2030	1990	2030
Austria				
coniferous sawnwood	− 2	− 13	+2	+ 6
reconstituted panels (particle- and fiberboard)	− 19	− 31	±0	+ 25
newsprint, printing and writing paper	− 8	− 27	+5	+ 20
North America				
coniferous sawnwood	− 4	− 3	+3	+ 2
reconstituted panels (particle- and fiberboard)	+ 1	+ 1	−1	− 1
newsprint, printing and writing paper	± 0	− 1	±0	+ 1

a second variant with modifed assumptions on exchange-rate fluctuations was tested. In that test, the shift was not undertaken in the "non-dollar" regions relative to North America but only in North America. The supply and demand curves in the other regions remain in the same position as in the base scenario. A strong dollar in this case means an upward shift of the curves in North America, and a weak dollar a downward shift.

The following conclusions from both variants can be drawn:

(1) The deviations from the base scenario are not primarily a function of relative price differences but depend on which region(s) is (are) shifted. If the curves in "non-dollar" regions are shifted and those in North America remain in the same position as in the base scenario (variant 1), only minor deviations occur in North America, but major changes take place in the other regions (mostly in the "wrong" direction). When the "non-dollar" regions are held constant and only the curves in North America are shifted, the deviations are larger in North America (also in the "wrong" direction). This is an indication that the compensation process due to the dissimilar shift of supply and demand curves has more impact on model results than relative price differences.

(2) The compensation problem cannot be solved by holding "non-dollar" regions constant and shifting only North America (variant 2). In both variants the deviations from the base scenario are more "correct" in the regions not shifted (the direction at least is correct, not necessarily the magnitude of the deviations).

This problem can only be solved by including investment and transportation costs in the shifts of the supply curves. For technical reasons this change could not be implemented in the current version of the ATM.

3.3.4 Roundwood import variations

Two simulation runs will be presented. One of them has an impact on world markets and is similar to the USSR timber exploitation scenario of Dykstra and Kallio (1987) ("Siberian scenario"), while the other has an influence on Austrian wood markets only ("import-stop scenario"). In the Siberian scenario, exogenous roundwood removals are assumed to increase more than in the base scenario (about one-third more). Austria is assumed to prevent any import of roundwood by 1990 in the import-stop scenario.

General and global trends

While in "Rest of Eastern Europe & USSR" production of both roundwood and final products in the Siberian scenario is about one-third above the base scenario in 2030, trade shows a different pattern. Roundwood exports are increasing more than those of final products, and imports of papers are not changing (Table 25). Consumption of coniferous sawnwood remains at the level of the base scenario, but consumption of all other final products rises.

Gross income in the other regions only slightly deviates from the base scenario. Most of the regions reduce their production somewhat. Prices remain relatively stable because the demand pattern for final products does not change very much.

Austrian trends

In terms of gross income, Austria is affected negatively by roundwood import variations. In the Siberian scenario, slightly lower prices cause lower profits (–3%), whereas in the import-stop scenario lower production is responsible for reduced profits (–11%). The latter scenario hardly affects world markets and thus Austrian prices also remain almost the same as in the base scenario.

Austrian forestry is not responding strongly to import changes in roundwood, which is mostly due to the inelastic timber-supply formulation. While import stops result in an increase of harvests only in the first phase of import stops (the main reason being existing capacities in the forest industries), the rise of imports from Siberia leads to lower removals only at the end of the projection horizon.

3.4 Model evaluation

Cardellichio and Adams (1988) argue that "it should be emphasized at the outset that the evaluation of a model of this scale is a subjective process. It is not possible to develop reasonable

Table 25: Production and trade in "Rest of Eastern Europe & USSR" for the Siberian scenario. Data are percentage differences between the Siberian and the base scenario.

	2000		2030	
Product	Production	Exp/Imp[a]	Production	Exp/Imp[a]
Coniferous logs	+16	+ 75	+32	+433
Non-coniferous logs	+14	+1363	+30	− 68
Coniferous pulpwood	+17	+ 85	+35	+446
Non-coniferous pulpwood	+18	+ 80	+36	+361
Fuelwood	± 0	–	± 0	–
Recycled paper	+ 7	− 49	+14	− 50
Mechanical pulp	+25	–	+30	–
Chemical pulp	+23	–	+30	–
Coniferous sawnwood	+15	+ 90	+30	+ 93
Non-coniferous sawnwood	+15	− 14	+30	− 20
Solidwood panels (veneer and plywood)	+15	− 30	+30	− 25
Reconstituted panels (particle- and fiberboard)	+15	+ 116	+30	+285
Newsprint, printing and writing paper	+15	± 0	+30	± 0
Other paper and board	+15	± 0	+30	± 0

[a]Exports for all products except paper products

statistical criteria to accept or reject the model, or to make precise statements regarding model validity". Cardellichio and Adams (1988) have undertaken an extensive evaluation of the GTM. Because of the similarities between the GTM and the ATM, almost all results of this evaluation are also true for the ATM or any GTM-type model. The following will therefore leave out the specific results of the Cardellichio and Adams (1988) study and will concentrate on one problem area only: comparison of ATM results with results of other studies and historical data.

3.4.1 Comparison of ATM results with results of other studies and historical data

ATM production in most cases is considerably lower than GTM production (Table 26). The main reason is the lower income elasticities implemented in the ATM (which include the time trend). Coniferous sawnwood is the only exception: ATM world production is higher mainly because of the significant increase in the Third World. In the formulation of the ATM, higher rates of new coniferous plantations are implemented than in the orginal GTM.

A comparison between ATM results and those of other studies must also be selective, because they differ in terms of regions and products (not counting the various methodological approaches). Although the task of comparison brings some insight into model accuracy, it should not be overemphasized. Again, most ATM quantities are lower than those of other studies (Table 27). There is a remarkable correspondence, however, with the study of Baudin (1988). While Baudin was using the same method as FAO, he implemented lower and decreasing growth rates over time, which made his exogenous assumptions very similar to those of the ATM.

For 1985, ATM figures can also be compared with historical data. ATM results, however, are not point data but rather period averages with 1985 in the center (see Cardellichio and Adams 1988). FAO-yearbook data currently end with 1986, so no accurate average can be produced. To reflect the long-term character somewhat, ATM results have been compared with averages of historical data 1982–1986 (Table 28).

Table 26: Production levels from the ATM and the GTM for selected products and regions in year 2000 for the base scenario. Data are in 1000 m^3 or tons.

Product	Model	World	Rest of Western Europe	North America
Coniferous sawnwood	GTM	380	75	120
	ATM	393	57	109
Reconstituted panels	GTM	102	35	23
(particle- and fiberboard)	ATM	94	33	21
Newsprint, printing	GTM	140	38	48
and writing paper	ATM	115	27	36
Other paper and board	GTM	150	34	65
	ATM	118	26	50

Table 27: Comparison of ATM world consumption of forest products in 2000 for the base scenario with results of other studies. Data are Mill. m^3 or tons.

Product	ATM	FAO[a]	FAO[b]	Baudin[c]
Industrial roundwood	1,743	2,085	1,706	–
Coniferous and non-coniferous sawnwood	522	542	578	497
Wood-based panels	156	225	202	175
Paper and paperboard	233	–	285	234

[a]FAO (1982)
[b]FAO (1986b), Chase-Manhattan Scenario
[c]Baudin (1988)

The correspondence of results on the global level can be considered satisfactory, while the regional results for some products differ significantly. In most cases the differences are due to the small size of the regions and to rounding errors.

4 A Simulation Model of the Austrian Forest Sector (FOHOW)

Technically speaking, FOHOW is a simulation model using the System-Dynamics (SD) language Dynamo. It is not a strict SD model because it is not a closed system and incorporates econometrically estimated parameters (for classical SD rules and criticism, see Sommer 1981).

4.1 Technical data

FOHOW was developed and installed on the Prime 9955-II of the computer-center of the University of Agriculture in Vienna. The model itself was written in a specific Prime-Dynamo version (Prime Computer 1973; Schwarzbauer 1984). Not counting the constants, FOHOW consists of ca. 800 equations, of which 60 are levels, 125 rates, 500 auxiliaries and 115 table functions. With the constants, FOHOW has more than 1,000 equations.

4.2 Model theory and model structure of FOHOW

Although FOHOW involves a totally different approach than the ATM, many mechanisms and relationships are implemented in FOHOW as well. This is especially true for those ATM-parts

Table 28: Comparison of ATM production of selected forest products in 1985 for the base scenario with data from the FAO Yearbooks (average 1982–1986). Data are Mill. m^3 or tons.

		Austria		World	
Product	Source	Absolute	Deviation from FAO	Absolute	Deviation from FAO
Coniferous logs	FAO	7.8		636.7	
	ATM	8.4	+ 8.7%	648.5	+1.9%
Non-coniferous logs	FAO	0.5		254.7	
	ATM	0.4	– 15.6%	278.2	+9.2%
Pulp	FAO	1.3		131.9	
	ATM	1.2	– 6.4%	133.7	+1.4%
Coniferous sawnwood	FAO	5.8		336.8	
	ATM	6.1	+ 4.3%	330.0	–2.0%
Non-coniferous sawnwood	FAO	0.2		112.9	
	ATM	0.4	+ 74.4%	118.6	+5.0%
Solidwood panels	FAO	0.02		44.4	
(veneer and plywood)	ATM	0.03	+ 21.0%	47.5%	+7.0%
Reconstituted panels	FAO	1.3		59.2	
(particle- and fiberboard)	ATM	1.3	+ 3.3%	60.8%	+2.7%
Newsprint, printing	FAO	1.0		75.4	
and writing paper	ATM	0.7	– 28.6%	77.3	+2.5%
Other paper and board	FAO	0.9		84.7	
	ATM	0.8	– 11.1%	85.4	–0.8%

which are not used for the optimization but for the updating between the periods, mainly shifting processes for the various curves.

For technical reasons, FOHOW was built as a national model. Although the product structure was made similar to that of the ATM, model size had to be reduced significantly because of capacity problems with the Dynamo compiler of the Prime. The reduction of model size means a reduced number of products.

Unlike the ATM, FOHOW runs start in 1965. This was done to be able to compare model performance and historical developments and thus make calibration easier. The model runs end in 2030.

Data are based on published information and econometric estimations (Schwarzbauer 1987, 1988, 1989). Implemented data sometimes differ from the original or estimated data because of calibration activities.

4.2.1 Regional and product aggregation

FOHOW consists of only two regions: Austria and one huge outside (competing) region which represents the aggregation of all Austrian trade partners in forest products (Figure 3). Because of the trade links to Austria, this competing region is represented by import and export equations. FOHOW also covers the entire forest sector, but with simpler product structure. The necessary reduction in the number of products mainly affects the paper industry, because this part of the forest sector would have required the highest number of equations due to the fact that the relationships of two roundwoods (coniferous and non-coniferous pulpwood – broken into wood from the forest and sawmill residues), two pulps (mechanical and chemical), recycled paper and

