ALTERNATIVE APPROACHES TO MODELING LONG-TERM WORLD PAPER AND BOARD CONSUMPTION: AN ASSESSMENT OF THEIR USEFULNESS FOR PRACTICAL FORECASTING PURPOSES

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January 1987
WP-87-10

PUBLICATION NUMBER 40 of the project:
Ecologically Sustainable Development of the Biosphere

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FOREWORD

The objective of the Forestry Case Study in the Biosphere Project is to examine the consequences of forest decline attributed to air pollutants. The emphasis is on issues of major relevance to industrial and government policy makers in Europe. The research program includes an analysis of future wood supply in Europe under different assumptions about the rate and extent of forest decline. In addition, a number of papers are being produced to address various topics related to forest decline and the European forest sector in general. The report, by Esko Uutela from the Finnish consulting company Jaakko Pöyry, is a contribution to the latter.

R.E. Munn
Leader
Environment Program

ACKNOWLEDGEMENTS

I am grateful to Mr. Mylle Jouhki from Finland and Prof. Sten Nilsson from Sweden for constructive discussions concerning different subjects in this paper. I am also indebted to Dr. Peter Duinker from Canada for editing and Ms. Mary McGechaen, Mrs. Marilyn Brandl, and Ms. Nora Avedisians for text processing this paper, as well as to IIASA for providing the necessary facilities and a creative working climate.

This paper is part of the project "Long-Term Forecasting of World Paper and Board Consumption: Two Practical Applications of Quantitative Models" undertaken by the author in 1985-1989 as partial requirement for a Ph. D. degree in Forestry at the University of Helsinki. It is gratefully acknowledged that this project is supported by grants from Alfred Kordelin's Foundation, Paulo's Foundation, Yrjö Jahnsson's Foundation, the Finnish Cultural Foundation and the Finnish Foundation for Natural Resources.

Laxenburg, December 1986
Esko Uutela

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1. INTRODUCTION

1.1. Background

Until the mid-1970s forecasting world paper and board consumption was relatively easy: there was a steady growth in world economy, driving paper consumption to higher levels year after year. The only variation was caused by business cycles. Neither real prices of paper and board nor other demand shifters than income changed much, and it was possible to use simple forecasting models with economic development, population growth and time trend as the only explanatory variables.

The first oil crisis and its consequences severely disturbed this steady development. After 1974 the whole world economy suffered from a long-lasting recession, and many industries had serious difficulties coping with the new economic situation. The effects on world paper and board markets were also strong: stagnation for several years, large demand fluctuations partly independent from economic development, rapid production cost increases and accelerated restructuring processes within the whole paper industry were the main consequences.

With the slowdown of world economic growth, the use of economic development (GDP per capita) and population as the only explanatory variables for paper consumption no longer produced satisfactory results. Since the mid-1970s, there has been a growing interest among researchers to improve the quality of forecasts by different means. So far, no new forecasting method superior to the old ones has been discovered; all the new models developed have included serious theoretical and/or empirical weaknesses.

1.2. Objectives

The purpose of this paper is to review the existing international models used for long-term forecasting of world paper and board consumption and to evaluate their major advantages and disadvantages from both theoretical and practical points of view. More specifically, this paper is intended to answer the following questions:

(1) What are the main theoretical approaches used so far in worldwide paper and board consumption models?

(2) What are the most important criteria for choosing paper and board consumption models for practical forecasting applications?

(3) Which are the main benefits and drawbacks of the different approaches?

(4) What is the direction into which the efforts on paper and board consumption modeling should be concentrated?

(5) What are the possibilities for creating a new, practice-oriented forecasting approach or combining the essential features of the existing approaches together to utilize the benefits but avoid the drawbacks of the current approaches?

1.3. Coverage of the Study

The main focus of this paper is given to global, regional and international studies on long-term paper and board consumption. Much research has been done at a national level, but this work will only briefly be touched upon because of the global perspective guiding the research following this preliminary survey.

The product range covers both one-product and multi-product studies within the paper and board sector. More emphasis is given to the multi-product studies.

The time period of the literature review is 1960–1985. Studies made earlier than the 1960s are not discussed mainly because of their relatively simple methodology, giving hardly any new ideas for further research.

The main attention is paid to long-term forecasting: short- and medium-term forecasting are not discussed in detail in this context. Forecasts with a time horizon of two years and more are generally defined to be long-term forecasts (Wheelwright and Makridakis 1980, p.28). However, the absolute definition in time is arbitrary, because the time span can vary according to the situation. For this reason Armstrong (1978, p.5) prefers a broader meaning: "Long-term is the length of time over which large changes in the environment may be expected to occur." This definition is sufficient also for this study.

1.4. On Terminology Used

In this study the terms "consumption" and "demand" are used interchangeably. Strictly speaking, demand has been used in a non-economic sense in many forest products studies for describing the observed quantities of products sold in the market. In reality, data deficiencies do not normally allow the identification of demand and supply functions per se. Thus the measured or estimated market quantities should rather be understood as conditional consumption (or more strictly, sales) quantities under a set of assumptions concerning the independent variables in the equation system. These terminological problems have been discussed in more detail by Gregory (1966, p.105–106) and Gregory and others (1971, p.6–8). Although the difference between the terms demand and consumption is important from the theoretical point of view, the synonymous use of these terms for practical reasons – most studies reviewed use the word demand and not consumption – will hopefully not disturb any reader.

2. MARKETS FOR PAPER AND BOARD AND FORECASTING LONG-TERM CONSUMPTION

2.1. Market Characteristics of Paper and Board

2.1.1. Nature of Competition

The following section is a summary and continuation of discussions of a joint working group of IIASA's[1] Forest Sector Project during the summer of 1982 (see also Adams and others 1982, p.13–15).

The basic point of departure in modeling the markets for industrial commodities such as forest products is a consideration of the degree of competitiveness of the market. Where the market lies in the continuum between full competition and monopoly has significant implications for the approaches used to model consumption, production, and prices. The basic classification criteria include:

(1) The number and size of buyers and sellers and the market influence of each;

(2) The costs and physical requirements for entering the market as either a buyer or seller; and

(3) The degree of homogeneity of the product and the ability of producers to differentiate their products.

Generally, where the number of market participants is large and their individual influence is small, barriers to entry are limited, and product differentiation minimal, markets resemble the competitive model of economic theory in their behavior. Where participants are few, market power concentrated, entry costs high, and product differentiation substantial, markets resemble the oligopolistic or monopolistic theoretical structure.

When applying these general principles to the paper and board markets, there are some special characteristics of the industry which have to be taken into account. Given what is known about paper and board markets in most countries of the world, some generalizations can be drawn:

(1) The capital intensivity of paper and board production results in high market entry costs; the maturity of the industry in the industrialized countries does not make the branch attractive for a newcomer either.

(2) The economies of scale play an important role in the industry; thus a limited number of big enterprises tend to dominate the market, though the total number of market participants is not necessarily very small. Market leaders, which often are low-cost producers, establish the price level and smaller companies have to follow them.

