LONG-TERM FORECASTING OF INTERNATIONAL FOREST PRODUCT MARKETS: THE GFPM MODEL AND IMPLICATIONS FOR EUROPE[1]

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ABSTRACT. —The Global Forest Products Model (GFPM) was developed to upgrade the FAO methodology for forest products outlook projections. Its purpose is to analyze and project the consumption, production, trade, and prices of forest products. The system deals with 180 individual countries, three classes of roundwood, sawnwood, three kinds of panels, three of pulp, waste paper, and three types of paper and paperboard. The system is built on market equilibrium theory, with imperfect foresight. The short-term equilibrium is modeled by price-endogenous linear programming determining production, consumption, trade, and market-clearing prices in any given year, subject to short-term capacities of production. Year to year changes are represented by equations predicting shifts in demand due to GDP growth, capacity expansion as a function of profitability, and technical change. The forecasts are conditional on exogenous estimates of timber availability in each country. Inertia constraints limit the short-term adjustment of trade in response to market forces. Results of applications of the model to forecast the situation in European countries until 2010 are described.

INTRODUCTION

Forest products are vital commodities for the sustenance and growth of every country in the world. The FAO is responsible for producing long-term projections of future consumption, production and trade of forest products, by country. The objective of this study was to revamp and make operational the FAO system for global forest products outlook projections.

The approach was to develop a dynamic spatial equilibrium model of the world forest sector. Then, the model was applied to project forest products consumption, production and trade under the most likely scenario of economic growth and timber supply constraints. As in past FAO projections, the assumed rates of economic growth, measured by GDP are critical in determining final demand. A new feature are the constraints defining the timber supply potential of each

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country. The projected demand for final products in the world cannot exceed the global wood growing potential, after allowing for trade in raw materials or finished products between countries. Depending on market conditions, less wood may be cut that can potentially be produced, but not more. Therefore, the assumptions regarding timber supply potential are also critical. Given the uncertainties surrounding these elements, three scenarios were simulated.

The first part of the paper introduces the methodology of the Global Outlook Study model of 1998 (GFPM), describes the countries/regions and the products included in the model, and discusses the demand equations and the supply constraint assumptions. Part two summarizes projections for 1995 to 2010 of consumption, production and trade in the main regions of the world.

THE GLOBAL OUTLOOK MODEL (GFPM)

The GFPM model, was developed with the Price Endogenous Linear Programming System (PELPS III) (Zhang et al. 1993). PELPS is a general modeling tool for sector analysis. It finds a spatial, competitive equilibrium by maximizing the sum of producer and consumer surplus subject to material balance and capacity constraints in each country, for each year. Because material flows throughout the system must balance, it help check the consistency of data, and insures the coherence of projections.

In each projection year, for each country and commodity, supply (domestic production plus imports) is equal to demand (final consumption, plus input in other processes, plus exports). Demand for wood or intermediate products derives from the demand for final products through input-output coefficients that describe the technology in each country. The supply of raw wood in each country is constrained by the wood supply potential. The supply of recycled paper is constrained by the waste paper supply, which depends on paper consumption and recycling rates. Imports and exports are balanced, at world level and in each country. And, the projected prices for each commodity are such that they clear markets: at those prices demands are equal to supplies in each country.

From one year to the next, demand changes in each country due to assumed changes in income. The wood supply potential changes according to the chosen scenario. Technology also changes, especially the amount of recycled fiber used in making paper and paperboard. Capacity increases or decreases according to new investments that depend on past production and the profitability of production in different countries, as revealed by the shadow price of capacity. Then, a new equilibrium is computed subject to the new demand and supply conditions, new technology, new capacity, and inertia constraints that limit the change in exports and imports from year to year. The general principle of the PELPS system is, then, that markets optimize the allocation of resources in the short run (within one year). Long run resource allocation is partly governed by market forces, as in capacity expansion and trade, and also by other forces such as: the wood supply potential determined by forest policy, the waste paper recovery rates by environmental policy, the trade inertia that depend in part on international agreements, and the techniques of production determined by exogenous progress.

This system has been used to develop the North American pulp and paper model (NAPAP), the North American solid wood model (NASAW), and by the International Tropical Timber Organization (ITTO) to develop the Asia-Pacific Tropical Timber Trade model. The Asia-Pacific Forest Products Model of Zhang et al. 1996, is also based on the PELPS system. The GFPM model is a natural extension of past FAO methodology. The demand for forest products continues to depend critically on income. The additions are: a detailed description of supply linked to demand so that production and consumption projections are fully consistent, and, prices that clear markets, as they must in the real world. The mathematical formulation of the model is given below.

Hierarchical Structure

The GFPM model has a hierarchical structure. It consists of one main model called WORLD, and one sub-model for each region: AFRICA, AMERICAS, ASIA/OCEANIA and EUROPE/FORMER USSR, each one solved with trade flows that are consistent with the WORLD model.

Each region of the WORLD model has: (1) demand (consumption) of fuelwood, other industrial roundwood, sawnwood, veneer & plywood, particle board, fiberboard, newsprint, printing & writing paper and other paper & paperboard; (2) production (supply) of fuelwood, industrial roundwood, other fiber pulp, waste paper, sawnwood, veneer & plywood, particle board, fiberboard, mechanical pulp, chemical pulp, newsprint, printing & writing paper and other paper & paperboard. Also, each region imports from and exports to the “world market”.