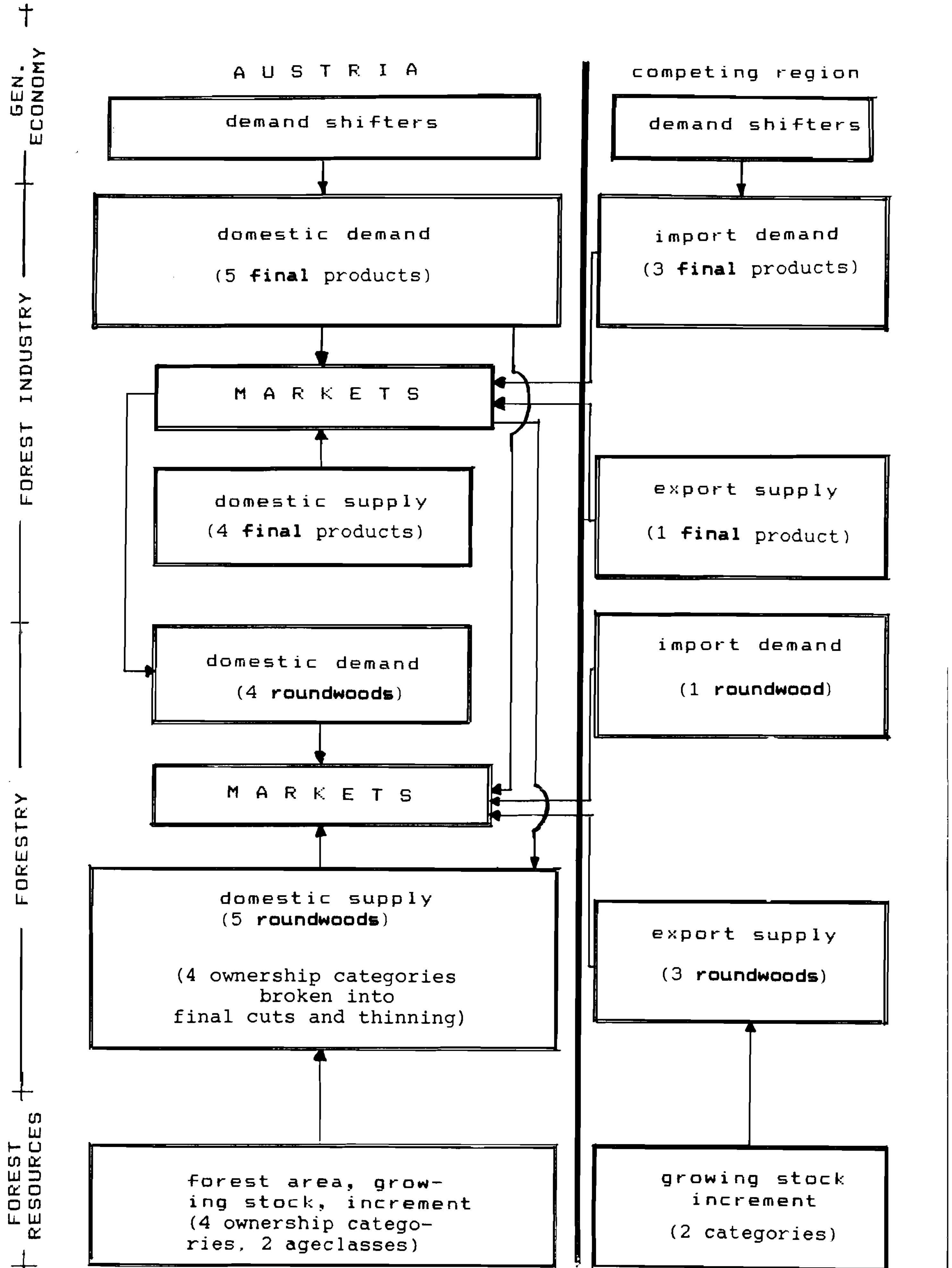

Figure 3: Outline of the FOHOW model structure.

two paper products would have to be considered. Recycled paper was left out, the pulps were modeled in roundwood equivalents (as if pulpwood would be the direct input for producing paper) and the two paper products were merged into one. The product group "solidwood panels" was neglected for the purpose of this modelling effort because of the very small share of roundwood consumption and production within the Austrian forest sector.

The following products are modeled in FOHOW (i=intermediate, f=final):

1 coniferous logs (i)
2 non-coniferous logs (i)
3 coniferous pulpwood (i) (incl. residues)
4 non-coniferous pulpwood (i) (incl. residues)
5 coniferous sawnwood (f)
6 non-coniferous sawnwood (f)
7 reconstituted panels (f)
8 paper and paperboard (f)
9 fuelwood (f) (incl. residues)
9a coniferous
9b non-coniferous

Depending on the activity, pulpwood and fuelwood are sometimes disaggregated. While the demand equation does not distinguish between coniferous and non-coniferous as well as fuelwood from the forest and fuelwood from residues, this breakdown has to be made in the production process.

4.2.2 The FOHOW modules

Considering the limited space here, the modules are discussed only generally. The mathematical formulation of model equations has been omitted (a copy of the full set of model equations can be produced upon request).

Many model parts are split into an historic period (1965–1985), in which exogenous variables are implemented with historic values (e.g. growth rates, costs, prices in competing region) and a projection period (1986–2030) with exogenous variables being assumptions. These exogenous assumptions are similar to those in the ATM. All monetary terms are expressed in real prices or costs based on 1975 Austrian Schillings.

General economy

Austria's general economy is represented in the model by population and population growth as well as GDP and GDP per capita growth. Population growth is strictly exogenous, whereas GDP growth in the projection period is dependent on the level of GDP itself (declining with higher GDP) with an exogenously given starting value in 1986.

Forest industries and forest-product markets

Supply, demand and prices only of "final" products are formulated. Potential demand is handled very similar to the ATM. A non-linear demand curve with a price/quantity relationship is shifted over time by demand shifters. However, two differences exist as compared with the ATM: the curves are non-linear and the shifters include the trend-factor (substitution effect) as a separate variable. Total potential demand for an Austrian forest product is calculated by adding potential export demand or subtracting potential import demand. Demand and supply of the outside region are represented by export and import equations. Domestic as well as foreign demand curves are shifted over time by population, GDP growth and time trend (substitution).

Potential supply is represented by a non-linear upward sloping supply curve with the existing capacity as an upper limit. The curve, again a price/quantity function, is shifted over time with the capacity. Total potential domestic supply is calculated by adding potential import demand or subtracting potential export supply.

The balance between potential demand and potential supply is determined with the product price. The mechanism to find actual supply (=actual demand) is based on lagged price information. Lagged prices instead of prices of the current period have to be used for two reasons.

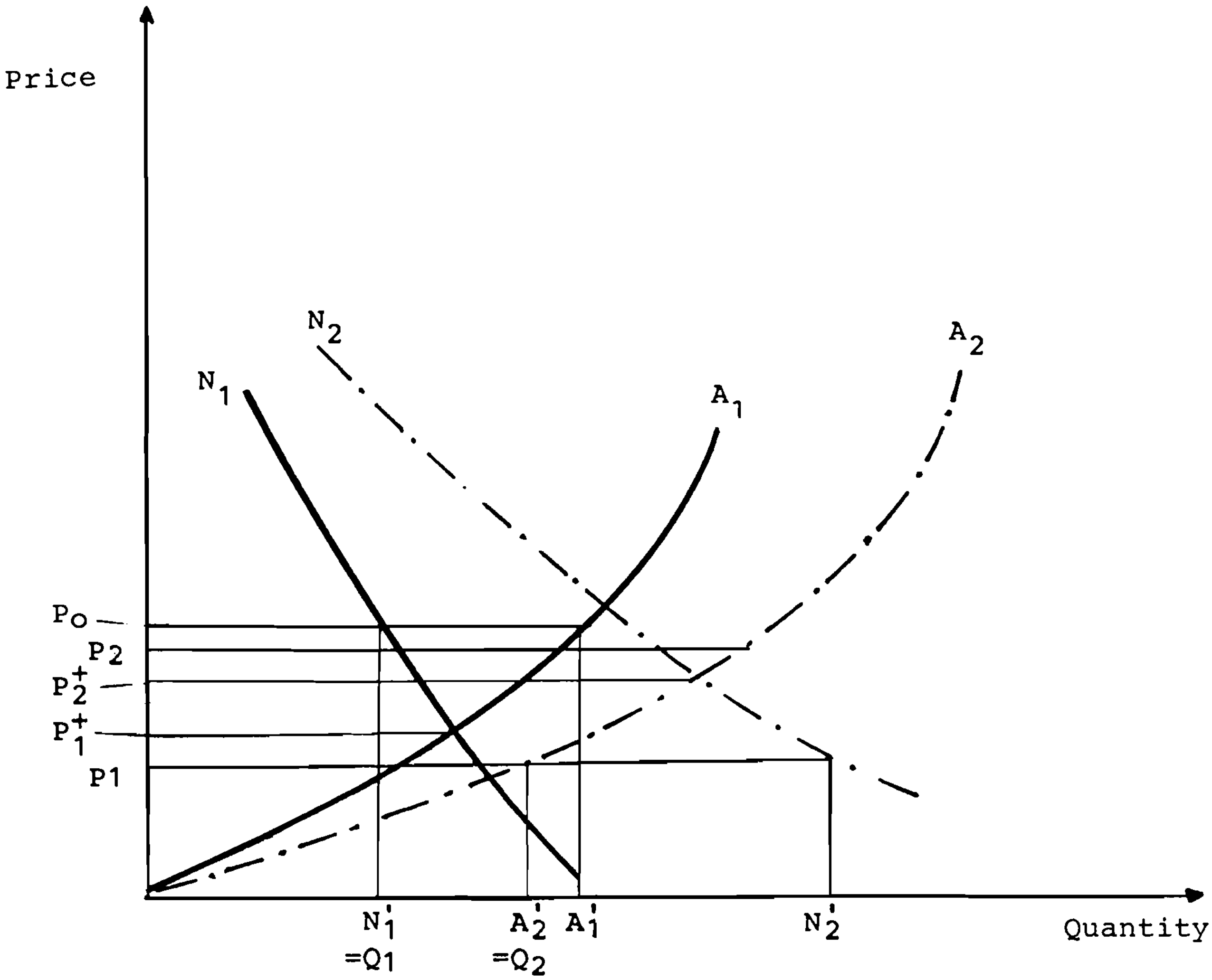

Figure 4: The mutual relationship between supply curve, demand curve, and product price.

Empirically, prices of the previous year proved to have a stronger impact on forest product demand than prices of the current year (see e.g. ECE/FAO 1986). Another aspect is the technical need for a lagged price. While in the ATM, by maximizing producer and consumer surplus because of dual solutions, quantities and prices can be determined simultaneously, the modelling of the simultaneous relationship between supply, demand and price is not directly possible in a SD model (existing SD models of the forest sector usually avoid this problem in treating prices as constant (e.g. Lönnstedt and Schwarzbauer 1984), in treating demand exogenously (e.g. Cavanna 1983) or in basing prices on cost developments instead on market forces (e.g. Lönnstedt 1983)).

In Figure 4, $N1$, $A1$, $N2$, $A2$ are the respective demand and supply curves for a product in period 1 and 2. In period 2 both curves have been shifted to the right. The equilibrium price for period 1 would be P_1*, for period 2 P_2*. Let P_0 be the price of the previous period (or a start value at the beginning of the run; for demonstration purposes P_0 is made significantly different from P_1*). P_0 results in a potential demand N_1' and potential supply A_1' in period 1. N_1' is the smaller value, and actual demand (=actual supply) Q_1 is modelled to be equal to N_1' (see also Friedman 1976). Because of surplus potential supply, the current price P_1 will be reduced (as compared to P_0) by a factor calculated by the relationship between potential supply and demand. P_1 is not identical with P_1*. P_1 is now functioning as the lagged price for the next period, which leads to a potential supply of A_2' and a potential demand of N_2'. This time potential demand N_2' is larger than potential supply A_2' (=actual demand=actual supply Q_2)

and the current price P_2 will increase as compared to P_1. Again P_2 is not equal to P_2*, but the current prices will always circulate within a certain magnitude around the equilibrium price, the magnitude being determined by the demand and supply curves.

The real mechanism in FOHOW is somewhat more complicated. Actual supply (=production) is calculated by a two-step minimization process. The supply and demand curves of the final product together with the lagged price result in a potentially possible production (this corresponds to Q_1 and Q_2 in Figure 4). This quantity would satisfy the market but is calculated independent of raw-material supply. The forestry module together with import equations and available residues provide potential raw-material supply and – by using conversion factors – a potentially available product supply. In the second step potential possible production (as derived from the supply and demand curves) and potential available supply (as derived from raw-material availability) are minimized. Between 1965 and 1985, conversion factors are historical data (BHWR 1980; Österreichisches Holzforschungsinstitut 1981; BMLF 1966, 1987).

As in the ATM, netted trade flows (instead of bilateral trade flows) are implemented in FOHOW, mainly because all products are treated as homogenous. Export and import equations are formulated similar to the supply and demand equations with the exception of prices. The trade equations are based on lagged relative product prices (a quotient in which the price of the importing region is in the numerator, the price of the exporting region in the denominator).

In the case of Austrian net exports, the trade relationship is represented by an Austrian export equation and by an import equation in the competing region, both non-linear. Potential import demand in the competing region is shifted like the demand curves in Austria, by GDP and time trend (substitution). The Austrian export curve is shifted by potential demand in the competing region itself. Potentially possible net export is determined by minimizing potential export supply (Austria) and potential import demand (competing region). Actual net export is then calculated by considering actual production. Net import is handled the opposite way.

Domestic consumption is calculated by subtracting net exports from production or by adding net imports to production. Fuelwood is treated as not traded internationally.

Current domestic prices of final products are calculated from the prices of the previous period by correcting them by a factor based on the relationship between total potential demand and potential available supply. Any lagged price other than the equilibrium price will lead to either a surplus demand or a surplus supply. The mechanism to determine the correction factor assumes that the equilibrium quantity lies halfway between potential demand and supply. As can be seen from Figure 5, the relationship between potential demand and supply is transferred to the price. Although the nonlinearity and the actual slope of the implemented functions make this procedure somewhat incorrect, test runs with several correction factors have shown that the model reacts only moderately to changed assumptions on these factors.