(3) Product development and differentiation based on quality aspects is becoming an increasingly important element of the paper business. Tightening requirements of the end-use industries, especially the runnability of paper/board on high-speed printing/packaging machines and the four-color reproduction ability in advertising materials, have obliged paper producers to cope with the technical development. Special paper qualities with their own brand names are developed and the traditional paper grades are divided into narrower market segments.

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(4) No paper or board grade displays all of the elements required for fully competitive behavior. Some form of oligopoly, perhaps nearer to monopolistic than full competition, seems to be the prevailing market structure, though there are differences in the competitive nature of various products.

(5) The length of the distribution chain from producer to consumer may partly explain the differences. With a short distribution chain, i.e. when direct deliveries dominate the business, the producers normally have better possibilities to control the price level in comparison to a longer distribution chain with wholesalers and other middlemen, whose often speculative actions cause stronger fluctuations in market prices. Against this argument, the markets for newsprint and magazine papers should be of a more oligopolistic nature than the markets for woodfree printing and writing papers and other special grades.

(6) What is said above on the market characteristics applies to most industrialized countries. In countries with regulated markets, like centrally planned economies, or some developing countries, especially those with inadequate paper and board supply, the market situation can be quite different.

2.1.2. Product Characteristics

A second important point is the product characteristics of paper and board. Consumption is widespread among numerous branches of the economy and buyers include both industrial enterprises and individual consumers as well as the public sector. A small fraction of paper and board goes directly to consumers for household use (such as household and sanitary papers). The bulk comprises intermediate – or rather complementary – products related to the output of other commodities. Thus, demand for paper and board may be viewed as *a derived demand* for a productive factor or input rather than as *a direct consumer demand*, and it is also more *supply driven* than the demand for consumer goods.

The role of paper and board is further complicated by the fact that paper and board generally account for a small fraction of the total costs of the producer or consumer. Åberg (1968, p.40) stated that paper and board costs in Sweden accounted for only 1–2 percent of the total consumption value in industry and trade, as well as in private households. The only exception in the paper and board sector is in printing houses; the costs of newsprint, which represent the bulk of the physical substance of a newspaper, can account for 20-30 percent of the total costs of newspaper publishing. In the magazine sector the cost of paper can in certain cases be even higher, up to 40 percent of the total costs. Therefore, substitution has to be understood in broad terms. The relative prices of substituting commodities may not be sufficient; there are many intervening variables such as labor intensity, installation or user cost, flexibility of use, and product performance, which together determine the choice of materials. It is a question of *system substitution* rather than *product or price substitution*. A change from one system to another often involves considerable investments or new procedures in end-use industries, which increases the rigidity to adopt a substituting product and/or system. Thus the substitution process may require more than one business cycle before the final decision on a change is made (Simula 1985, p.23). For these reasons, it is clear that the prices of substituting materials alone cannot be sufficient variables for describing all the reasons behind paper and board substitution processes.

2.1.3. Oligopoly Theory and Paper and Board Markets

The conclusion from the previous discussion was that paper and board markets have many features typical of oligopolistic, and in some cases also monopolistic, competition.

Oligopolistic competition usually refers to the partial equilibrium study of markets in which *the demand side is competitive*, while the supply side is neither monopolized nor competitive (Friedman 1982, p. 491). The market includes a finite number of sellers, each large enough to have some control over price. The buyers enter the market in a neutral way without having any observable effect on the behavior of sellers or other buyers. This traditional theory of oligopoly is also called the Cournot model of oligopoly, according to the first writer about this subject (Cournot 1927). Cournot's study dates back to as early as 1838; the model has been comprehensively reviewed and evaluated by Friedman (1983, p.19–49). Cournot's analysis is mainly concerned with static markets in which a fixed number of firms produce a perfectly homogeneous commodity, with each firm choosing its output level as its only decision variable. Cournot's basic approach has also been a cornerstone of a generalization for multi-period setting, called *the noncooperative equilibrium*, which has become famous due to its introduction to game theory by Nash (1951). Therefore this approach is often called the Cournot-Nash oligopoly (e.g., see Varian 1978, p.72; Lewis and Schmalensee 1980, p.133).

Oligopoly with differentiated products was first discussed by Hotelling (1929) in his model of spatial duopoly and further elaborated by Chamberlin (1956), who made prominent the notion of differentiated products. Two basic assumptions of differentiated products models are that no two firms produce identical products and that firms can be grouped according to the type of product they make. Within one group the products of two firms are very close substitutes, while between two groups the products of two firms are either complements or relatively weak substitutes. The consequence of assuming product differentiation is that each firm has its own demand function under which the demand faced by a firm is a continuous function of all the prices in the market (Friedman 1982, p.501).

Further research on oligopoly theory includes multi-period models that allow market dynamics. The first steps towards multi-period models were Cournot's (1927) *reaction curves* and Bowley's (1927) *conjectural variation*, followed by Stackelberg's (1934) *leader-follower* model and Sweezy's (1939) *kinky demand curve* model. All the above models are attempts at understanding dynamic behavior without being real multi-period models. The development of models which are explicitly dynamic is quite recent; these multi-period models include studies by Cyert and de Groot (1970), Friedman (1977) and Marschak and Selten (1977). Such models have their focus on the behavior of a firm in oligopolistic markets and have close connections to game theory.

Generally, the effects of oligopolistic markets on modeling paper and board demand are not widely discussed in the literature. One reason for this may be that the traditional definition of oligopoly (Cournot oligopoly) does not imply any specific impacts on the demand-side; the demand function itself is assumed to behave as under full competition. Oligopoly with differentiated products leads, according to Chamberlin (1956), to a situation where every product and producer has its own demand function, and the market demand for the whole product group would consist of a complex system of these individual demand functions with complete information on all possible output or price level choices of the producers. With several market participants the number of interconnections becomes very big, the amount of information required large, and thus the whole market system difficult to manage.

It should also be noted that imperfect competition models originate from the partial equilibrium study and usually start directly with demand functions on the consumers' side of the market, while competitive models are based on the well-established general equilibrium theory and customarily derive demand from market data. Considering that the analytical jewel of economic theory is the theory of general competitive equilibrium, it is only natural to wish to treat oligopoly within a general equilibrium framework (Friedman 1982, p. 530). Several attempts have been made to achieve this goal, beginning with Negishi (1961), and followed by Farrell (1970), Nikaido (1975) and Laffont and Laroque (1976), among others, but none of the research has been able to create a generally valid theorem based solely on reasonable assumptions about the behavior of market participants. Later on, it was shown that a simple grafting of the Cournot-Chamberlin model of noncooperative firms with market power onto the usual Arrow-Debreu model of general economic equilibrium fails to provide an integration of these two theories, since it does not provide an explanation of price and quantity determination even in the most simple cases (Roberts and Sonnenschein 1977, p.110). This holds at least if the usual assumptions are made about consumer preferences. In reality, there is not one equilibrium but a whole set of equilibriums, one for each product in question.