A similar structure applies to the regional sub-models. For example, in the AMERICAS sub-model, there are 35 countries, each with a demand and supply of the same products as in the WORLD model. Each country has imports from and exports to the “world market”. However, the total imports and exports of all countries in, say, the AMERICAS are constrained to be equal to the total imports and exports of the AMERICAS in the WORLD model.

Countries and products

The countries in each sub-model are those recognized in the FAO Yearbook of Forest Products. The AFRICA sub-model has 50 countries, the AMERICAS has 35, ASIA/OCEANIA has 50, and EUROPE/FORMER USSR has 45 countries. In addition to country detail, seven regions and two economic classes are used in reporting the results.

GFPM has final demand equations for fuelwood & charcoal, other industrial roundwood, sawnwood, veneer sheets & plywood, particle board, fiberboard, newsprint, printing & writing paper, and other paper & paperboard. The supply equations for fuelwood & charcoal, industrial roundwood, and other fiber pulp are horizontal, up to the maximum sustainable production. Waste paper supply is constrained by the quantity of paper recovered, a function of paper consumption.

Demand

The demand equations of GFPM assume that national demand for forest products is determined by economic activity (GDP) and real prices. Let q_{it} (of price p_{it}) be the amount of a forest product consumed or imported by a country i during year t; with i_{it} an index of the price of all other goods and services used in combination with this product to produce an output designated by the variable y_{it}, here the real gross domestic product. Then, assuming cost minimization under a Cobb-Douglas technology with constant returns to scale, coupled with a partial adjustment of actual towards desired consumption, leads to the following derived demand (Chou and Buongiorno 1984, Baudin and Lundberg 1987):

$$\ln(q_{it}) = \alpha_i + \beta \ln(\frac{p_{it}}{i_{it}}) + \gamma \ln(y_{it}) + \delta \ln(q_{it-1}) + u_{it}$$

For estimation, all countries in the world were divided into high, medium, and low income countries. The data on production, imports and exports were obtained from (FAO 1996). GDPs were measured in constant US dollar with data from World Bank (1995). The parameters were estimated by covariance analysis, one examples is in Table 1.

In the GFPM model, prices are endogenous (the equilibrium between demand and supply leads to the prices). Only national GDPs shift demands, and are strictly exogenous. Three scenarios regarding GDP growth were assumed. In the median scenario, Africa grew at 3.2 per cent per year in 1995, increasing to 3.4 percent in 1996 and then approaching 2.3 percent by 2010. For North and Central America, GDP grew at 1.8% per year in 1996, to 2.2% by 2010. In South America, growth that began at 1.1% in 1995 increased to 3.5 % in the first years of projection and then declined to 3% in 2000 and 2.3% in 2010. Asia continued to grow fast in the projections, but at lower rates. Growth began at 8.4% in 1995 and then declined progressively to 2.9% in 2010. In Europe, growth that started at 2.1% in 1996 was assumed to increase to 2.6% by 2000 and reach 2.3% by 2010. The former USSR projections assumed a progressive recovery, ending with a 2.5% GDP growth rate by 2010.

Wood Supply Constraints

A feature of GFPM is the application of explicit limits to the supply of timber and other raw materials in each country. The supplies of fuelwood and charcoal, industrial roundwood (logs, chips, particles, wood residues, and other industrial roundwood), other fiber pulp, and waste paper were represented by a reservation price, assumed to be equal to the world price, up to the sustainable production potential. This implies that the cost of production is constant up to the production potential. Costs and prices would then rise sharply when the potential was reached.

The maximum potential roundwood supplies in 1994 and 2010 for three scenarios were set as maximum growth rates, the actual supply could be less depending on demand, but it could not be more. Three scenarios were meant to cover the range of possible supplies, in each country. They were based on various information, FAO 1995a, UN-ECE/FAO 1993. In total, the growth rate of the world roundwood supply potential was assumed to be about 0.9%, 1.3% and 1.9%, depending on the scenario. The medium assumption was near those of Brooks et al. (1996).

Other Assumptions

Other assumptions governing the projections concerned changes in capacity, fiber input mix, and trade inertia constraints. In PELPS, capacity is governed by past production and by relative profitability. The simplest projection method of PELPS were used. It consisted of distributed-lag functions linking capacity changes to changes in past production at the global level, followed by allocating capacity growth to different countries according to the shadow price (the marginal value of one unit of additional capacity) revealed by the equilibrium computations (Gilless and Buongiorno 1987).

The technology, defined by input-output coefficients was held constant at the 1994 level, except for paper and paperboard. There, it was assumed that the fiber input mix for newsprint, printing and writing paper and paper and paperboard would change substantially between 1994 and 2010. The share of other fiber pulp would increase from 7.6% to 10.8% worldwide, while that of recycled paper would increase from 36.5% to 45.6% worldwide, and to nearly 50% in Europe. The potential recovery rates were allowed to reach 40% to 60% of paper and paperboard consumption, depending on the region. However the actual recovery rates projected by the model as a result of market forces were lower.