With FOHOW being a national model, prices in the competing region must be treated exogenously. For the period between 1965–1985 historical data have been implemented (Western Europe averages). The prices are held constant for the projection period in the base scenario.

Production capacity, the variable to shift the supply curve, is based on production profitability. Lack of data is again the weakest part of the model. Beside lacking information on costs, there is no published information on the quantitative relationships between profitability and investments and shut-downs. Another data problem arises from the fact that Austrian capacity figures are not available from Austrian sources but have to be taken from international statistics (e.g. ECE/FAO 1984, 1985; FAO 1981).

Investment and shut-down rates are calculated in the model as being dependent on the relationship between current gross profits (or losses) and a reference gross profit (an average for the historic period). Gross profits are determined by subtracting all variable costs (including wood costs) from the production value (production quantity times price).

Variable production-cost data between 1965 to 1985 for sawnwood are based on Deringer (1980, 1981, 1986); the others were largely taken – and later changed through calibration – from the IIASA databank for the GTM. Variable production costs are exogenous variables, which are

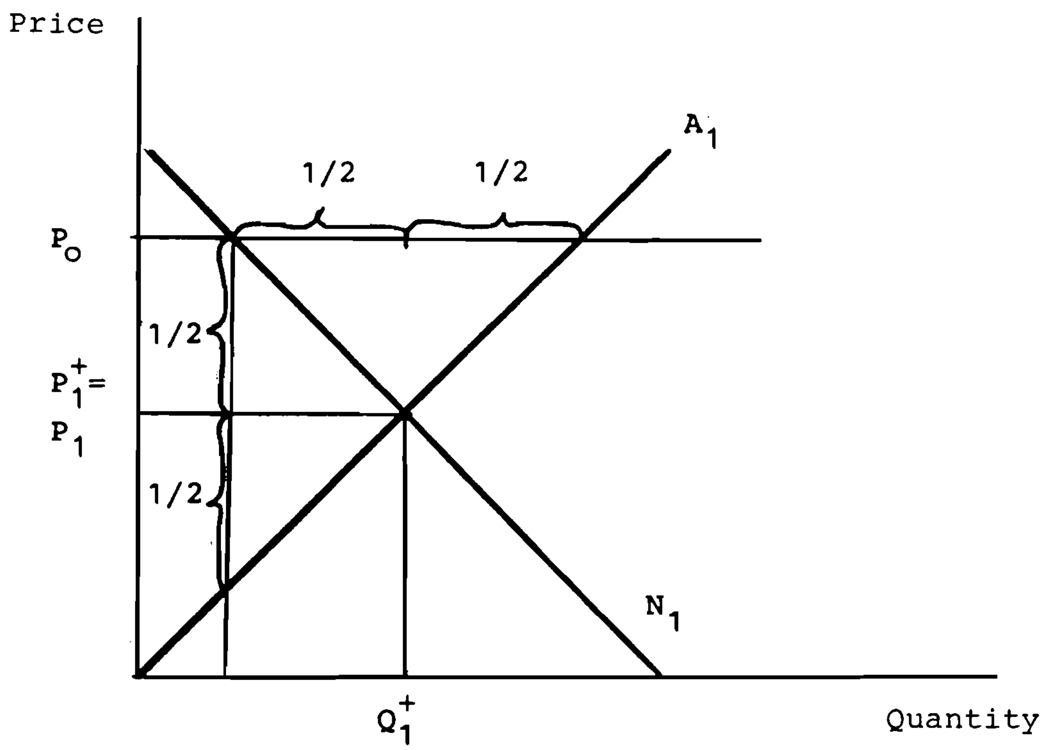

Figure 5: Calculation of the equilibrium price by using the relationship between potential demand and potential supply – as shown by linear supply and demand curves with a slope of +1 and -1.

held constant for the entire projection period (base scenario).

The forest industry module also produces information on the potential demand for wood raw material (roundwood and residues). This figure is calculated by multiplying the potential product supply (as derived from the supply and demand curves) with conversion factors. By doing that for all final products and considering net imports or net exports of wood as well as the available residues, a potential demand quantity for each roundwood product (coniferous logs, non-coniferous logs, coniferous pulpwood, non-coniferous pulpwood, fuelwood) from the Austrian forest results.

Modelling foreign trade with roundwood products is handled similar to that of final products. The main difference is that except for non-coniferous logs, Austria is a net importer. With the panel and paper industries basically using the same products (pulpwood), trade equations are formulated for each of the two branches. In the case of net imports, the Austrian import demand curve is shifted with production capacity of the correspondend final product. The export supply curve of the competing region is shifted by growing stock. Again the actual trade flow is determined by minimizing potential import demand and potential export supply.

Forestry

The forest module includes potential wood supply from the forest as well as the decision on actual timber harvest by considering the information on potential demand for roundwood from the forest industry module. This quantity decision results in a certain roundwood product price, the mechanism of which is also part of this module. Coniferous timber supply is broken down according to ownership categories (forest enterprises less than 200 ha; forest enterprises more than 200 ha; Austrian Federal Forests), while non-coniferous timber supply is modeled as a single unit because of its minor importance for Austria.

Potential timber supply is modelled with eight supply curves, according to another breakdown in final cuts and thinnings. These supply curves are price/quantity functions, which are shifted over time with growing stock (see Binkley and Dykstra 1987). Through conversion factors, timber is converted into the roundwood products. Actual harvests are determined by minimizing potential supply for a certain roundwood product (total of all supply curves) and potential demand (forest industry).

Although price elasticities for the supply curves have been estimated econometrically, they are – as in the ATM – "highly suspect" (see Binkley and Dykstra 1987). For the federal forests a price elasticity of zero was implemented because harvests in this ownership category do not react to price but are tied to sustainable yield.

The mechanism for roundwood-price calculation is different from that of final products. The basic concept is that a potential roundwood price is derived from the price(s) of (the) respective final product(s) or the price of another roundwood product. The actual price is the potential price corrected by a factor based on the relationship between potential supply and demand. Thus the mechanism reflects the fact that roundwood prices are not independent from each other and not independent from final products. The potential price is corrected by the percentage of over- or under-supply as compared to demand.

Forest resources

In all ownership categories, two age-classes are distinguished. Different from more detailed classifications, the first age-class is comprised of forests younger than sixty years, the second of stands older than sixty years (according to Austrian Forest Law, only stands over 60 years old can be clearcut). It is assumed that only thinnings occur in the first age-class and only final-cuts (which lead to reforestation) in the second. In terms of data, this module is largely based on the results of the Austrian Forest Inventories of 1961/1970 and 1971/80 (FBVA 1973, 1985).

In any period, forest area in the first age-class is calculated by adding to the area of the previous period the area from final cuts, coming from the second age-class, and from afforestation as well as by subtracting the area passing over to the second age-class. The area of afforestation is a potential exogenous simulation parameter not used in these model runs (afforestation set to 0). The area transferred to the second age-class is influenced by the size of the final cut area and by the area of the first age-class itself.

Growing stock in a certain period is calculated by adding increment to growing stock of the previous period and by subtracting harvests through thinning, dying stock and growing stock passing over to the second age-class. Increment and mortality percentage are both dependent on growing stock per hectare (density). Growing stock transferred to the second age-class results from multiplying growing stock per hectare with the transferred area, thus assuming for simplicity that the transferred growing stock represents an average of the whole age-class.

To bring harvests into compareable units with growing stock, they have to be corrected by harvesting losses. These losses, expressed in percentages, have been calculated from special-assortment yield tables (Sterba and Griess 1983; Sterba et al. 1986).

Forest resources in the second age-class are handled very similar to those in the first. The main difference is that the area and the growing stock added are those transferred from the first age-class. Besides mortality, the losses in growing stocks are the final cuts. The final cut area is derived by dividing the final cut harvests by average growing stock per hectare.

4.3 The base scenario

The assumptions for the base scenario are basically the same as in the ATM. Real prices in the competing region as well as variable production costs in Austria remain constant on the 1985 level through the whole projection period.

Table 29: Gross income of the forest sector in Bill. AS (real 1975 values) in the base scenario using FOHOW.

Sector/ Product	1965	1985	2000	2030	Changes 2030–1985 in %
Coniferous sawnwood	9.46	9.58	10.68	9.85	+ 3
Non-coniferous sawnwood	0.40	0.41	0.46	0.45	+ 10
Reconstituted panels					
(particle- and fiberboard)	1.34	2.38	2.72	2.98	+ 25
Paper	6.88	9.92	12.41	13.59	+ 37
Forest industries	18.08	22.29	26.27	26.87	+ 20
Forestry	6.70	6.71	7.73	6.67	− 1
Total forest sector	24.78	29.00	34.00	33.54	+ 16

4.3.1 Forest-product production and consumption

Between 1985 and 2030 gross income of the entire forest sector increases by 16% (in real terms) with significant variations among the specific sectors (Table 29). While the paper industry grows by 30%, forestry even slightly declines by 1%, thus leading to a higher share of the forest industries towards the end of the projection period.

Except for coniferous roundwood and sawnwood domestic, Austrian consumption is increasing more or decreasing less than production. This means reduced exports and rising imports in the future. Production and consumption of coniferous logs and pulpwood increase, while the respective non-coniferous products face a decrease. The decline of non-coniferous logs corresponds with the decline in sawnwood production, while reduced non-coniferous pulpwood production is a reaction to the rising profitability of imports. Fuelwood production (= consumption) goes down due to the negative income elasticity. Relatively high income elasticities together with non-negative trend parameters for reconstituted panels and paper are the reason for the high increase in consumption of these products.

Concerning the development over time, all products except reconstituted panels have a peak in production and consumption around 2010/2015 with a slight decline or a stagnation thereafter (Table 30). The main reasons for these developments are the changing trend factors over time: either the negative trend gets stronger (sawnwoods and fuelwood) or the positive trend goes down (reconstituted panels and paper).

4.3.2 Forest product prices

Two sets of product prices exist in the model: exogenously set constant prices for the competing region and endogenously determined domestic prices for Austria. Because the Austrian forest sector is not isolated from the outside region due to the importance of international trade, domestic prices, although endogenous, are not independent from foreign prices. Austrian prices adapt to foreign prices in the long run.

Prices for non-coniferous sawnwood and for paper rise significantly more than those for coniferous sawnwood and reconstituted panels, but for very different reasons. While the price increase of non-coniferous sawnwood is a result of the price adaptation process (foreign prices in 1985 are much higher than domestic prices), the increase of paper prices corresponds to the rising importance of the domestic market and its forces as compared to exports (domestic consumption rises by 24%, production only by 9%).

4.3.3 International trade in forest products

Over the projection period imports grow much faster than exports (Tables 31 and 32). Imports of pulpwood increase more than log imports, which reflects the production development of

Table 30: Austria's production and consumption in forest products in the base scenario using FOHOW. Data are in Mill. m^3 or tons and in %.

Product	1985	2030	Changes 2030–1985 in %
Coniferous logs			
production	7.6	8.0	+ 5
consumption	8.9	9.3	+ 3
Non-coniferous logs			
production	0.4	0.4	− 12
consumption	0.3	0.3	− 1
Coniferous pulpwood			
production[a]	4.4	4.4	+ 2
consumption[b]	5.8	6.4	+ 10
Non-coniferous pulpwood			
production[a]	1.0	0.9	− 12
consumption[b]	1.4	1.4	+ 1
Fuelwood			
production = consumption[a]	2.8	2.8	− 2
Coniferous sawnwood			
production	5.8	5.9	+ 2
consumption	2.7	2.7	± 0
Non-coniferous sawnwood			
production	0.2	0.2	− 5
consumption	0.2	0.3	+ 11
Reconstituted panels			
production	1.6	1.9	+ 19
consumption	0.9	1.2	+ 22
Paper			
production	2.0	2.2	+ 9
consumption	1.0	1.3	+ 24

[a]Including residues
[b]Including residues and imports

the corresponding final products. One reason for the high growth of roundwood imports is the inelastic supply of timber from the forests. Of all net exports those for reconstituted panels grow most, which reflects the higher income elasticity for that product category in the competing region as compared to Austria.

4.3.4 Timber removals and forest resources

Timber removals remain remarkably stable during the projection period with a slight peak in 1990/1995 and a slight decline thereafter. This situation is caused by the following factors:

(1) Inelasticity of timber supply;
(2) Implemented conversion factor for final products, which assume that raw-material input goes down over time as a result of improved technology;
(3) Constant conversion factors for timber (into roundwood products); and
(4) Decreasing consumption of fuelwood due to a negative income elasticity.