When examining the paper and board markets with reference to oligopoly theory, some important aspects have to be noted. First, there are clear indications of product differentiation even in the markets for such a traditional bulky product as newsprint is. Producers try to promote their products by stressing quality differences and giving trade names to products of a specific mill. Thus the theory of Cournot oligopoly cannot be applied in this case, and the Chamberlinian or other modification dealing with differentiated products should be invoked. However, it seems irrelevant to break the market demand down and build demand models separately for every differentiated product within the paper grade called newsprint, as the theory suggests.

Second, the assumption that each firm in the market knows the profit functions of all firms does not hold. In the paper industry a firm normally knows only its own profit function, or perhaps not even that. Changing the information conditions this way leads to the use of a probability distribution of possible profit functions of rivals, and the randomness may cause difficulties in estimating future market outcomes.

A third concern is the assumption of traditional oligopoly that neither a single buyer can have any effect on the seller nor buyers can form coalitions for cooperative purchases. There are often a few big paper or board buyers with a stronger bargaining power in relation to smaller buyers. For example, in the Federal Republic of Germany one single publishing company buys one-fifth of the total consumption of newsprint. Sometimes buyers communicate with each other and form a collusion, like in France, where the bulk of newsprint is bought by a cooperative purchase arrangement. Being such important customers, these buyers certainly have an effect on the behavior of sellers. And more generally, paper and board business is normally based on ***negotiations between the seller and the buyer*** rather than unilateral decision-making of either party.

And fourth, the oligopoly models discussed above have been developed assuming that the producers cannot collude, i.e., they are noncooperative. Strictly speaking, this is seldom the situation in the paper and board industry. Producers negotiate with each other, though this is normally done informally and confidentially, since cartel formation is forbidden by law in most countries to secure free competition. Economic theory brings only a few insights to cooperative oligopoly, and a search for theoretical background leads to cooperative game theory with little value to demand modeling.

2.1.4. Effects of Market Characteristics on Modeling Approach

As stated above, oligopoly theory does not assume any drastic differences to demand modeling compared with fully competitive markets, apart from the separation of demand functions for every differentiated product. The differences are more related to the price formation mechanism and profit determination of a firm than demand modeling as such. However, as far as the parameters of demand models are estimated from historical observations, which in reality are intersection points of individual demand and supply curves observed at successive points of time, the supply-side effects on the location of these intersections cannot be ignored without consideration. The producers' ability to have some price control increases the rigidity for price movements, which would otherwise be caused by market forces. This is most clearly to be seen as inflexibility to downward price adjustments during falling demand in the business cycle: prices are kept at an artificially high level as long as possible and output restrictions are preferred to price reductions.

Additionally, with the exception of newsprint and magazine papers, the small fraction of paper and board costs of the total costs of a producer or consumer further decrease the importance of paper and board prices as a consumption determining variable. This, together with the intermediate or complementary product's role, makes the applicability of price-induced substitution of paper and board products questionable.

As a consequence of these market characteristics, the effects on paper and board modeling can be concluded as follows:

(1) The short-term price elasticity of demand for paper and board tends to be quite low. Even large changes in prices have only limited impacts on total costs of the buyer and hence consumption in the short term changes only moderately.

(2) In the long term, however, the price sensitivity of demand may be substantially higher. Substitution has to be understood as a system substitution and not as price substitution between alternative materials. Sustained differentials in the costs per unit of the end use activity between paper and board and substitutes may present opportunities for permanent cost-saving shifts in production techniques, once the full set of short-term rigidities is worked out (Adams and others 1982, p.15).

(3) Since the assumption of competitive markets does not hold for paper and board products, and the own-price variable seems not to be very essential in the analysis, simple supply-demand models with simultaneous quantity and price adjustment as such may not be the most reasonable way to describe market behavior. Rather, the potential significance of long-term system substitution calls for a need to analyze the end-use sectors of individual paper and board grades in more detail in order to identify critical factors and understand basic mechanisms in these end-use sectors.

(4) Although the markets for paper and board clearly resemble imperfect competition, the theories of oligopoly and monopolistic competition seem not to provide any generally acceptable framework for demand or consumption modeling as the theory of general competitive equilibrium does. The researcher has three main alternatives to choose from:

a) to base the theoretical background of models still on the assumption on competitive markets irrespective of the somewhat violent simplification of the actual market picture,

b) to approach the problem area from another direction, e.g., from the end-user's point of view by using the theory of production and cost functions, or

c) to try to find a combination of the two above approaches.

2.2. General Requirements for Practical Forecasting Models

The requirements for a practical forecasting model are twofold: first, the model has to be well established on relevant assumptions, and second, it has to be easily applicable and understandable by users. These requirements are often contradictory, and thus it is difficult for a researcher to choose the right combination between theoretical acceptability and practical applicability. Some researchers stress only one of the two properties. On one side there are proponents of very simple models based only on time-series of the dependent variable or on the use of linear regression models with one or two explanatory variables. The strongest argument here is that the future is so uncertain that it is not worthwhile to do anything else than have very rough assumptions on the future state of affairs. On the other side there are builders of highly sophisticated econometric models with well-argued reasoning behind the variables used in the model. This type of model may explain the historical development extremely well, but unfortunately its value for a practical forecaster is often limited because of the uncertainty related to the future values of the numerous explanatory variables needed to make projection(s) for dependent variable(s).

It is evident that neither of these extreme cases can be the desirable direction of research. A suitable solution has to be found as a compromise between theoretical and practical requirements. Several criteria for a good forecast or forecasting method have been defined in the literature (e.g. see Gregory and others 1971, p.4–5; McKillop 1971, p.4; Wheelwright and Makridakis 1980, p. 9–10). With reference to these criteria, and several years practical experience from forecasting work, the following requirements for a suitable model for practical forecasting purposes can be listed. An acceptable forecasting model should:

(1) rely on a sound theory with explicitly stated general assumptions on the prevailing economic conditions,

(2) utilize substantial part of all relevant data on the economic environment to which the forecast is related, so that data requirements will not place a serious hindrance on the usability of the model,

(3) be flexible to enable its use in several occasions and show dynamic properties of adaptation to changes within the time horizon of forecasting,

(4) produce accurate forecasts, conditional upon the underlying assumptions about independent variables (whose reliability can be assessed by rigorous statistical analysis),

(5) be easy to apply and understand by decision makers, so that it stands a chance actually being used, and

(6) neither cost more than the additional value of information, nor more than any other method yielding equally good results.

2.3. Available Forecasting Methods

Several criteria can be used in grouping available forecasting methods. Many of these are technically oriented (e.g. Spencer and others 1961), although other dimensions can also be found: the type of model built (Hair 1967), the context in which the forecast is used (Chambers and others 1971), the level of formality in forecasting (Wheelwright and Makridakis 1980) and the degree of sophistication of the methods used to analyze the data (Armstrong 1978). Distinctions can be made, e.g. between statistical and nonstatistical methods, time-series and causal methods, and quantitative and qualitative techniques. These dichotomies can also be combined together and arranged into a hierarchical order.