The levels and trends of trade in forest products are determined by a wide range of factors of which only the main elements were recognized– levels of demand, costs of wood and costs of other factors. With the implementation of GATT-WTO, the member countries should reduce or eliminate trade tariffs and non-trade barriers. However the adjustment of trade flows is bound to take time, thus inertia constraints were introduced to limit trade in a given year to be within a specified fraction of the previous year's trade (Buongiorno and Gilless 1984, Kallio et al. 1987, Zhang and Buongiorno 1996). The trade inertia in scenario 1 and 2 constrained exports and imports of a country in a given year to be within 5 to 15% of that in the previous year. Scenario 3 assumed that trade enhancing policies would be such that the yearly variation of imports or exports could be between 10 and 20%.

GLOBAL OUTLOOK TO 2010

The GFPM model has been applied to project production, consumption, exports and imports from 1995 to 2010, under each scenario. The detailed tables by country and product are in FAO (1997)[3]. The projections indicate that the global demand for forest products should continue to rise, pulled by the demand in rapidly growing economies, especially in Asia. The total roundwood consumption and production would reach 3.9 billion m^3 by the year 2010, for an average growth rate of 1% per year, but faster in the former USSR (Table 3). Of this, about 2 billion m^3 would be fuelwood consumed largely in developing countries. World sawnwood consumption, at near 470 million m^3 would be lower in 2010 than in 1990, due to the sharp decline in the former USSR from 1990 to 1994, not fully recovered by 2010. In the rest of the world, sawnwood consumption would be slightly higher than in 1990 (Table 4). Wood-based panels consumption would total 170 million m^3 worldwide by 2010, growing at an average of 1.6% per year in developed countries and 3.2% per year in developing, with plywood, particleboard and fiberboard maintaining approximately constant shares (Table 5). Paper consumption is expected to grow the fastest, averaging 2% per year in developed countries and 4% per year in developing, leading to a world consumption of 400 million metric tons in 2010.

[3] Alternative projections are available in Zhu et al. (1998).

In 2010, Asia is projected to be the largest net importer, for all products (Figure 1 to 4). South America and the former USSR would become the main net exporters of industrial roundwood. North/Central America and the former USSR would be the main exporters of sawnwood, while for panels that role would be taken by South America and the former USSR. Europe and North/Central America would be the main net exporters of paper and paperboard.

Under the medium scenario, the real prices of industrial roundwood, sawnwood and wood-based panels are projected to change little until the year 2010 (Figure 6). The real prices of paper and paperboard would also generally remain constant (Figure 7). Strong price increases were obtained in the scenario assuming the lowest potential timber supply, but even then paper products would be less affected due to the growth in the world waste paper recovery (Figure 5).

For comparison, Table 6 summarizes the projections of the European Timber Trends Study (ETTS V, Baudin and Brooks, 1995). The projections of this study tend to be lower for consumption, the main difference being for total paper and paperboard. For production, the projections for total paper and paperboard, sawnwood and wood-based panels are close, and so are the projections of production for each paper grade. The largest relative differences are in the production of different types of panels: the forecasts of plywood and fiberboard production are higher in this study, while those of particleboard are lower.

APPENDIX: Mathematical formulation of GFPM

GFPM was built with the general PELPS III structure (Zhang et al., 1993). It simulates a dynamic market equilibrium for the global forest sector. Every year, demand, supply, trade and prices are computed that clear markets for all products and in all regions (static phase). Then, the model parameters are updated to reflect exogenous and endogenous changes from one year to the next (dynamic phase). Yearly exogenous changes include economic growth, technical change, potential timber supply and trade inertia, they are assumptions. Yearly endogenous changes include capacity growth and availability of recycled fibers, they are determined by the model. The model then computes the quantity-price equilibrium next year as shaped by the intervening changes. It reiterates the static and dynamic phases for every year until the end of the projection.

Static phase

The equilibrium for each year of the projection is obtained with an optimization model that simulates world markets. It finds the production, consumption and trade that maximizes the total value of consumption minus the total cost of production for all products in all countries, in a given year. All the variables refer to that year.

Objective function:

$$\max Z = \sum_i \sum_k \int_0^{D_{ik}} P_{ik}(D_{ik})\, dD_{ik} - \sum_i \sum_k \int_0^{S_{ik}} P_{ik}(S_{ik})\, dS_{ik} - \sum_i \sum_k Y_{ik} m_{ik}$$

where: i,k = country, commodity, P = price in US dollars, D = final product demand, S = raw material supply, Y = quantity manufactured, m = cost of manufacture.

Demand for final products:

$$D_{ik} = a_{ik} P_{ik}^{\ \sigma_{ik}} X_i^{\ \alpha_{ik}} D_{ik,-1}^{\ \ \eta_{ik}}$$

where: D_{-1} = demand in the previous year, X = gross domestic product, in real US dollars, σ,α,η = elasticities with respect to price, GDP, and past demand.

Wood supply:

$$P_{ik} = P_{ik}^{\ 0} \quad with \ \ S_{ik} \le S_{ik}^{\ U}$$

where: P^0 = cost of production, S^u = potential supply.

Material balance:

$$\sum_j T_{jik} + S_{ik} + Y_{ik} - D_{ik} - \sum_n a_{ikn} Y_{in} - \sum_j T_{ijk} = 0 \qquad \forall i,k$$

$$T_{ijk}^L \le T_{ijk} \le T_{ijk}^u \qquad \forall i,j,k$$

where: a_{ikn} = input of commodity k per unit of n, T = trade flow. Each country exports to and imports from a "world market", T^u, T^L = upper and lower bounds on imports and exports.