Caused by stagnating coniferous sawnwood production, decreasing non-coniferous sawnwood production and fuelwood consumption, final cuts go down by 2% between 1985 and 2030, while thinning in 2030 are about 4% above the 1985 level. Removals by ownership categories reflect

Table 31: Foreign net trade of roundwood products in the base scenario using FOHOW. Data are in Mill. m^3; (+) net exports; (−) net imports.

Product/ Importing Sector	1965	1985	2000	2030	Changes 2030–1985 in %
Coniferous logs/sawmills	–	−1.3	−1.4	−1.4	+ 10
Non-coniferous logs	–	+0.1	+0.1	+0.1	− 40
Coniferous pulpwood[a]	−0.1	−1.4	−1.7	−2.0	+ 29
panel industry	–	−0.4	−0.5	−0.6	+ 43
paper industry	−0.1	−1.0	−1.2	−1.4	+ 23
Non-coniferous pulpwood[a]	−0.5	−0.4	−0.5	−0.5	+ 28
panel industry	−0.1	−0.1	−0.1	−0.1	+ 28
paper industry	−0.4	−0.3	−0.4	−0.4	+ 28
Total	−0.6	−3.0	−3.5	−3.8	+ 27

[a]Including residues

Table 32: Foreign net trade of final products in the base scenario using FOHOW. Data are in Mill. m^3 or tons; (+) net exports; (−) net imports.

Product	1965	1985	2000	2030	Changes 2030–1985 in %
Coniferous sawnwood	+2.7	+3.1	+3.3	+3.2	+ 3
Non-coniferous sawnwood	–	–	–	−0.1	–
Reconstituted panels (particle- and fiberboard)	+0.1	+0.6	+0.6	+0.7	+ 14
Paper	+0.3	+1.0	+1.1	+0.9	− 6

the implemented price elasticities for supply; in forest enterprises smaller than 200 ha, harvests rise by 10% (2030 as compared to 1985). In those larger than 200 ha they fall by 7%, and in the federal forests the increase is about 3%. Non-coniferous harvests are 12% lower in 2030 than in 1985 due to the large share of fuelwood. Both growing stock and increment rise by ca. 10% in the projection period.

4.4 Scenario variations

4.4.1 Economic growth variations

In the high-growth scenario, GDP growth in Austria and in the competing region were both doubled. In the low-growth scenario, GDP growth rates in both regions were halved. Prices in the competing region remain at the base scenario level.

Forest sector income reacts more moderately than does GDP itself. High growth leads to a increase of the entire forest sector income in 2030 of 31% as compared to the base scenario, while GDP is 70% higher (in real terms) (Table 33).

Forestry reacts stronger to changes in economic growth than do the forest industries. Within the forest industries, the log-based sectors are the most sensitive ones, which will be explained together with prices and raw-material input.

While coniferous sawnwood production reacts stronger than consumption, all other final products show the reverse (Table 34). High economic growth leads to a higher export share of coniferous sawnwood, and low growth to a lower one. The opposite is the case with reconstituted panels and paper. These developments are again based on the implemented income elasticities, or more precisely, on the relative income elasticities between Austria and the competing region.

Table 33: Gross income of the forest sector in 2000 and 2030 using FOHOW for the growth-rate scenarios. Data are percentage differences with the base scenario.

	2000		2030	
Sector/Product	High Growth	Low Growth	High Growth	Low Growth
Coniferous sawnwood	+ 21	− 11	+ 54	− 32
Non-coniferous sawnwood	+ 27	− 5	+ 46	− 25
Reconstituted panels (particle- and fiberboard)	+ 7	− 4	+ 12	− 7
Paper	+ 5	− 4	+ 9	− 11
Forest industries	+ 12	− 7	+ 26	− 18
Forestry	+ 37	− 10	+ 50	− 31
Total forest sector	+ 14	− 8	+ 31	− 21

Table 34: Final-product production and consumption in 2000 and 2030 using FOHOW for the growth-rate scenarios. Data are percentage differences with the base scenario.

	2000		2030	
Product	High Growth	Low Growth	High Growth	Low Growth
Coniferous sawnwood				
production	+ 7	−3	+ 12	− 11
consumption	+ 3	−2	+ 10	− 10
Non-coniferous sawnwood				
production	+ 17	−5	+ 24	− 19
consumption	+ 22	−6	+ 46	− 24
Reconstituted panels (particle- and fiberboard)				
production	+ 6	−6	+ 15	− 17
consumption	+ 6	−7	+ 17	− 18
Paper				
production	+ 3	−2	+ 5	− 7
consumption	+ 5	−5	+ 8	− 13

Because of the inelastic wood supply from the forests, imports of roundwood react stronger to economic variations than exports of final products. While exports of coniferous sawnwood in the high-growth scenario in 2030 are 13% above the base scenario level, imports of coniferous logs are 23% higher. It should be emphasized, however, that these model results are based on the assumption that prices in the competing region are the same as in the base scenario.

Prices for pulpwood react more moderately to growth variations than those for logs. This can be explained by the fact that pulpwood consists not only of wood from the forests but also of residues. High economic growth leads to a higher production of sawnwood as well as sawnwood residues and higher imports of pulpwood, thus increasing pulpwood supply and limiting price increases. Non-coniferous prices are additionally tied to fuelwood prices, which are lower with high growth and higher with low growth (negative income elasticity).

High growth decreases the share of wood consumption from the forest by the paper industry (31% in 2030), while low growth increases it (42%). The panel industry reacts similarly but more moderately, with the respective figures being 16% and 18%.

Inelastic wood supply from forests leads to moderate changes in removals. High growth results in a 5% higher timber harvest, low growth in a 7% reduction. In high growth, final cuts in 2030 rise 6% above the base scenario level. Final cuts are mainly used in sawmills. Through increased production of sawnwood also more pulpwood is available, which in turn has an impact on thinnings; even with high growth they decline.

4.4.2 Forest decline scenarios

FOHOW forest decline scenarios basically involve the same considerations as for the ATM, one difference being that FOHOW is a national model with exogenously given product prices in the competing region. In this case, two additional assumptions on the price developments in the outside region were tested.

Both FOHOW forest decline scenarios operate under the following assumptions:

(1) The timber supply curves are shifted to the right between 1990 and 1995 by 40%. The shifting factor increases linearly from 1 to 1.4 between 1985 and 1990 and decreases from 1.4 to 1 between 1995 and 2000.

(2) All roundwood export supply curves are shifted in the same way, because the competing region is assumed to be affected by forest decline as well.

(3) Starting with 1990, increment-percentage reference values on affected forest areas are reduced by one-third (Austria and competing region).

(4) The share of affected forest area on the total forest area increases from 0% to 30% between 1985 and 1990, then to 90% by 2005 and remains at that level until 2030.

The price reactions of the competing region are exogenously modeled in two variants:

Variant 1: All prices in the competing region remain at the level of the base scenario;

Variant 2: Foreign prices for products for which Austria is a net exporter follow the Austrian prices, while prices for products for which Austria is a net importer (imports from CPE-regions mostly) remain at the base scenario level.

Table 35 shows that for both variants, forest sector income in times of oversupply (around 1990) is lower than in the base scenario, while it is considerably higher in times of scarcity (2030). Forestry is reacting stronger than forest industries, the main reason being that wood costs comprise only a small share of total costs in the industrial sectors, and their price-affecting power is thus limited.

Forest sector income follows price developments rather than production. Caused by inelastic demand as related to price (all price elasticities except for non-coniferous sawnwood are smaller than 1), demand reacts less than the price. With oversupply and considerably lower prices demand goes up only slightly, while with wood scarcity prices jump up, but demand does not go down in the same magnitude. Wood scarcity therefore means less production but at a much higher price.

Deviations from the base scenario are higher for variant 2 than for variant 1. This is caused by the fact that especially in times of scarcity, foreign prices are no limitation for Austrian prices (as in variant 1). Both domestic and foreign prices can rise.

In terms of removals, both variants go into the same direction with no significant deviations from each other. The increase of actual removals as a reaction to the shift of the supply curves to the right by 40% is only moderate. In 1990 only 4% more than in the base scenario is harvested, which is much less than in the ATM. While in the ATM actual quantities lie exactly in the intersection of the supply and demand curves, quantities in FOHOW are determined by minimizing potential demand and supply. An increase in removals can only occur if potential demand is increasing too. This can only happen through increased production of final products, which itself is influenced by increased demand through lower prices. Assumptions on increment reduction influence model results much more than assumptions on increased supply. Total harvests in 2030 are one-third, growing stock one-fifth and increment two-thirds below the base scenario.

Table 35: Gross income of the forest sector in 1990 and 2030 using FOHOW for the forest-decline scenarios. Data are percentage differences with the base scenario.

	1990		2030	
Sector/Product	Variant 1	Variant 2	Variant 1	Variant 2
Coniferous sawnwood	– 14	– 17	+ 42	+ 96
Non-coniferous sawnwood	– 13	– 13	+ 8	+ 114
Reconstituted panels (particle- and fiberboard)	– 8	– 7	+ 10	+ 21
Paper	± 0	+ 2	– 1	+ 31
Forest industries	– 7	– 7	+ 17	+ 55
Forestry	– 20	– 22	+ 30	+ 72
Total forest sector	– 10	– 10	+ 19	+ 59

Table 36: Final-product production and consumption in 1990 and 2030 using FOHOW for the forest-decline scenarios. Data are percentage differences with the base scenario.

	1990		2030	
Product	Variant 1	Variant 2	Variant 1	Variant 2
Coniferous sawnwood				
production	+ 3	+ 2	– 16	– 11
consumption	– 2	+ 6	– 10	– 23
Non-coniferous sawnwood				
production	– 3	+ 3	– 32	– 36
consumption	– 7	– 6	– 27	+ 3
Reconstituted panels (particle- and fiberboard)				
production	± 0	± 0	– 9	– 9
consumption	– 1	– 2	– 6	– 15
Paper				
production	+ 3	+ 2	– 8	+ 9
consumption	– 5	– 12	± 0	– 10

Final products based on pulpwood (reconstituted panels and paper), where the share of wood costs of the product price is relative small, react less to forest decline assumptions than sawnwoods (Table 36). In variant 1 after 1995, production decreases more than consumption; exports fall, imports rise. Variant 2 shows the opposite, non-coniferous sawnwood being an exception. Because of a higher compensation effect through roundwood imports in variant 2, and because of constant profitability of Austrian exports, export quantities of final products can be held at the base scenario level, and in one case (paper) production and exports can even increase.

In times of Austrian oversupply (1990), total roundwood imports do not change very much; only coniferous pulpwood imports fall, while all other roundwood imports rise. The latter is the result of the shift of the export supply curves in the competing (CPE) region.

In times of increased harvests (1990), all prices are below the base scenario, and in times of wood scarcity (2030) significantly above. Because prices in variant 2 are not limited by constant prices in the competing region for export products, price deviations are generally larger in variant 2 as compared to variant 1. Price deviations are considerably larger than deviations in quantities.

Table 37: Gross income of the forest sector in 1990 and 2030 using FOHOW for the exchange-rate scenarios. Data are percentage differences with the base scenario.

	1990		2030	
Sector/Product	Strong Dollar	Weak Dollar	Strong Dollar	Weak Dollar
Coniferous sawnwood	+ 9	– 12	+ 33	– 29
Non-coniferous sawnwood	+ 17	– 11	+ 39	– 24
Reconstituted panels (particle- and fiberboard)	+ 5	– 14	+ 21	– 24
Paper	+ 27	– 29	+ 39	– 36
Forest industries	+ 17	– 18	+ 35	– 32
Forestry	+ 17	– 30	+ 42	– 39
Total forest sector	+ 17	– 21	+ 36	– 33

4.4.3 Exchange rate variations

Variations in FOHOW are expressed through price shifts by a certain factor. While domestic prices are not changed, prices in the competing region are multiplied by a factor, depending on the strength or weakness of the Austrian Schilling. In order to use the same notion as in the ATM, two variations have been tested:

(1) **Strong 'Dollar' (= weak Schilling)**
All foreign prices are multiplied by a factor of 1.4 between 1990 and 2030. Between 1985 and 1990, this factor rises linearly from 1 to 1.4.

(2) **Weak 'Dollar' (= strong Schilling)**
All foreign prices are multiplied by a factor of 0.7 between 1990 and 2030. Between 1985 and 1990, this factor falls linearly from 1 to 0.7.

These relative price changes lead to developments which partly compensate each other, caused by the fact that the multiplication factors are applied to import and export prices.

Despite compensation procedures, FOHOW performs as expected. A strong Dollar (a weak Austrian Schilling) means a one-third higher income of the forest sector in 2030 as compared to the base scenario, and a weak Dollar means a one-third reduction (Table 37). There are no significant variations among the different sectors.