Chambers and others (1971, p.49) divide forecasting methods simply into three basic types, namely:

(1) Qualitative techniques

(2) Time-series analysis and projection

(3) Causal models

Apart from the mathematical characteristics of the forecasting techniques, the functional use of forecasting at different stages in a product's life cycle is emphasized to determine the requirements for the forecasting method to be applied in each situation.

Armstrong (1978, p. 67 and 71) organizes different forecasting methods in his "forecasting methodology tree" along three continuums:

(1) Subjective vs. objective methods

(2) Naive vs. causal methods

(3) Linear vs. classification methods

Armstrong starts his methodology tree by dividing forecasting methods into subjective (or judgmental) and objective methods.. Objective methods are further divided into naive and causal methods. With naive methods he means all time-series methods (including also Box-Jenkins and time-regression models) and calls them extrapolation methods. Causal methods are again subdivided into linear (called econometric) methods and classification methods (called segmentation; see Armstrong 1978, p. 227–246). This classification is somewhat artificial, and the last distinction of causal methods especially is unclear.

Wheelwright and Makridakis (1980, p. 34–35) provide a more technical classification of forecasting methods. They use the following dichotomies in the following hierarchical order:

(1) Informal vs. formal methods

(2) Quantitative vs. qualitative methods

(3) Time-series vs. causal methods (subdivision of quantitative methods)

(4) Subjective assessment techniques vs. technological forecasting (qualitative methods)

The above classifications of forecasting methods are examples of how they can be categorized when discussing forecasting on a general level. When the concern is with paper and board consumption over a long-term time horizon, the existing forecasting practices can be classified in a more appropriate way. The following types of paper and board consumption models for Western Europe were discussed in an earlier paper (Uutela 1983, p.269):

1. The traditional time-series approach
2. The cross-sectional and combined cross-sectional and time-series approach
3. The single-equation regression approach
4. Simultaneous equation models
5. Subjective panel and market research approaches

The above classes were based on three main criteria: the objectivity/subjectivity of forecasting, the forecasting technique used, and the type of model applied.

In this paper, more emphasis is given to the theoretical background of forecasting models. Time-series or extrapolation methods rely strictly on the observed historical pattern of the endogenous variable and are not directly supported by any behavioral or economic theory. The regression and other econometric models for paper and board consumption have traditionally been based, either directly or indirectly, on the general theory of consumer demand. The derivation of a consumption model for forest products from the conventional short-term model of Marshallian theory has been thoroughly discussed by Gregory (1966, p. 105–108). In the following, this approach is called the ***direct-demand approach.***

In the 1980s, the relevance of the direct-demand approach for such intermediate industrial products as sawnwood, wood-based panels, pulp or paper and board was criticized (Simula 1985, p.22). A clear argument for this critique is given by Andersson (1984, p.1) who states that the share of forest products delivered to households for direct consumption is less than 15 per cent of the total output, and that a projection for the United States indicates that the household purchases of paper will drop below 10 percent of total output in the 1980s. So far, relatively few studies using the intermediate-demand approach are available, and the superiority of this approach against the traditional approaches with respect to the quality and accuracy of forecasts has not been shown by any researcher.

In this paper the available forecasting methods for estimating paper and board consumption have been classified by taking also the theoretical background of the models into account. In grouping individual methods, the basic principles presented in Chambers and others (1971), Armstrong (1978), Wheelwright and Makridakis (1980) and Andersson (1984) have been considered and adapted together to yield a more uniform classification.

The second group in Table 1 is often called causal methods. However, the term explanatory is preferred in this paper, because all of the models belonging to this group do not necessarily assume the existence of a strictly causal relationship between the dependent and independent variables (e.g. see discussion in Sundelin 1970, p.74).

3. REVIEW OF RELEVANT RESEARCH AND LITERATURE

3.1. Introduction

Past studies on paper and board demand or consumption have been grouped in this paper according to the main groups of methods as presented in Table 1. Under each group the basic principles of different models are discussed, previous studies referred to and major advantages and drawbacks of the approaches evaluated.

TABLE 1. Forecasting methods for paper and board consumption modeling.

Basic Approach and Model Group	Forecasting Techniques
1. Time-Series Extrapolation	* Graphical extrapolation * Moving averages * Smoothing techniques * Adaptive filtering * Decomposition methods * Box-Jenkins and other autoregressive/moving average (ARMA) methods * Trend extrapolation and time regression * Statistical fitting along life cycle and growth curve models
2. Explanatory Methods with Direct Demand Approach	* Leading indicators * Simple regression and correlation * Single-equation multiple regression * Econometric modeling (simultaneous equation methods) * Mathematical programming * Segmentation methods (Armstrong 1978, p.225-246)
3. Methods with Derived Demand Approach	* Use-factor approach * Traditional input-output modeling * Production-function approach * Diewert-cost-function (or generalized Leontief cost function) approach
4. Subjective Assessment	* Historical analogy * Delphi method * Expert panel consensus * Market research and end-use techniques * Visionary future judgment

3.2. Time-series Extrapolation Approach

A classical approach to forecasting is to base the analysis on historical observations of the endogenous variable only. A pattern is sought in the historical consumption series by using different techniques, such as moving averages or smoothing, adaptive filtering, decomposition, simple regression or more complex techniques like the Box-Jenkins method. The revealed pattern is then prolonged to the future. A linear trend is the simplest case, but even much more sophisticated patterns can be applied (e.g. see Jenkins 1979).

Time-series extrapolation is no longer a widely used technique for projecting long-term demand for paper and board. The weaknesses of the method were clearly seen in the 1970s, when the historical, relatively steady growth patterns were badly broken by economic disturbances. The dangers involved in time-series extrapolation, which can make long-term projections unrealistic, have been discussed by Sundelin (1977, p.1–2), and they can be summarized in the following three points:

(1) The projections are based purely on historical data and do not utilize the available indicative information about the future.

(2) The choice of the span of the time series can greatly affect the projection, since a few successive temporary deviations from the general trend line at either of the ends of the time series can have very strong influences on the projections far in the future.

(3) The choice of the pattern, to which the historical data are fitted and by which the projections are made, is of great importance to the results of the projections.

The obvious advantage of time-series extrapolation is the ease of model construction and projection. The technique still has supporters among researchers who, after trying more sophisticated mathematical or statistical methods, have concluded that "simplest is best". The simplicity does not necessarily mean that the model itself would be simple in the mathematical sense, but rather that the basic principle to rely strictly on historical development makes the model simple to understand.

A recent example of believing that world paper consumption has a predetermined path which can be projected by fitting historical data is given by Graff (1983). He argues strongly against the use of GNP or GNP per capita as an explanatory variable, and bases his own analysis on an assumption that world paper consumption follows a life-cycle curve with a fixed saturation level. The fitting was based on consumption observations from 1946 to 1981, and the type of function used was the probability density of the normal distribution:

$$C(t) = k \cdot e^{\frac{-(t-a)^2}{2b^2}} \tag{1}$$

where k is the saturation level, t is time and a and b are parameters. The fitting was done with "a specially designed computer program" identifying the value of k from the curvature (Graff 1983, p.52). The value for k, to be interpreted as the maximum value of world paper consumption, was 217.4 million tons to be reached in 1995.