Manufacturing capacity:

$Y_{ik} \le K_{ik} \quad \forall i,k$ where: K = current capacity of production.

Waste paper recovery:

$S_{ir} \le S_{ir}^U \quad \forall i,r$ where: r = recycled paper, S^U = upper bound on recycled paper supply.

Dynamic phase:

Yearly changes in the market equilibrium constraints are brought about by:

1) shifts of the demand curves, due to changes in X at the projected GDP growth rate,

2) shifts of the upper bounds on wood supply, S, at the assumed rate of growth of potential supply,

3) changes of manufacturing coefficients m to reflect technical change, especially increasing use of paper recycling,

4) changes of capacity, determined as follows: At global level, capacity change is a function of changes in production during the past three years:

$$\Delta K_k = b_{1k} \Delta Y_{k,-1} + b_{2k} \Delta Y_{k,-2} + b_{3k} \Delta Y_{k,-3}$$

then, global capacity change is allocated to each country in proportion of its production level and the marginal value of capacity revealed by the shadow price of capacity in the static phase.

$$\Delta K_{ik} = \frac{Y_{ik}^{\theta}\pi^{\varpi}}{\sum_j Y_{ik}^{\theta}\pi^{\varpi}}\Delta K_k$$

where: Δ = yearly change, π = shadow price of capacity (endogenous, from capacity constraint), b,θ,ϖ = parameters.

5) Changes in waste paper recovery:

$$S_{ir}^{U} = \sum_k w_{ikr} D_{ik,-1}$$

where: w_{ikr} = maximum possible recovery rate (exogenous).

6) Trade inertia:

$$T_{ijk}^{u} = (1+\varphi)T_{ijk,-1} \quad and \quad T_{ijk}^{uL} = (1-\varphi)T_{ijk,-1}$$

where φ = upper bound on relative change in trade flow (exogenous).

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Table 1.--Example of elasticities used in the GFPM model.

	Price	GDP	Lag	Long-term Price	Long-term GDP	R^2	DW	DF
Fuelwood								
High	-0.08	-0.34	0.71	-0.28	-1.17	0.87	2.36	320
	(0.19)	(0.12)	(0.04)*					
Low	-0.09	0.70	0.15	-0.11	0.82	0.91	2.01	225
	(0.14)	(0.29)*	(0.07)*					
World	-0.04	-0.15	0.59	-0.10	-0.37	0.89	2.31	548
	(0.12)	(0.18)	(0.03)*					
Sawnwood								
High	-0.13	0.15	0.53	-0.28	0.32	0.99	2.17	434
	(0.04)*	(0.03)*	(0.04)*					
Low	-0.07	0.19	0.66	-0.21	0.56	0.95	1.98	945
	(0.04)**	(0.06)*	(0.03)*					
World	-0.08	0.16	0.65	-0.23	0.46	0.97	2.00	1382
	(0.03)*	(0.04)*	(0.02)*					
Printing and Writing Paper								
High	-0.38	0.47	0.54	-0.83	1.02	0.99	1.95	415
	(0.06)*	(0.05)*	(0.04)*					
Low	-0.22	0.76	0.42	-0.38	1.31	0.96	2.05	793
	(0.04)*	(0.08)*	(0.03)*					
World	-0.25	0.65	0.45	-0.46	1.18	0.98	2.06	1211
	(0.03)*	(0.05)*	(0.03)*					

Note: Standard errors of short-term elasticities in parentheses. * significant at 5% level, ** at 1%.

Table 2.--Subset of GFPM input-output and manufacturing cost coefficients for Italy.

Input	Output: Newsprint	Output: Printing and writing paper	Output: Other paper and paperboard
Mechanical pulp	0.05	0.01	0.01
Chemical pulp	0.25	0.45	0.31
Other fiber pulp	0.03	0.02	0.02
Waste paper	0.70	0.56	0.70
Manufacturing cost ($/t)	246	536	486

Table 3.--Roundwood consumption (10^6 m^3)

	Actual			Projection		% yr^{-1}	
	1970	1990	1994	2000	2010	1970-1990	1994-2010
Africa	257	438	490	539	605	2.7%	1.3%
N America	471	724	727	754	792	2.2%	0.5%
S America	164	294	320	344	379	3.0%	1.1%
Asia	751	1097	1168	1267	1401	1.9%	1.2%
Oceania	24	31	30	34	36	1.4%	1.1%
Europe	351	402	352	378	412	0.7%	1.0%
Former USSR	370	375	123	195	212	0.1%	3. 5%
Developed	1284	1559	1255	1377	1464	1.0%	1.0%
Developing	1102	1803	1955	2135	2372	2.5%	1.2%
World	2387	3362	3210	3512	3836	1.7%	1.1%

Table 4.--Sawnwood consumption (10^6 m^3)