The following aspects determine the level of production and consumption (Table 38):

(1) Reduced imports with a strong Dollar reduce the available roundwood base for production. Thus, production must not necessarily increase because of a strong Dollar and decrease because of a weak one.

(2) Consumption decreases with a strong Dollar and increases with a weak Dollar result from the mutual relationships between production and trade. A stronger Dollar means higher export profitability; production cannot be expanded significantly because of roundwood import limitations, and thus domestic consumption is reduced to use increased export profitability. A weak Dollar generally means the opposite.

(3) Production increases with a strong Dollar and decreases with a weak Dollar are definitely the direct result of a relative increase or decrease of Austria's competitiveness.

Foreign trade follows relative price differences. A strong Dollar means higher exports and lower imports, a weak Dollar lower exports and higher imports. The results demonstrate the process of price adaptation. While foreign prices with a strong Dollar are 40% higher than in the base scenario, domestic prices have increased less (9–29%) by 1990. At the end of the projection period, domestic prices approach the 40% level. Prices for fuelwood, which is not traded, do not change very much.

Higher prices and lower imports with a strong Dollar result in higher removals, and a low Dollar to lower harvests within a magnitude of +5% to –11%.

Table 38: Final-product production and consumption in 1990 and 2030 using FOHOW for the exchange-rate scenarios. Data are percentage differences with the base scenario.

	1990		2030	
Product	Strong Dollar	Weak Dollar	Strong Dollar	Weak Dollar
Coniferous sawnwood				
production	− 1	− 5	+ 5	− 6
consumption	− 14	+ 5	± 0	− 2
Non-coniferous sawnwood				
production	+ 1	− 2	+ 8	− 8
consumption	− 5	+ 11	+ 2	+ 4
Reconstituted panels (particle- and fiberboard)				
production	− 4	− 1	− 3	+ 2
consumption	− 12	+ 7	− 10	+ 9
Paper				
production	− 1	− 15	+ 7	− 20
consumption	− 23	+ 6	− 9	− 5

Table 39: Gross income of the forest sector in 2000 and 2030 using FOHOW for the import-stop scenario. Data are percentage differences with the base scenario.

Sector/Product	2000	2030
Coniferous sawnwood	+ 14	+ 22
Non-coniferous sawnwood	+ 6	+ 6
Reconstituted panels (particle- and fiberboard)	+ 2	+ 8
Paper	− 16	− 13
Forest industries	− 1	+ 2
Forestry	+ 34	+ 48
Total forest sector	+ 7	+ 12

4.4.4 Import-stop scenario

In an import-stop scenario, it is assumed that Austria will prevent any roundwood imports by 1990. Here, the impacts of drastic limitations to imports from CPE-countries for the Austrian forest sector will be tested.

In general, an import-stop with a reduced roundwood supply for the Austrian forest industries has similar consequences as the forest decline scenarios. Gross income of the forest sector rises above the level of the base scenario because prices are increasing more than production and demand is going down. Again forestry is reacting much more than the forest industries. Incomes of the paper industry even decline (Table 39).

The decline in the paper industry and the moderate income growth in the panel industry as compared to the base scenario can be explained by the fact that these two sectors are specifically dependent on pulpwood imports; in 1985 23% of the pulpwood consumption in the panel industry and 29% in the paper industry were imported. Another aspect of the income reduction in the paper industry is the relatively high price-difference elasticity of foreign paper demand (as compared to other products). This leads to reduced exports with increasing domestic prices. In this sector, lower production cannot be compensated by higher prices.

The deviations in production and consumption correspond with the degree of dependency on roundwood imports. Products based on pulpwood react much stronger than those based on logs. Consumption generally falls less than production, which means that exports are more reduced than production.

Prices are all above the level of the base scenario (+ 21–63%), thus reflecting scarcity. Non-coniferous logs, which are not affected by import-stops, non-coniferous sawnwood and the non-traded fuelwood have almost no reaction.

Caused by inelastic timber supply from the forest, removals in 2030 are only 5% higher than in the base scenario, despite the fact that imports are reduced to zero.

4.5 Model evaluation

Model evaluation follows the approach of Cavanna for validating his SD model for the New Zealand forest sector (Cavanna 1983). Validation of FOHOW was not undertaken after the model was finished but was a constant process during model construction. Forrester and Senge (1980) argue that "there is no single test which serves to 'validate' a system dynamics model. Rather, confidence in a system dynamics model accumulates gradually as the model passes more tests and as new points of correspondence between the model and empirical reality are identified".

4.5.1 Verification tests

Verification Test 1

A test was conducted to clarify whether the individual relationships in the model can be defended in their own right and not because the model as a whole produces the desired behavior. FOHOW was not built as one block. Before FOHOW was in existence as a whole, its modules were built and tested seperately. The first module was "forest-resources", the next was "forestry". Only after both modules produced satisfying results on their own, were they linked together. For each final product, a separate module was created and later linked to "forestry" and "forest resources". During the separate test-runs, influences from other modules were treated as exogenous. All strengths and weaknesses of the equations have been documented not the least to pass this test (see Schwarzbauer 1989).

Verification Test 2

The question to be answered is: "Are the parameter values consistent with the known data or other information?". The implemented parameters are not without problems. In case the econometric estimations did not produce parameters consistent with existing information, other sources were used. Non-econometrically estimated parameters (conversion factors) were taken from published sources, when available. For some of the parameters no other known data or other information existed (e.g. investment rates).

4.5.2 Validation tests

Validation Test 1

My first validation test asks whether the model is producing any unrealistic values. Examples of unrealistic values would be negative prices or a negative production. Neither in the base scenario nor in any other scenario run did such unrealistic values appear.

Validation Test 2

Another validation test assesses whether the model behaves 'like' the real system. This test involves comparing the model output with historical values and future results from other studies. FOHOW runs start in 1965, thus a comparison with historical data is possible. The results of

Table 40: Comparision of FOHOW results in 1985 for the base scenario with historical data. Data are Mill. m^3 or tons.

Product	FOHOW	Historical Value	Deviation from Historical Value in %
Conif. and non-conif. logs			
production	8.0	8.1[a]	− 1.2
consumption	9.2	9.3[b]	− 1.1
Conif. and non-conif. pulpwood			
production	5.4[c]	5.4[d]	± 0.0
consumption	7.2	7.2[e]	± 0.0
Industrial roundwood			
production	13.4[c]	13.6[f]	− 1.5
consumption	16.4[c]	16.5	− 0.6
Fuelwood			
production	2.8[c]	2.4[g]	+ 16.7
consumption	2.8[c]	2.7[h]	+ 3.7
Total roundwood			
production	16.2[c]	16.0	+ 1.3
consumption	19.2	19.2	± 0.0
Conif. and non-conif. sawnwood			
production	6.0	6.0[i]	± 0.0
consumption	2.9	3.0[i]	− 3.3
Reconstituted panel			
production	1.6	1.3[i]	+ 23.1
consumption	0.9	0.7[i]	+ 28.6
Paper and paperboard			
production	2.0	2.1[i]	− 4.8
consumption	1.0	0.9[i]	+ 1.1

[a]BMLF (1987); calculated from consumption and net trade
[b]BMLF (1987)
[c]Including residues
[d]FAO (1986a), BMLF (1987); total amount of residue "production" assumed to be pulpwood
[e]Österreichischer Agrarverlag (1987); BMLF (1987)
[f]BMLF (1987); total harvests + residues
[g]BMLF (1987); as shown in harvest statistics
[h]BMLF (1987); calculated from harvests and net trade
[i]BMLF (1987)

this effort should not be overemphasized, however, because (i) SD models never produce accurate predictions for a certain point of time, and (ii) some of the variables which are made endogenous for the projection period have been fed into the model as exogenous values for the historical period.

Larger deviations appear for few products (Table 40). The reason for fuelwood is partly the uncertainty of historical data themselves. One problem is the deviation for reconstituted panels. Because of exploding panel production and consumption in the historical period, the model overshoots actual figures around 1985. But the problem stops around 1985. Table 41 shows that FOHOW does not produce higher values than other studies for reconstituted panels in the future.

Considering the variations in methods among the other presented studies and results, FOHOW deviations from these results are acceptable.

Although there will be a general comparative evaluation of the ATM and FOHOW (Sec-

Table 41: Comparison of FOHOW base-scenario results in 2000 with results of other studies. Data are Mill. m^3 or tons.

Product	FOHOW	FAO[a]	ECE/FAO[b]	Baudin[c]	BHWR[d]
Total roundwood					
production	16.9[f]	–	13.7[h]	–	17.0
consumption	20.3[f]	–	21.0	–	24.4
Conif. and non-conif. sawnwood					
production	6.1	–	–	–	6.6[e]
consumption	3.1	3.5	3.4	3.2	3.2
Reconstituted panel					
production	1.7	2.4[f]	1.6[f]	–	1.7[e]
consumption	1.0	1.2[f]	1.0	1.1[f]	1.2
Paper and paperboard					
production	2.2	2.5	1.9	–	2.2[e]
consumption	1.1	1.2	1.2	1.1	1.3

[a]FAO (1986b); Chase-Manhattan Scenario
[b]ECE/FAO (1986), Vol. II – low scenario
[c]Baudin (1988)
[d]BHWR (1980)
[e]Total of domestic consumption, exports (+) and imports (–)
[f]Including solidwood panels

tion 5), some results of both models are presented here (Table 42). The results of both models differ significantly with increasing magnitude over time. The discrepancies can be explained by model structure and exogenous assumptions, the most important of which are outlined below:

(1) In the ATM "Rest of the World" becomes the driving force for demand due to population and income growth. In FOHOW the competing region is modeled after Western Europe (as far as Austrian exports are concerned), which has relatively lower growth rates in income and population than "Rest of the World" in the ATM. Thus, demand for Austrian forest products and Austrian production is lower in FOHOW.
(2) Because domestic consumption is modelled similar in both models, consumption values differ less than production.
(3) Foreign product prices in the ATM rise over time, partly because of the demand increase in "Rest of the World", while they are held constant in FOHOW. This too causes a smaller Austrian production and less exports.
(4) The ATM does not distinguish between forest ownership categories with different supply behavior. Generally Austrian timber supply in the ATM is modelled more elastic than in FOHOW, thus allowing higher harvests.

Because discrepancies in model results can be traced down and explained, their existence is no indication for the "correctness" or "wrongness" of either model. However, these discrepancies demonstrate the need for an indepth understanding of model structures and underlying assumptions to interpret model results correctly.

In both models, the base scenario runs are used as standards against which runs with different assumptions can be tested. Comparing model results must therefore also include other scenarios. Two of them, with similar assumptions, are presented (Table 43).

While the results of both forest decline runs correspond strikingly well, this is not always the case for the high-growth scenario. Again the different structure of the foreign region is the main reason:

(1) Demand in "Rest of the World" grows much more than Austrian demand in the ATM.
(2) Due to higher income elasticities in the ATM, demand for final products, based on pulp-

Table 42: Differences between the ATM and FOHOW in 2000 and 2030 for the base scenario for Austria. Data are Mill. m^3.

	2000		2030		Deviations ATM/FOHOW in %	
Product	ATM	FOHOW	ATM	FOHOW	2000	2030
Coniferous logs						
production	9.0	8.1	10.3	8.0	+ 11	+ 29
consumption	9.5	9.4	10.5	9.4	+ 1	+ 12
Non-coniferous logs						
production	0.4	0.4	0.5	0.4	± 0	+ 25
consumption	0.5	0.3	0.5	0.3	+ 66	+ 66
Coniferous pulpwood						
production	6.1	4.6	8.6	4.4	+ 33	+ 95
consumption	6.5	6.3	10.1	6.4	+ 3	+ 58
Non-coniferous pulpwood[a]						
production	0.8	0.9	0.9	0.9	− 11	± 0
consumption	1.6	1.4	2.4	1.4	+ 14	+ 71
Fuelwood						
production = consumption	1.8	2.9	1.4	2.8	− 38	− 50
Coniferous sawnwood						
production	6.1	6.1	6.6	5.9	± 0	+ 12
consumption	3.1	2.8	2.7	2.7	+ 11	± 0
Non-coniferous sawnwood						
production	0.3	0.2	0.3	0.2	+ 50	+ 50
consumption	0.4	0.3	0.3	0.3	+ 33	± 0
Reconstituted panels (particle- and fiberboard)						
production	1.9	1.7	4.1	1.9	+ 12	+ 116
consumption	1.0	1.0	0.7	1.2	± 0	− 42
Paper[a]						
production	1.8	2.2	3.7	2.2	− 18	+ 68
consumption	1.0	1.1	1.1	1.3	− 9	− 15

[a]For the ATM total of newsprint, printing and writing paper, and other paper and board

wood, grows more than demand for sawnwood.