It is evident that the use of this type of a model lacks of theoretical justification. The model can show good *statistical validity*, and maybe in some cases *forecasting ability*, but it lacks *theoretical validity*, and the *interpretation of saturation level* will cause problems. It can be generally accepted that there will be some ceiling for paper and board consumption per capita, but establishing a limit for the whole world with a continually growing population is difficult to justify.

Another problem is how to define the right level of saturation and the reasons which cause saturation. Additionally, the model is a typical growth curve defined by three parameters, and is unable to reflect market fluctuations caused by economic factors. One can easily agree with Meade's (1984, p.445) statement about the use of growth curves in forecasting market development that "the justification for using growth curves to forecast consumption over long lead-times is negligible, since growth curves are insufficiently flexible to efficiently use the information available to model consumption."

3.3. Explanatory Methods with Direct-Demand Approach

3.3.1. Types of Models Used

The bulk of past studies on long-term paper and board consumption belongs to the category of explanatory methods with the direct-demand approach. The models developed differ from each other with respect to the level of detail, statistical methodology, estimation techniques and the type of data and variables used in the models. To provide a concise overview, with little attention to methodological aspects, the studies can be classified, based on the treatment of prices, into four main groups which are:

(1) *Demand models without prices,* in which demand (either total or per capita) is explained with lagged values of consumption, or a time-trend variable, and national income (GNP, GDP) or a similar measure of macroeconomic activity, with or without lags. Population may be taken into account exogenously (in per-capita models), but some other demographic variables such as age distribution or number of households can be employed as explanatory variables.

(2) *Demand models with price-based substitution,* in which demand is related directly to product price and substitute prices with or without lags, lagged values of consumption, national income or end-use activity and other relevant demand shifters.

(3) *Reduced-form consumption models,* in which demand, or rather consumption, is explained with both demand and supply shifters, but where product price has been eliminated by solving supply and demand equations algebraically.

(4) *Market models,* in which prices are taken endogenously, and supply and demand are integrated by the means of either traditional econometric simultaneous-equations techniques, or mathematical programming within a partial equilibrium framework. These models normally allow trade flows between regions and/or countries, making the equilibrium solution spatial.

Further distinctions can be made within each group based on the type of data set employed (cross-section on time-series), modelling principle (single- or multi-equation system) and model dynamics (static or dynamic).

In this context it should be noted that a few researchers consider some of the models in group (2) to be rather *derived-demand* than *direct-demand* models, since the level of end-use activity and relative prices of substitutes may be included as explanatory variables (e.g. see discussion in Adams and others 1982, p.22). However, the basic approach is still the same, starting from the demand concept from the consumer's point of view, and end-use activity and relative prices have to be understood only as alternative demand shifters. In this paper the term *derived demand* is used when *the approach is essentially related to the user of in-*

termediary products: i.e., the analysis starts from the producer's production or cost function, or involves directly the quantities or prices of the final product to derive the demand function for paper and/or board.

3.3.2. Demand Models without Prices

Many of the early international demand models for paper and board were relatively simple regression models using only one to three explanatory variables related to economic and cultural factors. These studies, made in the post-war period until 1960, have been summarized and evaluated in one of the very basic studies in the pulp and paper industry (FAO 1960, p.83-92) and will not be discussed in this paper.

A general demand model without prices for paper and board can be written as:

$$C(i,t) = f(Y(i,t),\ C(i,t-l),\ \varepsilon(i,t)) \tag{2}$$

where $C(i,t)$ is consumption of a specific paper or board grade or group of grades in country i at time t either in total or per capita terms; $Y(i,t)$ is total or per capita GNP/GDP or some other measure of macroeconomic activity; l shows the number of periods by which past consumption variable is lagged; and $\varepsilon(i,t)$ is the disturbance term. Sometimes the term $Y(i,t-l)$ may be included in the model. The model (2) is in fact a "dynamized" Engel curve; it assumes that relative prices of paper and board and their substitutes are constant, Y is the only demand shifter, and the lagged consumption C represents changes in the consumers' preferences over time.

The simple time-series form of (2):

$$C(t) = f(Y(A),\ \varepsilon(t)) \tag{3}$$

is often used if available data are scarce and the model structure must be very simple. This type of model has been used by e.g. Hair (1967) and, more recently, by USDA (1980). Although the statistical fit of this type of model can be quite good (e.g. see experiments by Uutela (1979, p.76–77), or Wibe (1984, p.5)), it does not guarantee the validity of the model; the model itself has very little to contribute to the understanding of the factors that influence consumption.

The simple static cross-sectional form of (2):

$$C(i) = f(Y(i),\varepsilon(i)) \tag{4}$$

was already used in relatively early international studies on paper and board (e.g. FAO/ECLA 1954, FAO/ECLA 1955), but later on pure cross-sectional studies based on the relation between consumption and income have been quite rare (e.g. FAO 1966, Uutela 1979). Gregory (1966) also used a cross-sectional approach but employed another explanatory variable, wood availability index, in addition to income; this was the case in Uutela's (1979) model for developing countries, too. The use of a cross-sectional approach has been considered to be an advance in relation to pure time-series analysis, though it also has its drawbacks. As Buongiorno (1979, p.142) has stated, pure cross-sectional analysis increases the variability in the observations (in comparison with time-series analysis), but it is questionable whether variations across countries are relevant to explaining changes over time.

The first attempt to "dynamize" the static cross-sectional model was made in a well-known study by FAO (1960), since it was noted that paper and board consumption in North America, Western Europe and Latin America grew in the 1950s faster than would be expected from income growth alone (FAO 1960, p.47). In this study, a time trend factor was included to take into account the shift of the cross-sectional curve over time. The functional form of the demand model was an S-shaped Engel curve based on the log-normal distribution:

$$C(i) = S_{\infty} \int_{-\infty}^{\ln Y(i)} \frac{1}{\rho\sqrt{2\pi}} \cdot e^{-\frac{1}{2}\left[\frac{\ln Y(i)-\mu}{\rho}\right]^2} d\ln Y(i) \qquad (5)$$

where $C(i)$ and $Y(i)$ are paper consumption per capita and GDP per capita, respectively, S_{∞} the saturation level of consumption (kg/capita) defined *a priori*, and ρ and μ parameters defining the position and shape of the curve. The time trend effect was defined by calculating consumption elasticity (with respect to income) from historical series and subtracting the elasticity calculated from cross-sectional series (see FAO 1960, p.99). The time trend was assumed to describe the effects of long-term price movements, development of new products and markets, etc. The same approach was used also in subsequent studies by FAO (1963a, 1963b).

The use of trend factors was further elaborated by Sundelin (1970, 1977) who separated the effects of variables other than income into a "general trend" and "specific-country trend" (see Sundelin 1977, p.5-9). The reason for this separation was that apart from a common time trend at a given income level, which changes the location and/or shape of the whole cross-sectional curve from year to year, there were historically also individual country patterns, which tend to change the country's position in relation to the cross-sectional curve in a foreseeable manner. Sundelin (1977) suggested a simple sigmoid function:

$$C\ (i) = \alpha \cdot Y(i)^{\beta} \cdot Y(i)^{\gamma \cdot \log Y(i)} \qquad (6)$$

which is, in logarithmic form, a second-degree curve.