	Actual			Projection		% yr^{-1}	
	1970	1990	1994	2000	2010	1970-1990	1994-2010
Africa	6	10	9	10	12	3.0%	2.0%
N America	107	153	149	155	167	1.8%	0.7%
S America	12	24	24	26	29	3.4%	1.3%
Asia	79	112	112	114	119	1.8%	0.4%
Oceania	6.2	6.5	6.7	6.3	5.6	0.2%	-1.1%
Europe	92	103	87	96	104	0.6%	1.1%
Former USSR	113	99	24	34	38	-0.6%	3.0%
Developed	361	398	298	324	348	0.5%	1.0%
Developing	53	110	112	118	126	3.8%	0.7%
World	413	508	410	442	474	1.0%	0.9%

Table 5.--Wood-based panels consumption (10^6 m^3)

Region	Actual 1970	1990	1994	Projection 2000	2010	% yr^{-1} 1970-1990	1994-2010
Africa	0.7	1.4	1.5	1.8	2.4	3.7%	3.1%
N America	29	39	41	43	49	1.6%	1.2%
S America	1.2	3.3	3.6	4.0	4.9	5.2%	1.9%
Asia	10	24	36	42	54	4.3%	2.6%
Oceania	0.8	1.5	1.6	2.0	2.4	3.0%	2.5%
Europe	23	42	38	43	51	3.1%	1.8%
Former USSR	5	12	4	7	9	4.1%	4.9%
Developed	66	106	97	109	127	2.4%	1. 7%
Developing	4	18	28	34	46	7.5%	3.1%
World	70	123	126	143	173	2.9%	2.0%

Table 6.--Paper and paperboard consumption (10^6 t).

	Actual 1970	1990	1994	Projection 2000	2010	% yr^{-1} 1970-1990	1994-2010
Africa	1.6	3.7	3.6	4.4	5.5	4.3%	2.6%
N America	55	88	96	106	125	2.4%	1.7%
S America	3.5	8	10	12	14	4.0%	2.5%
Asia	19	62	81	102	148	6.1%	3.9%
Oceania	1.9	3.3	3.7	4.3	5.4	3.0%	2.4%
Europe	38	65	70	80	93	2.7%	1.8%
Former USSR	6.5	10	2.5	4.2	4.8	2.4%	4.2%
Developed	113	193	199	225	265	2.7%	1.8%
Developing	13	47	67	88	131	6.8%	4.2%
World	126	240	266	313	396	3.3%	2.5%

Table 7.--Alternative forecasts for Europe

	Consumption		Production	
	FAO 1997	ETTS V	FAO 1997	ETTS V
Newsprint(10^6 t)	12.2	13.9	11.5	12.1
Printing and writing paper(10^6 t)	33.6	37.6	40.2	36.5
Other paper and paperboard (10^6 t)	42.6	52.5	46.7	45.4
Total paper and paperboard (10^6 t)	88.4	104.0	98.5	93.9
Sawnwood (10^6 m^3)	89.5	97.1	75.4	81.9
Plywood(10^6 m^3)	8.6	8.1	6.3	3.2
Particleboard(10^6 m^3)	30.2	36.1	30.4	34.6
Fiberboard(10^6 m^3)	5.1	5.3	5.0	3.9
Wood Panels (10^6 m^3)	43.9	49.5	41.8	41.7

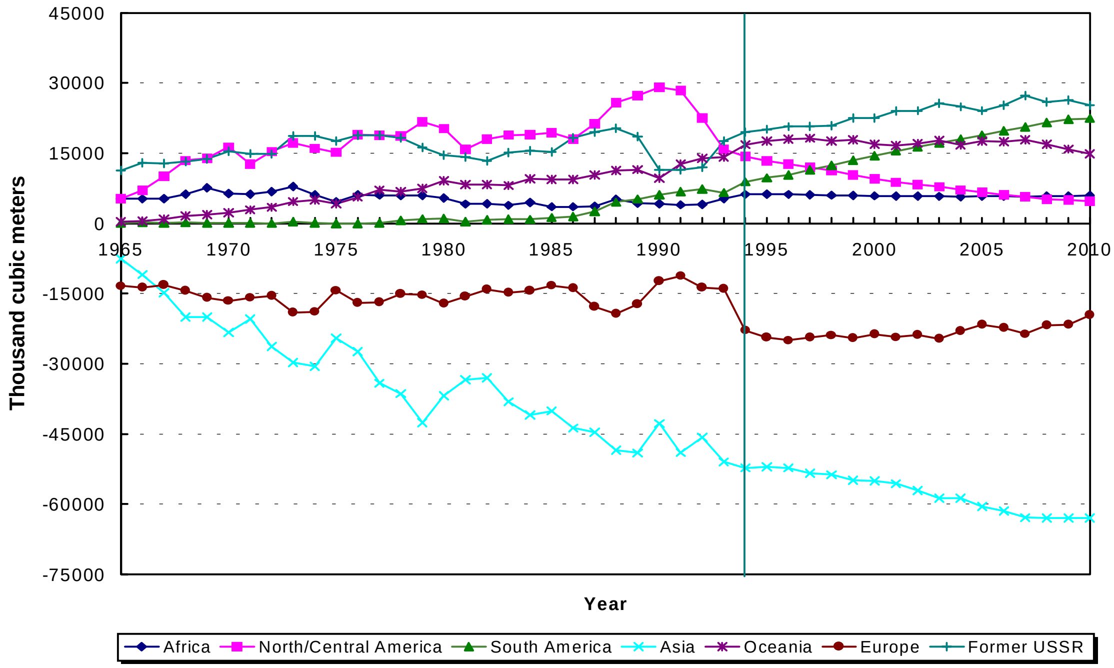

Figure 1. Industrial roundwood net trade.