(3) A significant amount of the Austrian log production in the ATM is converted to pulpwood, resulting in an expansion of reconstituted panel production and in decreased coniferous sawnwood production.

(4) In the ATM domestic Austrian consumption of final products decreases, because exports are more profitable (especially to "Rest of the World").

The differences in scenario variation results are also caused mainly by the different regional structure and underlying assumptions, not by a specification error. Thus it can be concluded that FOHOW has passed this test.

Validation Test 3

The final aspect of 'like' behavior is what happens if the parameter values are changed. The parameters to be changed for this test were selected according to their importance for the model and the uncertainty of their estimation. To limit the number of test runs, only parameters affecting coniferous logs and coniferous sawnwood (as two of the bulk products of the Austrian

Table 43: Comparison of selected percentage differences with the base scenario using the ATM and FOHOW for two scenarios in 2030. Data are for Austria only.

Scenario	Product	Variable	Percentage Differences with Base Scenario 2030 ATM	FOHOW
High economic growth	coniferous	production	+ 12	+ 10
	logs	import	± 0	+ 23
	coniferous	production	− 13	+ 12
	sawnwood	consumption	− 24	+ 10
	reconstituted	production	+ 36	+ 15
	panels	consumption	− 17	+ 17
Forest decline[a]	coniferous	production	− 25	− 23
	logs	import	+ 550	+ 55
	coniferous	production	− 12	− 11
	sawnwood	consumption	− 24	− 23
	reconstituted	production	− 15	− 9
	panels	consumption	− 17	− 15

[a]For FOHOW variant 2

forest sector) were changed. It seemed to be appropriate to make drastic assumptions, according to the uncertainty of the estimated parameters.

(1) Income elasticity for coniferous sawnwood demand (+/−50%).
(2) Price elasticity for coniferous sawnwood demand (+/−30%).[2]
(3) Investment rate for coniferous sawnwood production (+/−30%).
(4) Price elasticities of coniferous timber supply – final cut (+/− 30%).[3]

The results can be interpreted as follows (Table 44):

(1) Quantity deviations are much lower than the deviations of the parameters themselves.
(2) The strong price reactions are again a result of the inelastic demand for final products. Even small changes in quantities lead to relatively high changes in prices.
(3) Although the income elasticity was changed more than the other parameters, the effects are relatively small.
(4) Although the weakest part in the model, increased investment rates do not have much effect because they mainly affect capacity, not production. Decreased investment has considerably more impact, because it reduces capacity functioning as the upper limit for production.
(5) Removals are higher than in the base scenario for increased as well as decreased income elasticities for coniferous sawnwood demand. This can be explained by log imports. While increased income elasticities lead also to increased harvests, the decreased income elasticity makes log imports fall considerably. In order to keep up production, harvests have to be increased too. Changed assumptions on price elasticities work the other way.
(6) The model is rather sensitive to changed price elasticities for timber supply.

The sensitivity analysis demonstrates that most of the deviations can be traced down and have a smaller magnitude than the changed parameters themselves. An improvement of param-

[2]The price elasticity is negative. An increase of +30% here means an increase of the absolute value (e.g. from −.45 to −.6; decrease: −.45 to −.25).

[3]Forest enterprises > 200 hectar are modeled to have an negative price elasticity of supply (−0.24). To move them into the same direction as forest enterprises > 200 ha with a positive price elasticity (increase of price elasticity should simulate increased harvests), an increase of +30% means a multiplication with 0.7 (−0.17; going toward 0), a decrease of −30% means a multiplication with 1.3 (−0.31; moving away from 0).

Table 44: Sensitivity analysis with FOHOW. Results for year 2000.

Scenario and Result Variable	Coniferous Sawnwood Production (Mill. m^3)	Coniferous Sawnwood Price (AS/m^3)	Total Harvests (Mill. m^3 o.b.)
Base scenario	6.098	1524	13.345
Income elasticity +50% (0.75/1.35)	6.514	1998	13.480
% deviation from base scenario	+6.8%	+31.1%	+1.0%
Income elasticity −50% (0.25/0.45)	6.042	1056	13.539
% deviation from base scenario	−0.9%	−30.7%	+1.5%
Price elasticity +30% (−0.6)	5.609	801	13.025
% deviation from base scenario	−8.0%	−47.4%	−2.4%
Price elasticity −30% (−0.32)	7.503	3948	12.718
% deviation from base scenario	+23.1%	+159.1%	−4.6%
Investment rate +30%	6.264	1526	13.600
% deviation from base scenario	+2.7%	+0.1%	+1.9%
Investment rate −30%	5.319	1449	12.211
% deviation from base scenario	−12.8%	−4.9%	−8.5%
Price elasticity, timber supply +30% (private < 200 ha +0.42) (private > 200 ha −0.17)	7.386	1105	15.871
% deviation from base scenario	+20.9%	−27.6%	+18.9%
Price elasticity, timber supply −30% (private < 200 ha +0.23) (private > 200 ha −0.31)	4.958	2398	11.005
% deviation from base scenario	−18.7%	+57.3%	−17.5%

eters, especially in timber supply, would be desirable.

4.5.3 Legitimation tests

Legitimation tests are applied to determine whether the model obeys the formal SD laws of system structure. The Dynamo-compiler prevents a good deal of potential errors by error-messages during model construction.

Legitimation Test 1

The first issue is to clarify whether the model is structurally coherent. SD and its software are based on the relationship of elements, which do not allow certain forms of equations. Level equations must have only the level variable of the previous period and rate variables on the right side. Rate variables must not be dependent on other rate variables (without a lag). All potential errors of this kind are thrown out by the Dynamo-compiler and do not appear in FOHOW.

Legitmation Test 2

Are the equations dimensionally valid? This question cannot be answered by the available Dynamo-compiler (other SD softwares do have a dimension routine). The fact that FOHOW starts in 1965 and that model behavior can be compared to historical data makes it easy to find dimension errors. No dimensional errors have been found in FOHOW.

Legitimation Test 3

The final question to be answered is whether the model's flows (rates) are working properly. It is necessary to check the arithmetic operations in a model as double counting could occur, or small quantities could be unwittingly lost or gained, which could accumulate into significant quantities over time. In FOHOW total forest area functions as one control variable. Because no afforestation and no losses are assumed, total forest area must be constant over time, despite flows between age-classes and a breakdown in ownership categories. This is the case with FOHOW.

5 ATM AND FOHOW – A Comparative Evaluation of Model Strengths and Weaknesses

The models differ in geographical scope, general methodological approach and specific model features. In this chapter the following strengths and weaknesses of both models will be discussed:
(1) implementation;
(2) conceptual issues; and
(3) potential for improvements.

5.1 Implementation

Handling, speed and system control

Because of its relatively smaller size, FOHOW is much easier to handle, runs much quicker and is easier to control than the ATM. The SD language, Dynamo, is easy to work with and does not require an indepth understanding in programming. The Prime-Dynamo-compiler on the other hand is a severe restriction to further model development.

Model complexity and the software of the ATM leads to some severe limitations. Both models are large models and therefore not easy to control. The ATM with nine regions and fourteen products (vs. FOHOW with only two regions and 9 products) has so many mutual relationships built in that adjustments of one parameter often results in many unexpected and untraceable unwanted changes. While FOHOW can be handled by a single person, any implementation of the GTM, which deviates from the original IIASA model, requires consultation with a member of the original IIASA core team. Because the MINOS-optimization package, although adapted for the model, is not model-specific, 10-period model-runs can take hours. This increases analytical burden.

Regional and product aggregation

Regional disaggregation is almost impossible with a model using SD software (see also Pestel 1988). The Dynamo-compiler capacity also limited the number of products in FOHOW, affecting especially the paper industry. Therefore FOHOW in this respect is a less complete representation of the forest sector than is the ATM.

Personnel and computer capacity set limits to the numbers of regions and products for the ATM too. Any model implementation with even small deviations from the original IIASA-GTM is a very time-consuming and costly task (see Kornai and Schwarzbauer 1987). With the exception of Western Europe – a single region in the original GTM – the main issue of restructuring the GTM was to merge regions and products together rather than creating a much more detailed representation for the specific Austrian needs.

In the ATM another problem comes into play. Already the original model had a disharmony in region size. In the ATM, with the small region Austria (from a global point of view) as the center of the world, disharmony increased significantly. Small problems in larger regions (e.g. data) can have more impact on model behavior than bigger problems in smaller regions (see Nilsson 1987).

Data

Data problems are occuring in both models, especially economic data for costs, prices, investment etc. The larger geographical scope of the ATM makes data collection much harder. Data availability and quality are generally higher in Austria than in other countries, especially in forest resources and forestry. For the ATM, data and structures have to consider the "smallest common denominator" for all regions; FOHOW in this respect is preferable to the ATM.

Presentation to decision-makers

The large size of the ATM as well as the necessary effort and the long time to implement alternative scenario assumptions create a problem for presenting its results to decision makers. The complicated model structure and the large number of underlying assumptions, which must be understood before one can properly interpret the results, create a barrier of acceptance for the ATM. Thus, the possibility exists that the ATM will not be used as an analytical tool by practical decision-makers but only serves scientific interests. FOHOW is simpler and thus easier to understand. However, there are still complications in presenting and understanding its results.

5.2 Conceptual issues

Market representation

In maximizing consumer and producer surpluses to determine market equilibrium, the ATM is based on the illusion of a perfectly competitive market. Market equilibrium occurs at the intersection of the supply and demand curves. The main underlying assumption is that consumers and producers act in economically rational ways only (cost minimizers and profit maximizers). Obviously, this is an incomplete representation of real markets. Linstone (1978) argues that for systems which incorporate nature, economics, and technology, an "optimal" solution to real problems can hardly be found.

FOHOW is only partly built upon the fiction of a perfectly competitive market. There is no exact equilibrium of demand and supply, but the model is constantly meandering around the equilibrium. In this respect FOHOW is closer to reality than the ATM.

Interactions between regions and products

One of the most important features of both models is the fact that they allow interactions between regions and products. Many other models, especially those for forecasting purposes, involve only single product-region equations. In terms of regional interaction, the advantage lies with the ATM, which covers the whole world. With this model it is possible, for example, to demonstrate direct and indirect impacts of regional disparities. With only two regions, this is only possible to a limited extent with FOHOW.

Product-wise, both models allow interactions. Depending on profitability and demand, pulpwood, for example, can be used as input for pulp-and-paper production or for panels. Increased sawnwood demand can lead to increased production, which also means a growth in residues. More residues mean more pulpwood, which will influence the price. The ATM has an additional specific feature allowing sawlogs to be converted to pulpwood, and pulpwood to fuelwood, where conversion profitability warrants.

Simultanous representation of demand, supply and price

The major difference between these two models and other forest sector models is that the ATM as well as FOHOW have a simultaneous representation of demand, supply and price. In other studies, demand and supply functions are usually estimated separately and independently, and prices are not often forecast. Although the models involve different methods, they can calculate all three market elements.

Production

For both models, problems exist in handling industrial capacity, especially investment and shut-down. One of the problem areas in both models is data and information shortage. One advantage for FOHOW exists in this respect: while capacity shutdown in the ATM is occurring by a fixed given percentage, independent of the market situation, shut-down as well as investment rates in FOHOW depend on market forces.

Another problem is the representation of the supply curve. According to different technologies the supply curve in the ATM consists of a step-function with fixed proportions in resource use. Regardless of profitability, investments always occur in the most efficient technology. Cardellichio and Adams (1987) suggest to merge the two technologies of the GTM: "old" and "new" into one, which was done in the ATM ("existing"). They also suggest that non-linear smoothly increasing supply functions would be even better. That approach was followed in FOHOW.

Trade

Both models treat products as homogeneous and deal with net trade instead of bilateral trade flows. This, of course, is a severe deviation from reality, which affects both models in the same way.

While the ATM has more regions than FOHOW and thus has the advantage of representing world trade more accurately, one major problem arises together with the optimization approach. Optimization leads to the utilization of profitable trade routes, while others decline quickly over time. To represent trade inertia, which should counterbalance pure, rational economic considerations, using somewhat arbitrary upper and lower bounds is a questionable undertaking (see Cardellichio and Adams 1987; Nilsson 1987; Weeks 1987). Still there is almost a must to set upper and lower bounds in the current versions of the ATM to keep trade flows either from disappearing or exploding. FOHOW does not implement any such bounds.

Exchange rates

Due to a specification problem, exchange rates cannot be implemented accurately in the ATM. Unfortunately, although the regional structure of this model is excellently suited to testing the impact of different exchange rates, this important potential feature cannot be predicted in the ATM. In this respect, FOHOW is superior to the ATM.