The use of trend factors as artificial variables to replace all factors other than income and population has been criticized especially by econometricians. McKillop (1971, p.3) pointed out that use of a time-trend adjustment factor is an attempt to correct bias due to omission of factors, a logical procedure but suffering from two handicaps:

(1) Cyclical or erratic factors may obscure any systematic movement over time.

(2) The trend factor tends to be a subjective generalization about the net effect of a number of diverse factors, and thus it is extremely difficult to estimate the future values of this trend factor, since it can represent any net systematic effect of all unidentified factors.

Additionally, Sundelin's breakdown of other factors into two components further increases the subjectivity of the method. It is not known whether the effects of these components are additive as suggested or whether they are interdependent.

Recent studies have been aimed at combining cross-sectional and time-series information for long-term consumption models to allow for dynamic changes in the consumption-income relationships, and for differences in the initial conditions of the countries considered. These studies, where possible price effects are still ignored, include FAO (1975), FAO/ECE (1976), Buongiorno (1977) and Buongiorno and Grosenick (1977). In these studies, equation (2) was employed in its most general form.

A recent study prepared for FAO by Baudin and Lundberg (1985a) on paper and paperboard demand in the OECD countries with detailed product breakdown is based on the use of indicators of economic activity as the only explanatory variable. The lack of actual price data on individual paper and board grades prohibited the analysis of substitution in all other cases except newsprint (Baudin and Lundberg 1985a, p.14 and 30). The model included two sets of dummy variables and was reported in its logarithmic form:

$$\log C_{it} = a_0 + \sum_{i=1}^{n-1} a_i D_i + b_0 \cdot \log Y_{it} + \sum_{j=1}^{4} b_j H_j \log Y_{it} + u_{it} \qquad (7)$$

where D_i is a countrywise dummy variable, Y_{it} is GDP, private consumption or industrial production, depending on the product in question, H_j is a second dummy showing into which of a total of five country groups, defined by economic and geographical criteria, the country belongs, and u_{it} is an error term. The specific country dummies D_i were assumed to reflect social, cultural and other traditional differences between countries. The study used pooled cross-sectional and time-series data of the OECD countries in 1971–1981.

Although "dynamization" of the cross-sectional approach with lagged endogenous variables and pooled time-series and cross-sectional data has the advantage of considering time-dependent changes within the model framework, the method also has its drawbacks. In a model of type (2) the introduction of lagged endogenous variables easily leads to strong serial correlation and to the result that lagged consumption is the most important explanatory variable in the model. Furthermore, there may be high collinearity between variables $Y(i,t)$ and $C(i,t-l)$. By pooling cross-sectional and time-series data, multicollinearity can normally be reduced substantially.

Pooling cross-sectional and time-series data gives more reliable estimates of model parameters, but only when time-dependent changes follow a certain pattern. A traditional pooled cross-sectional and time-series consumption model is heavily based on two key elements – historical development within and between countries, and an assumption about analogous development of consumption in different countries at a certain level of economic development. It is not an appropriate model for forecasting turning-points or any other expectable new development trends. Additionally, Baudin (1985a) has shown in his recent critique that the uncertainty of projections based on a pooled time-series cross-sectional model is considerable, and, although the coefficient of determination of the model is high, the projection confidence intervals for a given country may be substantial, and increasing with increases in the forecasting time horizon. The model error was noticed to be related to the level of consumption of the country, indicating that the residuals of pooled time-series cross-sectional models are obviously heteroscedastic. Finally, the error variance of a region was concluded to be smaller than the sum of variances for individual countries (Baudin 1985a, p.17).

3.3.3. Demand Models with Price-Based Substitution

Until the mid-1970s, there was little interest in studying the effects of price changes on paper and board consumption because:

- Real prices of paper and board did not change much from the early 1950s up to 1972.
- In contrast with many other industrial products, paper and board do not have direct substitutes at a cheap price; measuring the relative prices is complicated because of the nature of the product.
- Paper and board are complementary products whose share of the total price of products to which they are related is very small and, therefore, even large price increases would not much affect their consumption (USDA 1973, p.149–150).
- There has been a lack of reliable price data (FAO 1960, p.2; Baudin and Lundberg 1985a, p.14).

- The consumption of paper and board is of an habitual nature and thus the effects of price movements are weak (Åberg 1968, p.41).
- The use of price as an exogenous variable in a practical forecasting situation would require that reliable price forecasts are available. Theoretically, both consumption and price are determined simultaneously and, therefore, forecasting price developments is at least as difficult as forecasting future demand levels.

Rapid increases in real prices of paper and board in 1973–77 caused a growing interest in studying their effects on consumption, which led to studies in which own-price and substitute-price variables were included as exogenous variables to explain consumption. A general model of this type can be written:

$$C(i,k) = f\left(\sum_k \alpha_k Y(i,t-k), \sum_l \beta_l P(i,t-l), \sum_m \gamma_m P'(i,t-m), \sum_n \Psi_n Z(t-n), \varepsilon(i,t)\right) \tag{8}$$

where Y refers to some measure of general economic activity (income), P to paper and/or board price, P' to the price of the most direct substitute, Z is a qualitative dummy variable, and ε the disturbance term.

Model (8), or some variant, is currently the most commonly used approach to demand modeling in the forest sector. The simple time-series form of (8):

$$C(t) = f(Y(t), P(t), P'(t), \varepsilon(t)) \tag{9}$$

has been used, for example, by McKillop (1967), Adams and Blackwell (1973), Baudin (1977) and Adams (1977) in national or regional studies. A simple static cross-sectional form of (8):

$$C(i) = f(Y(i), P(i), P'(i), \varepsilon(i)) \tag{10}$$

has not been widely used in long-term studies, since it is not possible to determine whether the cross-sectional relationships hold over time. Åberg (1968) used different models with data on Western European countries, including price variables, but had to conclude that the demand for paper and board appears to have very low price elasticity. Another observation in his analysis was that there might be a certain lag in the effect of price changes on demand, partly caused by the habitual nature of paper and board consumption.

The increases in real prices of paper and board resulted in two important international studies (FAO 1977, Buongiorno 1978), in which model (8) was used with pooled cross-sectional and time-series data from 43 countries over the period 1968-1973. Contrary to the results of Åberg (1968), the own-price parameter had values that significantly differed from zero in both studies. In spite of the same data base, the estimated parameters of the variables received different values in these two studies. The reason for the differences was obviously that Buongiorno (1978) used specific country dummies which were not employed in FAO's (1977) study. Additionally, in FAO's study, literacy rate (L_{it}) was included as an explanatory variable for cultural papers in developing countries, thus the model being:

$$C_{it} = A \cdot Y_{it}^{b} \cdot P_{it}^{c} \cdot P_{it}'^{d} \cdot L_{it} \cdot \varepsilon_{it} \tag{11}$$

which is a static model using pooled data. Without the literacy rate variable, this is one of the most important static functions used in general demand studies (e.g. see Houthakker 1965).