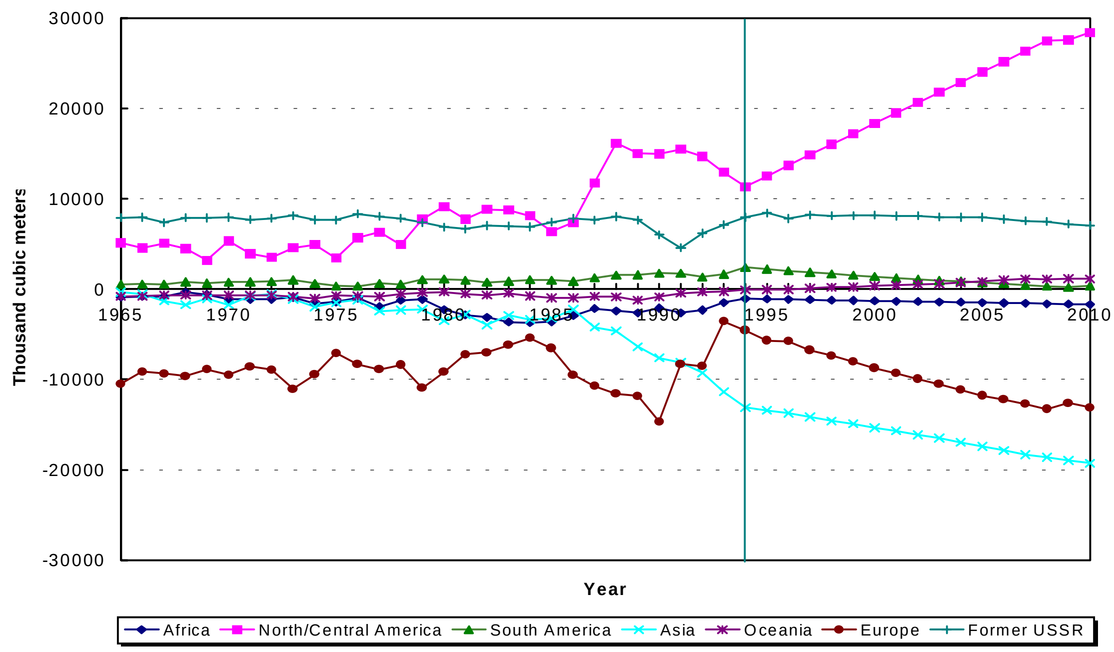

Figure 2. Sawnwood and sleepers net trade.

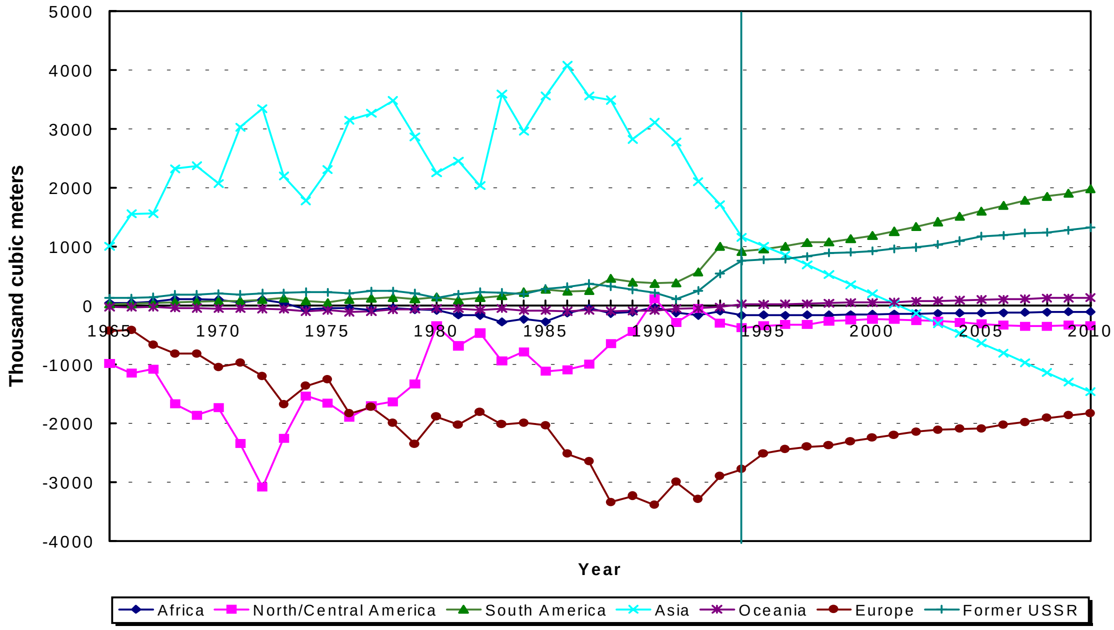

Figure 3. Veneer sheets and plywood net trade.