Timber supply

Unlike the ATM, timber supply in FOHOW represents different ownership categories and different ownership behavior. Also, forest resources in FOHOW are broken in two age-classes, which is not the case in the ATM.

Demand shifters

Given the large computer space needed for both models, only a selected number of demand shifters could be included. As the "smallest common denominators" for all final products, only income, population and time trend (substitution) are implemented. This is, of course, a simplification of reality.

Shifting of the demand functions over time is similar in both models, but there is a specific shortcoming in the ATM. Although the ATM has developed the GTM further by integrating the demand shifter "time trend" and "income elasticity" into a "reduced income elasticity", this is only a suboptimal solution, because time trend is not handled as a separate variable. In FOHOW time trend is treated separately and is open to changes during the projection period, thus allowing a changing substitution pattern over time.

Constant parameters over time

Many model parameters in both models are treated as being constant over time. Constant elasticities are certainly a shortcoming of both models, because they can change in the real world (see e.g. Meyer 1982). One exception is the change of income elasticities in the ATM. This is necessary because of the disparity in incomes across the nine regions, which change over time due to different growth rates. Regions may be transferred to a different income class with a different income elasticity. Incomes in both FOHOW "demand" regions (Austria, Western Europe) are similar, with little disparity.

Roundwood conversion factors are another problem area because they too are basically held constant over time in both models. FOHOW offers more flexibility, because conversion factors are implemented for potential supply. Actual supply in roundwood products can vary to a limited extent according to demand. On the other hand, only the ATM offers the possibility to convert sawlogs directly to pulpwood, if the demand and the profitability of doing so is high enough. Despite this, the rigidity of roundwood conversion in the ATM is unrealistic (Cardellichio and Adams 1987).

Changing technologies

Technology changes are represented in the models only to a very limited extend, with the FOHOW being a little bit more flexible. In terms of product conversion, technical change in the ATM is modeled by exogenously given, identical conversion factors for all regions in 2030. These factors are independent of economic developments. Depending on the situation in 1980, all regions approach the 2030 goal with different convergence rates.

The higher flexibility of FOHOW arises from the possibility to change the trend factor of demand (which represents technical change) during the projection period. Product conversion in FOHOW is handled similar to the ATM and is as problematic.

Because "structural change remains difficult to model and even more difficult to predict" (Cardellichio and Adams 1988), both models in their current versions do not represent technological change in one important aspect: they deal with existing products and not with product innovation.

Linearization and non-linearities

Because of technical problems, many relationships in the ATM have been modeled as linear functions or have been transferred to linear functions (demand function). As argued by Cardellichio and Adams (1987), for the GTM the linearization of the demand curve leads to increasing price elasticities with increasing prices. The higher the implemented elasticity, the quicker the increase of price elasticity. Demand function linearization pushes demand down in those areas, where, according to international forecasts, demand is expected to grow most. Linearization can therefore bias the results. This problem is somewhat less important for the ATM, because the absolute values of most implemented price elasticities are lower than 1. Both supply and demand functions are non-linear in FOHOW and therefore the problems with linearities is avoided.

Economic reactions and complexity

In the ATM as well as in FOHOW, model complexity prevents economic overreactions. Austrian dependency in exports, for example, leads to a stabilization of even dramatic domestic developments. A timber shortage in Austria would increase forest product prices, which in turn would lead to a lower profitability in exports, which means a lower demand. Lower demand results in lower prices. Many of these mechanisms are built into both models. The higher complexity of the ATM, due to nine regions and fourteen products, is the main reason for different model results.

5.3 Potential for improvements

5.3.1 ATM

The possibilities that exist for improving a model of the GTM type have been discussed by Cardellichio and Adams (1988) and will not be repeated here. Some additional comments will be added, however. The most important precondition to improve the ATM is software which is more user-friendly and runs the model quicker. Such software for PCs has been developed by the Institute for Economic and Market Research and Informatics (Budapest), but has not yet been tested for the ATM.

Because it is technically possible to formulate the trend parameter as a separate variable in the ATM demand function, this would be desirable in order to better represent product substitution. In order to get rid of the exchange rate problems, capital and transportation costs should be made responsive to exchange rates. This would guarantee a similar shift of the curves on the demand and supply side.

Even with improvements certain problems cannot be overcome:

(1) Any GTM model type is generally better suited to analyze a global situation, disaggregated into regions of similar size, rather than for analyzing the world from the point of view of a small country.

(2) A GTM model will always produce long-term results, which cannot be used as time-specific and exact forecasts.

(3) What is true for any future oriented model is true for the ATM too. Because exogenous influences in the future can only be assumptions, considering historical developments, the model will always reflect history to a certain degree, and this may not be a good guide to the future.

(4) Because of model complexity and the need to understand model structure and underlying assumptions, it will be always hard to present ATM results to practical decision-makers.

5.3.2 FOHOW

As with the ATM a better software, especially with higher capacity, is also necessary for improving FOHOW. Beside that, the model could be structurally developed in the following areas:

(1) Elasticities should be allowed to change, the magnitude of change depending on other model variables or time.

(2) FOHOW could incorporate a greater variety of product-specific demand shifters.

(3) Pulps and recycled paper should be included as intermediates for the paper industry.

(4) To represent product innovation, a fictitious product could be included, penetrating the market anytime in the projection period. This could be done by either exogenous assumptions on supply, demand and roundwood consumption, or by handling the product similar to the already implemented final products.

Also with FOHOW there are some problems that cannot be solved:

(1) A further disaggregation of the competing region is hardly possible.

(2) This model will always produce long-term results, which cannot be used as time-specific and exact forecasts.

(3) Because exogenous influences in the future can only be assumptions, considering historical developments, the model will always reflect history to a certain degree, and this may not be a good guide to the future.

5.4 Concluding remarks

Both of the models have their strengths and weaknesses. Both models are an attempt to cover the whole forest sector and thus allow more insight into this sector than many less comprehensive models. Beside structural problems, their general disadvantage is certainly the lack of detail. The ATM and FOHOW should be considered as first-generation models that require additional development to realize their full potential as analytical systems.

6 Summary

Two separate macroeconomic computer-based models have been developed to study long-term trends of forest products markets. Both models try to cover the entire Austrian forest sector with its internal and external relationships, from biological aspects, like wood increment, to economic aspects, like paper consumption.

The "Austrian Model of Production, Consumption and Trade in Forest Products" (ATM) is a partial market-equilibrium model cast in a non-linear programming framework, based on the "Global Trade Model" (GTM) developed at IIASA. It divides the globe into nine countries/regions with Austria as the center. Starting with 1980 and up to 2030, every five years for all nine regions, the model calculates production, consumption, trade and prices of fourteen forest products.

As the name "Simulation Model of the Austrian Forest Sector" (FOHOW) suggests, the second model uses a pure simulation approach, based on the System Dynamics language Dynamo. FOHOW is mainly a national model representing only two regions: Austria and a fictitious outside region as the aggregation of all important Austrian trade partners in forest products. Starting with 1965 and up to 2030, on a yearly basis, the model calculates production, consumption, trade and prices of nine forest products.

Using historical trends, conservative assumptions for exogenous variables were implemented for base runs with both models to serve the purpose of creating reference scenarios for the evaluation of other scenarios with changed assumptions. According to the high growth rates of population and per capita income in developing countries, the major changes in the ATM base-run occur in trade between developed and developing countries. While Austrian exports of coniferous sawnwood to regions outside of Europe are small in 1980, they make up about half of the exports in 2030. FOHOW base-results are less dramatic than those of the ATM, the main reason being that the outside region is formulated after the European situation and does not reflect developments in the Third World.

Both models were used to test scenarios with changed assumptions for exogenous variables. Alternative scenarios concerning economic growth, forest decline, exchange rates, and imports were run.

In comparing results of the base-runs and the scenario-runs for both models, it is obvious that differences occur mainly because of the different regional aggregation and not so much because of different model approaches (optimization and simulation). This emphasizes the need to have a clear understanding of model structures and underlying assumptions for interpreting results.

Both models cannot be seen as "final products" but have to be developed further to move them closer to reality. This means investments into software as well as improvements of data and model structure. Because of model complexity and comprehensiveness, there are strong limits on further disaggregating the models in terms of products and regions.

7 References

Baudin, A. 1988. Long-Term Economic Development and Demand for Forest Products. *WP-88-05.* International Institute for Applied Systems Analysis, Laxenburg, Austria.

Bigsby, H. and Kornai, G. 1987. Forest products consumption, production and trade from an oceanic perspective, adapting the Global Trade Model. Pages 87–93 in P.A. Cardellichio, D.M. Adams and R.W. Haynes, eds. *Forest Sector Models: Theorie and Application.* Proceedings of an International Symposium, November 3–4, 1987, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, USA.

Binkley, C. and Dykstra, D. 1987. Timber supply. Pages 508–533 in M. Kallio, D. Dykstra and C. Binkley, eds. *The Global Forest Sector – An Analytical Perspective.* John Wiley & Sons, New York.

BHWR (Bundesholzwirtschaftsrat). 1972. *Die Entwicklung der Österreichischen Forst- und Holzwirtschaft im Jahre 1971* (The Development of the Austrian Forest Sector in the Year 1971). Annual Report. Vienna, Austria.

BHWR (Bundesholzwirtschaftsrat). 1977. *Die Entwicklung der Österreichischen Forst- und Holzwirtschaft im Jahre 1976* (The Development of the Austrian Forest Sector in the Year 1976). Annual Report. Vienna, Austria.

BHWR (Bundesholzwirtschaftsrat). 1980. Holzbilanzstudie 1926–1978 (79) des Bundesholzwirtschaftsrates (Timber balance study 1926–1978 (79) of the Federal Timber Council). *Holzkurier* 48 (Special Edition).

BHWR (Bundesholzwirtschaftsrat). 1982. *Die Entwicklung der Österreichischen Forst- und Holzwirtschaft im Jahre 1981* (The Development of the Austrian Forest Sector in the Year 1981). Annual Report. Vienna, Austria.

BHWR (Bundesholzwirtschaftsrat). 1987. *Die Entwicklung der Österreichischen Forst- und Holzwirtschaft im Jahre 1986* (The Development of the Austrian Forest Sector in the Year 1986). Annual Report. Vienna, Austria.

BMLF (Bundesministerium für Land und Forstwirtschaft). 1966. *Jahresbericht über die Forstwirtschaft 1965* (Annual Report on Forestry 1965). Vienna, Austria.

BMLF (Bundesministerium für Land und Forstwirtschaft). 1972. *Jahresbericht über die Forstwirtschaft 1971* (Annual Report on Forestry 1971). Vienna, Austria.

BMLF (Bundesministerium für Land und Forstwirtschaft). 1981. *Jahresbericht über die Forstwirtschaft 1980* (Annual Report on Forestry 1980). Vienna, Austria.

BMLF (Bundesministerium für Land und Forstwirtschaft). 1982. *Jahresbericht über die Forstwirtschaft 1981* (Annual Report on Forestry 1981). Vienna, Austria.

BMLF (Bundesministerium für Land und Forstwirtschaft). 1987. *Jahresbericht über die Forstwirtschaft 1986* (Annual Report on Forestry 1986). Vienna, Austria.

BMLF (Bundesministerium für Land und Forstwirtschaft). 1988. *Jahresbericht über die Forstwirtschaft 1987* (Annual Report on Forestry 1987). Vienna, Austria.

Cardellichio, P.A. and Adams, D.M. 1987. U.S. experience with the Global Trade Model. Pages 41–51 in P.A. Cardellichio, D.M. Adams and R.W. Haynes, eds. *Forest Sector Models: Theorie and Application.* Proceedings of an International Symposium, November 3–4, 1987, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, USA.

Cardellichio, P.A. and Adams, D.M. 1988. *Evaluation of the IIASA Model of the Global Forest Sector.* Working Paper 13. Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, USA.

Cavanna, R.Y. 1983. *Managing the Plantations in New Zealand.* Dissertation. University of Bradford, New Zealand.

Deringer, P. 1980. Betriebsvergleich 1979 aus der Sägeindustrie (Economic comparison of sawmill plants 1979). *Holzkurier* 47:17–19.

Deringer, P. 1981. Einmal Gewinn in sechs dürren Jahren (Finally a profit after six poor years). *Holzkurier* 47:12–15.

Deringer, P. 1986. Wie kommen wir aus der Krise? (How do we get out of the crisis?). *Holzkurier* 46:5–9.

Dykstra, D. and Kallio, M. 1987. Scenario variations. Pages 648–672 in M. Kallio, D. Dykstra and C. Binkley, eds. *The Global Forest Sector - An Analytical Perspective.* John Wiley & Sons, New York.