Buongiorno (1978) also built a dynamic version of model (11) based on Nerlove's (1958, p.308-310) partial adjustment model which gives the possibility of estimating long-term elasticities. The model has the form:

$$C_{it} = A \cdot C_{i,t-1}^{\lambda} \; Y_{it}^{b} \; P_{it}^{c} \; P_{it}^{\prime d} \; \varepsilon_{it} \tag{12}$$

where the only difference with equation (11) is the introduction of a lagged dependent variable $C_{i,t-1}$. It was shown by Nerlove and Addison (1958, p.864–865; see also Buongiorno 1978, p.236; Uutela 1984, p.3) that the long-term elasticities can be calculated from the relations:

$$B = \frac{b}{1-\lambda} \quad \text{(long-term income elasticity)}$$

$$C = \frac{c}{1-\lambda} \quad \text{(long-term own-price elasticity)}$$

$$D = \frac{d}{1-\lambda} \quad \text{(long-term cross-price elasticity)}$$

where λ measures, according to Nerlove's theorem, the velocity of adjustment to demand rigidities. The closer λ is to unity the faster the velocity of adjustment, the static model being an ultimate case where the adjustment of consumption is completed within one year ($\lambda = 1$).

A similar model was used also later by Buongiorno (1979) for mechanical wood products and by Suhonen (1984) for paper and board. Baudin and Lundberg (1984), though deriving the theoretical background of their model as a derived demand model from production theory, used in principle a quite similar model, where price variables (P,P') were represented by one variable measuring the relative price of sawnwood/panels in relation to other construction inputs, and the income variable (Y) was replaced by construction activity (Baudin and Lundberg 1984, p.28–29). Suhonen (1984) found demonstrably lower price elasticities than Buongiorno (1978) or FAO (1977), and in the case of printing and writing papers and wrapping and packaging papers, the own-price and cross-price parameters were even insignificant. It should be noted that the historical data in Buongiorno's (1978) and FAO's (1977) studies ended just when real prices of paper and board had begun to rise; after 1977, price development evened out and real prices actually declined up to 1980, which was the last year for observations in Suhonen's (1984) study.

Baudin and Lundberg (1984) made trials with both static and dynamic functions, with and without countrywide dummy variables, and constructed also a first-order difference model:

$$\Delta C_{it} = \Delta Y_{it}^{b} \cdot \Delta P_{it}^{c} \cdot \Delta C_{i,t-1}^{\lambda} \cdot \varepsilon'_{it} \tag{13}$$

where

$$\Delta C_{it} = C_{it} - C_{i,t-1}$$

$$\Delta Y_{it} = Y_{it} - Y_{i,t-1}$$

$$\Delta P_{it} = P_{it} - P_{i,t-1}$$

$$\Delta C_{i,t-1} = C_{i,t-1} - C_{i,t-2}$$

$$\varepsilon'_{it} = \varepsilon_{it} - \varepsilon_{i,t-1}$$

Like the country dummies, differentiation eliminates the variation between countries from the data and makes use only of the variation over time. By differentiating the data one may reduce some of the estimation problems that are likely to be present, in particular the existence of common trends in the independent variables Y and P, which give rise to multi-collinearity and thus to high standard errors of the estimates, and the existence of serially correlated residuals (Baudin and Lundberg 1984, p.20). The analysis showed that the introduction of country-specific dummy variables, or the use of a difference model, reduces the estimated elasticities for both the demand shifter (construction) and price. Baudin and Lundberg (1984, p.45 and 52) concluded that the ignorance of the systematic inter-country differences in consumption patterns caused by some omitted factors and not by income differences may lead to an overestimate of the sensitivity of demand to changes in demand shifter(s) and price.

In his work, Wibe (1984) used a simplified form of the dynamic model (12) where time (T) represented (as a yearly index) substitution effects over time:

$$C_{it} = Ae^{\alpha \cdot T} \cdot Y_{it}^{b} \cdot P_{it} \cdot \varepsilon_{it} \tag{14}$$

where T is measured in years and α is interpreted as the yearly rate of substitution for forest products. Wibe (1984) also used dummies for grouping countries according to their income group, but did not use specific dummies for taking the systematic differences in consumption levels between countries into account. Obviously, this is the reason why the study resulted in relatively high price elasticities for paper and board (from -0.3 for household and sanitary papers to -1.2 for newsprint, and for newsprint at the income level of more than USD 2500 per capita, -2.7; see Wibe (1984, p.8–9)). The unidentified variables behind the countrywide dummies, when left out of the regression equation, will result in biased estimates of income and price elasticities, to the extent that they are correlated with these variables, and will decrease the explanatory value of the regressions.

Baudin and Lundberg (1985b), in their recent study on newsprint, used both countrywide dummies and a stratification of countries with respect to per-capita income and size, as well as a time-trend factor (T) to represent other systematically changing factors such as the introduction of new information media competing with newspaper. Their model was (see Baudin 1985a, p.4):

$$C_{it} = Ao \cdot \sum_{j} A_j D_{ji} \cdot Y_{it}^{b_0} \cdot \left[\sum_{k} D_{ki} \cdot Y_{it} \right]^{b_k} \cdot P_{it}^{c} \cdot T^{h} \cdot \varepsilon_{it} \tag{15}$$

where

D_{ji} = 1 if *country* $i = j$

0 otherwise

D_{ki} = 1 if country i belongs group k

0 otherwise

The data used covered the period 1961–1981 and the resulting income and price elasticities were 0.8 to 1.0 and -0.3, respectively, which are of the very same magnitude as those found by Suhonen (1984) for newsprint. The time-trend parameter (h) received a small though negative value.

In his most recent paper, Baudin (1985b) made trials with different pooled time-series cross-sectional models for three product groups, namely newsprint, printing and writing papers, and other paper and paperboard. The data set, spanning the years 1961–1981, covered 56 countries for newsprint, 44 for printing and writing papers, and 53 for other paper and paperboard. Baudin (1985b) started estimation with a basic demand function with total GDP (Y_{it}) and price (P_{it}) as the only explanatory variables. He then added logged variables, specific country dummies, different types of time variables (linear, second order, inverse time trend, trend break in time elasticity caused by the oil crisis) to represent paper demand determinants other than economic activity and prices, and finally, a second dummy variable for testing differences in income elasticities between different income groups. A difference model of type (13), without a lagged consumption variable, was also constructed, but the results were unsatisfactory, especially with respect to the price variable (Baudin 1985b, p.7).

The results showed the economic activity and price variables to, be highly significant in all cases (except price in the difference model), and the time variable in most cases (positive effect on printing and writing paper demand, negative effect on newsprint and other paper and paperboard demand). The effects of the factors represented by the time variable were noticed to be particularly unfavorable for other paper and board, and it was shown that there was a clear negative trend break for other paper and paperboard in the mid-1970s, but not for the cultural papers (Baudin 1985b, p.8). It was also concluded, based on the finding that static elasticities were almost identical to the long-term elasticities obtained from the dynamic model, that for the purpose of long-term analysis of paper demand, a dynamic model is not necessary.