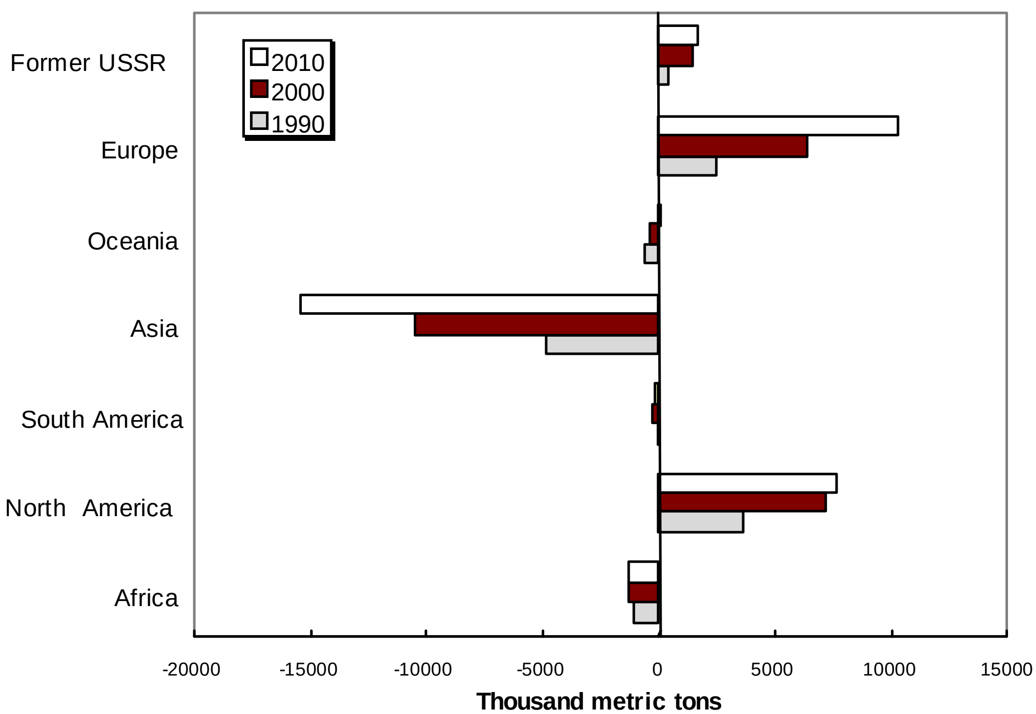

Figure 4. Paper and paperboard net trade.

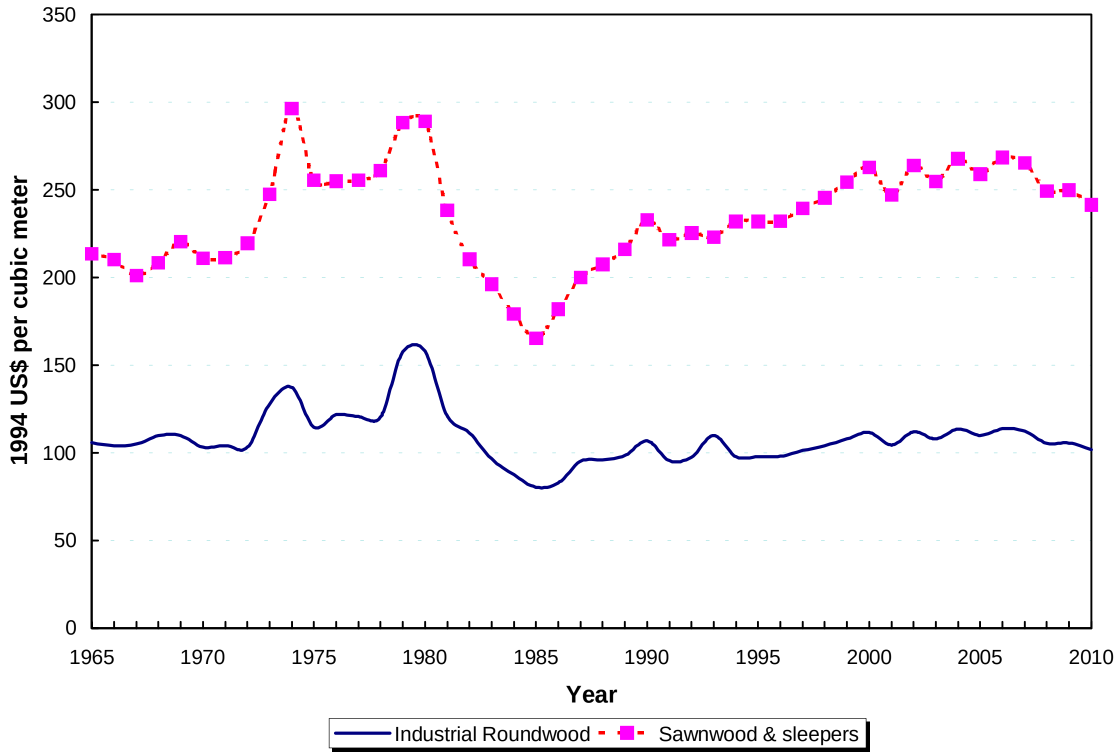

Figure 5. Real world price of solid wood products.