ECE/FAO (Economic Commission for Europe/Food and Agriculture Organisation). 1982. Conversion factors for forest products. *Timber Bulletin for Europe.* Volume XXXIV, Supplement 12. Geneva, Switzerland.

ECE/FAO (Economic Commission for Europe/Food and Agriculture Organisation). 1984. Survey of the wood-based panel industries. *Timber Bulletin for Europe.* Volume XXXVII, Supplement 2. Geneva, Switzerland.

ECE/FAO (Economic Commission for Europe/Food and Agriculture Organisation). 1985. Special issue: Survey of the structure of the saw-milling industry. *Timber Bulletin.* Volume XXXVIII, Number 3. Geneva, Switzerland.

ECE/FAO (Economic Commission for Europe/Food and Agriculture Organisation). 1986. *European Timber Trends and Prospects to the Year 2000 and Beyond.* Volumes 1 and 2. New York.

ECE/FAO (Economic Commission for Europe/Food and Agriculture Organisation). 1987a. *Conversion Factors for Forest Products 1983.* GE.87-40197. New York.

ECE/FAO (Economic Commission for Europe/Food and Agriculture Organisation). 1987b. Survey of the wood-based panel industries 1986. *Timber Bulletin.* Volume XL, Number 3, Supplementary Information. New York.

Fachverband der Säge-Industrie Österreichs. 1984. Jahresbericht 1983 des Fachverbandes der Sägeindustrie Österreichs (Annual report 1983 of the Association of Austrian Sawmills). Pages 5–12 in *Sägerinformation.* Number 3. Vienna, Austria.

Fachverband der Säge-Industrie Österreichs. 1988. Jahresbericht 1987 des Fachverbandes der Sägeindustrie Österreichs (Annual report 1987 of the Association of Austrian Sawmills). Pages 5–12 in *Sägerinformation.* Number 4. Vienna, Austria.

FAO (Food and Agriculture Organisation of the United Nations). 1963. *Yearbook of Forest Products Statistics 1963.* Rome, Italy.

FAO (Food and Agriculture Organisation of the United Nations). 1975. *Yearbook of Forest Products 1964–1974.* Rome, Italy.

FAO (Food and Agriculture Organisation of the United Nations). 1981. *Pulp and Paper Capacities 1980–1985.* Rome, Italy.

FAO (Food and Agriculture Organisation of the United Nations). 1982. *World Forest Products Demand and Supply 1990 and 2000.* FAO Forestry Paper 29. Rome, Italy.

FAO (Food and Agriculture Organisation of the United Nations). 1986a. *Yearbook of Forest Products 1975–1985.* Rome, Italy.

FAO (Food and Agriculture Organisation of the United Nations). 1986b. *Forest Products World Outlook Projections 1985–2000.* Rome, Italy.

FAO (Food and Agriculture Organisation of the United Nations). 1988. *Yearbook of Forest Products 1975–1986.* Rome, Italy.

FBVA (Forstliche Bundesversuchsanstalt). 1973. *Österreichische Forstinventur 1961/70* (Austrian Forest Inventory 1961/70). Volumes 1 und 2. Vienna, Austria.

FBVA (Forstliche Bundesversuchsanstalt). 1985. *Österreichische Forstinventur 1971/80 – Zehnjahresergebnis* (Austrian Forest Inventory 1971/80 – Results of the Decade). Vienna, Austria.

FBVA (Forstliche Bundesversuchsanstalt). 1986. *Österreichische Forstinventur 1981–90, Auswertung 1981–85* (Austrian Forest Inventory 1981–90, Results of 1981–85). Vienna, Austria.

Forrester, J.W. and Senge, P.M. 1980. Tests for building confidence in system dynamics models. In Legasto et al., eds. *System Dynamics: TIMS Studies in the Management Sciences.* Volume 14. North Holland Publishers, Amsterdam.

Friedman, M. 1976. *Price Theory.* De Gruyter, New York.

Institut für Forst- und Holzwirtschaftspolitik. 1970. *Umrechnungszahlen 1970* (Conversion Figures 1970). Vienna, Austria.

Kallio, M. 1987. Forest industry modules. Pages 534–560 in M. Kallio, D. Dykstra and C. Binkley, eds. *The Global Forest Sector – An Analytical Perspective.* John Wiley & Sons, New York.

Kallio, M., Dykstra, D. and Binkley, C., eds. 1987. *The Global Forest Sector – An Analytical Perspective.* John Wiley & Sons, New York.

Kornai, G. 1987. Trade barriers and inertia in international trade. Pages 569–578 in M. Kallio, D. Dykstra and C. Binkley, eds. *The Global Forest Sector – An Analytical Perspective.* John Wiley & Sons, New York.

Kornai, G. and Schwarzbauer, P. 1987. The Austrian model of production, consumption and trade in forest products (ATM). Pages 71–78 in P.A. Cardellichio, D.M. Adams and R.W. Haynes, eds. *Forest Sector Models: Theorie and Application.* Proceedings of an International Symposium, November 3–4, 1987, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, USA.

Linstone, H.A. 1978. Von der Theorie zur Praxis: Die fehlenden Stufen (From theory to practical work: The missing links). Pages 393–406 in G. Bruckmann, ed. *Langfristige Prognosen* (Long-Term Forecasting). Physica Verlag, Würzburg and Vienna.

Lönnstedt, L. 1983. Mathematical Formulation of a Forest Sector Prototype Model. *WP-83-69.* International Institute for Applied Systems Analysis, Laxenburg, Austria.

Lönnstedt, L. and Schwarzbauer, P. 1984. The Austrian Sawmill Industry – Some Possible Futures. *WP-84-33.* International Institute for Applied Systems Analysis, Laxenburg, Austria.

Mantau, U. 1981. *Rohstoffmarkt Holz – Strukturen, Entwicklungen und Preise in der Bundesrepublik Deutschland* (Raw-Material Market – Structures, Developments and Prices in the FRG). Hochschulverlag, Freiburg i. Br., Federal Republic of Germany.

Meyer, P. 1982. Die Preiselastizitäten des schweizerischen Holzmarktes (The price elasticities of the Swiss wood market). *Schweizerische Zeitschrift für Forstwesen* 12:1045–1057.

Nilsson, S. 1987. A critical review of the GTM: A Swedish viewpoint. Pages 53–62 in P.A. Cardellichio, D.M. Adams and R.W. Haynes, eds. *Forest Sector Models: Theorie and Application.* Proceedings of an International Symposium, November 3–4, 1987, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, USA.

Ollmann, H. 1988. Der Holzmarkt – ein bisher erst oberflächlich bearbeitetes Forschungsobjekt (The wood market – A so far only superficially researched object). *Forstarchiv* 4:123–127.

Österreichischer Agrarverlag, ed. 1987. *Österreichisches Holz-Jahrbuch 1987* (Austrian Yearbook of Wood 1987). Vienna, Austria.

Österreichischer Agrarverlag, ed. 1989. *Österreichisches Holz-Jahrbuch 1989* (Austrian Yearbook of Wood 1989). Vienna, Austria.

Österreichischer Arbeiterkammertag. 1988. *Wirtschafts- und Sozialstatistisches Taschenbuch 1988* (Yearbook of Economic and Social Statistics 1988). Verlag der Arbeiterkammer, Vienna, Austria.

Österreichisches Holzforschungsinstitut. 1981. Holz in Österreich 1980 bis 2000: Aufkommen-Angebot-Bedarf-Nachfrage (Wood in Austria 1980 to 2000: Production-supply-consumption-demand). *Holzkurier* 39.

ÖstZA (Österreichisches Statistisches Zentralamt). 1965. *Land- und Forstwirtschaftliche Betriebszählung vom 1. Juni 1960, Gesamtergebnisse für Österreich, Teil B. Forstwirtschaft* (Agricultural Census of June 1, 1960, Results for all of Austria, Part B, Forestry). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1967. *Industriestatistik 1966* (Industrial Statistics 1966). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1977. *Ergebnisse der Land- und Forstwirtschaftlichen Betriebszählung 1970, Österreich, Teil 2. Forstwirtschaft* (Results of the Agricultural Census 1970, Austria, Part 2, Forestry). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1978. *Industriestatistik 1977* (Industrial Statistics 1977). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1979a. *Hauptergebnisse der nichtlandwirtschaftlichen Bereichszählung 1976, Teil 2* (Main Results of the Non-Agricultural Census of the Production Sector 1976, Part 2). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1979b. *Österreichs Volkseinkommen 1964–1977* (Austrian GDP 1964–1977). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1983. *Land- und Forstwirtschaftliche Betriebszählung 1980, Hauptergebnisse Österreich, Section Forstwirtschaft* (Agricultural Census 1980, Main Results for Austria, Section Forestry). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1986. *Hauptergebnisse der nichtlandwirtschaftlichen Bereichszählung, Teil 2* (Main Results of the Non-Agricultural Census of the Production Sector, Part 2). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1987a. *Industrie- und Gewerbestatistik 1986, Teil 1* (Industrial and Manufacturing Statistics 1986, Part 1). Vienna, Austria.

ÖstZA (Österreichisches Statistisches Zentralamt). 1987b. *Österreichs Volkseinkommen 1986* (Austrian GDP 1986). Vienna, Austria.

Pestel, E. 1988. *Jenseits der Grenzen des Wachstums – Bericht an den Club of Rome* (Beyond the Limits to Growth – Report to the Club of Rome). Deutsche Verlags-Anstalt, Stuttgart, Federal Republic of Germany.

Prime Computer. 1973. *Dynamo: RGB 73-12-16, Dynamo Processor.* SD Software installed on the Prime 99552 at the University of Agriculture, Vienna, Austria.

Schwarzbauer, P. 1984. *Dynamo – eine Schreibweise für "System Dynamics Modelle"* (Dynamo – A Language for "System Dynamics Models"). Materials for the introduction of Dynamo at the Computing Center of the University of Agriculture, Vienna, Austria.

Schwarzbauer, P. 1987. Österreichs Nachfrage nach Holzprodukten im internationalen Vergleich, Teil 1: Historische Trends. (Austrian demand of wood products as compared to international developments, part 1: Historical trends). *Centralblatt für das gesamte Forstwesen* 4:225–263.

Schwarzbauer, P. 1988. Österreichs Nachfrage nach Holzprodukten im internationalen Vergleich, Teil 2: Die Schätzung von Nachfragegleichungen (Austrian demand of wood products as compared to international developments, part 2: The estimation of demand functions). *Centralblatt für das gesamte Forstwesen* 2:63–104.

Schwarzbauer, P. 1989. *Der Österreichische Holzmarkt im Modell – Wirkungsanalysen holzmarktrelevanter Entwicklungen und wirtschaftspolitischer Entscheidungsmöglichkeiten* (Models of the Austrian Wood Market – Impact Analyses of General Development and Macroeconomic Decisions). Inaugural Dissertation. University of Agriculture, Vienna, Austria.

Sommer, M. 1981. *System Dynamics und Makroökonometrie – Dynamische makroökonomische Modellierung in multimethodologischer Sicht* (System Dynamics and Macroeconometrics – Dynamic Macroeconomic Modelling from a Multi-Methodological Viewpoint). Haupt, Bern and Stuttgart.

Sterba, H. and Griess, O. 1983. *Sortentafeln für Fichte* (Assortment Tables for Spruce). Österreichischer Agrarverlag, Vienna, Austria.

Sterba, H., Kleine, M. und Eckmüllner, O. 1986. *Sortentafeln für Tanne, Lärche, Kiefer und Buche* (Assortment Tables for Fir, Larch, Pine and Beech). Österreichischer Agrarverlag, Vienna, Austria.

Takayama, T. and Labys, W.C. 1986. Spatial equilibrium analysis. Pages 171–199 in P. Nijkamp, ed. *Handbook of Urban and Regional Economics, Volume 1.* North Holland.

Vereinigung Österreichischer Papierindustrieller. 1965–1988. *Die österreichische Papierindustrie 1964–1987* (The Austrian Paper Industry 1964–1987). Annual Report. Vienna, Austria.

Weeks, J. 1987. Using the IIASA Global Trade Model to examine the location effects of ocean shipping on developing country timber producers. Pages 79–85 in P.A. Cardellichio, D.M. Adams and R.W. Haynes, eds. *Forest Sector Models: Theorie and Application.* Proceedings of an International Symposium, November 3–4, 1987, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, USA.

Wibe, S. 1984. Demand Functions for Forest Products. *WP-84-103.* International Institute for Applied Systems Analysis, Laxenburg, Austria.

Wisdom, H.W. 1987. The transportation cost model. Pages 579–591 in M. Kallio, D. Dykstra and C. Binkley, eds. *The Global Forest Sector – An Analytical Perspective.* John Wiley & Sons, New York.