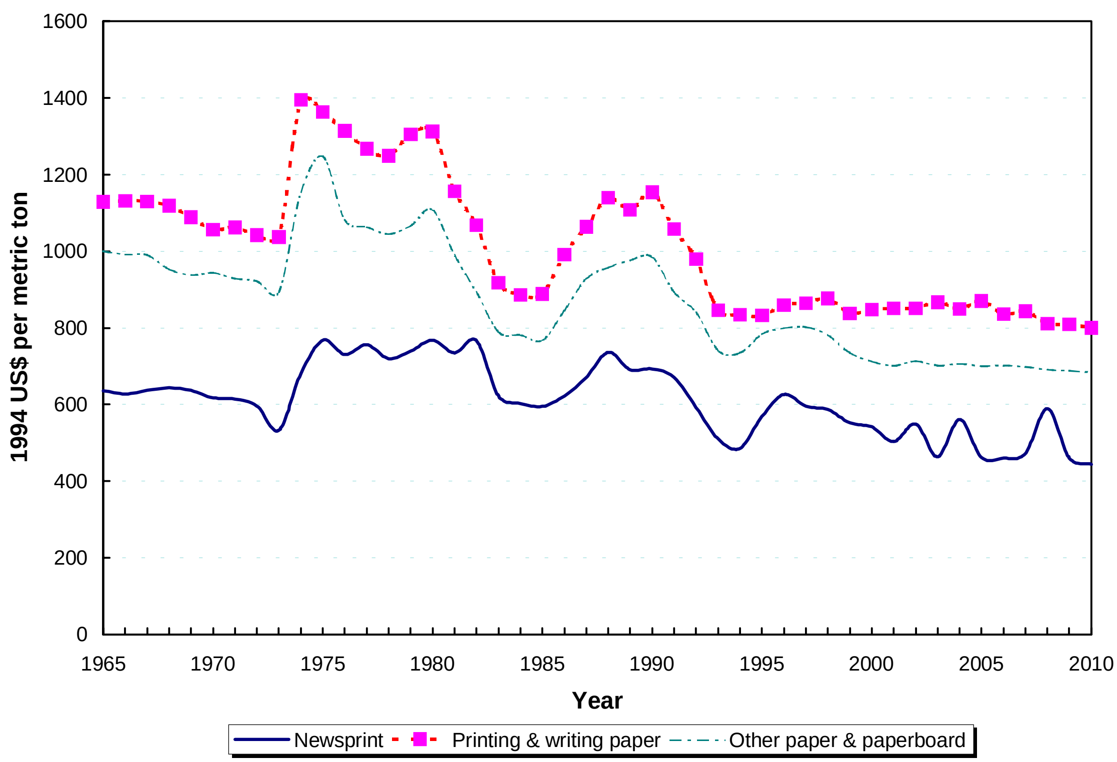

Figure 6. Real world prices of paper and paperboard.

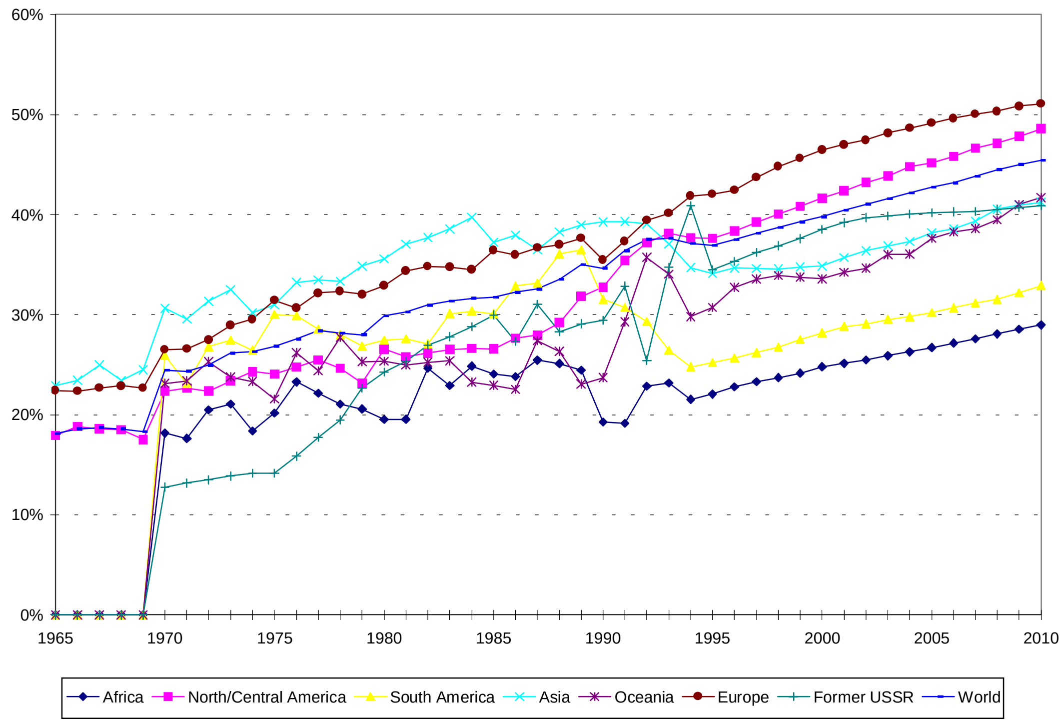

Figure 7. Recycled fiber utilization rates.