The studies of Buongiorno (1978, 1979), Suhonen (1984), Baudin (1985b) and Baudin and Lundberg (1984, 1985a and 1985b) can be included among the most advanced international studies on forest products demand, since these studies:

(1) utilize a wide international data base with a large number of observations and great inherent variability;

(2) allow differences between individual countries and levels of economic development;

(3) try to take price-based substitution effects into account;

(4) give the possibility to analyze the effects of demand rigidities with dynamic model formulation; and

(5) construct models that are, in spite of the large amount of data needed, relatively easy to understand and interpret by the user.

However, there are also several drawbacks which should not be ignored, including:

(1) Actual price data are difficult to obtain, and often the available data are of questionable quality. The use of import or export values of products may not give a correct indication of average prices, especially if the quantities imported are small compared with consumption, or exports are manifold to domestic consumption.

(2) The substitution process cannot be described sufficiently through the use of material prices alone for reasons discussed earlier in this paper.

(3) The use of dummy variables is only a trick to improve the statistical properties of the models; the omitted variables behind observed differences between countries remain unidentified.

(4) The models do not consider supply-side effects; in fact, supply is assumed to be perfectly elastic, satisfying the demand at any given price.

(5) Models of this category are often developed for fairly broad product groups, which tend not to be homogeneous either in terms of product characteristics or in terms of the various end uses in which they are employed. It cannot be guaranteed that the use of a single, average-price variable will suitably represent the individual price behavior of the products included in the group. Another problem may be multi-collinearity if several indicators of different end-use activities are included in the model.

(6) Prices are treated exogenously, and for forecasting purposes they have to be projected separately.

(7) As shown by Baudin (1985a), the projection confidence intervals for an individual country may be substantial although the coefficient of determination of the model is high and the residuals are obviously heteroscedastic. From a practical forecasting point of view, this is a very serious drawback.

3.3.4. Reduced-Form Consumption Models

A comprehensive model describing the determination of consumption and price levels in the market with the assumption of full competition should contain equations for both supply and demand, where both depend on price. These supply and demand relationships are linked together by the price of the product and by the equality of supply and demand, and they are often referred to as structural relationships (e.g. McKillop 1971, p.6). Generally, the supply and demand framework can be written as follows:

$$\bar{Q} = Q_d = Q_s \quad (16)$$

$$Q_d = f_1 (P, X_i, \varepsilon_i) \quad (17)$$

$$Q_s = f_2 (P, Z_j, \varepsilon_j) \quad (18)$$

where (16) is the equilibrium condition, (17) the demand equation and (18) the supply equation. Demand and supply are functions of product price (P), exogenous (or predetermined) demand shifters (X_i), and exogenous supply shifters (Z_j), respectively. By substituting $\bar{Q}$ for Q_d in (17) and Q_s in (18) and by using simultaneous equation techniques, it is possible to solve the quantity ($\bar{Q}$) both supplied and demanded as well as the equilibrium price (P) for the solution.

Although both supply and demand functions theoretically should be solved simultaneously, this is seldom done because of statistical identification problems. Estimation of parameters would require maximum likelihood, two-stage least-squares or instrumental variable methods, since the ordinary least squares method with more than one endogenous variable would result in biased and inconsistent estimates (e.g. see Maddala 1977, p. 242–251). For these reasons, the model system is often returned back to a single-equation model by solving the equations algebraically. The result is called a reduced-form equation in which a single endogenous variable is expressed in terms of exogenous variables only. When the interest is in consumption, it is possible to eliminate P from equations (17) and (18) to determine the quantity consumed as a function of demand and supply shifters or:

$$Q = f (X_i, Z_j, \varepsilon_{ij}) \quad (19)$$

Reduced-form models are thus simplifications of simultaneous-equation econometric models. In forest products studies, simultaneous equations have been used at a national level for both short-term and long-term forecasting purposes. Gregory (1960, 1965) developed a multi-equation model for short-term forecasting in the hardwood flooring market. One of the most famous long-term multi-equation models for a wide range of forest products (from roundwood to paper products) was developed by McKillop (1967). McKillop and others (1980) used both structural estimation and reduced-form estimation to developing a basis for the simulation model used for analyzing competition between wood products and substitute structural products. However, to my knowledge there does not exist any ***international study*** with empirical results on paper and board supply and demand which used simultaneous estimation techniques. One reason for this might be the huge amount of data which would be required for this type of a comprehensive model.

Reduced-form consumption models have been developed also for use with international data. In principle, any consumption model which incorporates both demand and supply shifters as explanatory variables can be included in this category. Gregory's (1966) study, using a sample of both developed and developing countries, showed the dependence of sawnwood and industrial roundwood consumption on wood availability. The consumption functions used were of the form:

$$C(i) = f(Y(i), W(i), \varepsilon(i)) \tag{20}$$

where Y refers to income per capita and W is defined as an index of wood availability based on the forested area of each country.

The same static approach was used by Uutela (1979) for building a cross-sectional model of paper and board consumption in developing countries. Recently a dynamic reduced-form model was used by Laarman and Wohlgenant (1984) in their international study on fuelwood consumption. The model used was of the form:

$$C_{it} = A_0 \cdot \sum_j A_j D_{jt} \cdot Y_{it}^{\alpha} \cdot P_t^{\beta} \cdot C_{i,t-1}^{\lambda} \cdot W_{it}^{\gamma} \cdot \varepsilon_{it} \tag{21}$$

where C_{it} is fuelwood consumption per capita, D_{jt} a specific country dummy, Y_{it} GDP per capita, P_t real commercial energy price as an internationally weighted index, W_{it} forest area in hectares per capita, and ε_{it} the unexplained residual (see Laarman and Wohlgenant 1984, p.386). The inclusion of the lagged consumption variable $C_{i,t-1}$ made it possible to calculate long-term elasticities.

A reduced-form model facilitates estimation, since ordinary least squares can be applied to relationships containing only exogenous variables on the right-hand side. The reduced-form parameters are always identified, implying knowledge of the conditional distribution of the dependent variables given the predetermined variables, and a parameter of the structural equations is identified if and only if it can be uniquely deduced from the reduced-form parameters (Goldberger 1964, p.311). Therefore, the reduced-form method is preferred to simultaneous estimation in situations where forecasting is the principal objective. Since the own-price variable can be eliminated from the structural equations, reduced-form is often used when the price data are unreliable or not available at all. Gregory (1966, p. 107–108) has argued for eliminating the price variable on the grounds that price is not a variable influencing consumption in the usual sense and can be disregarded only because it is simply another measure of exactly the same point – the point of intersection of demand and supply curves. If the objective is that of estimating future consumption, not price, the latter can be ignored if so wished.

On the other hand, by using a reduced-form model where price is eliminated, the possibility for getting potentially interesting information on supply and demand is missed. McKillop (1971, p.18) concluded that an alternative, and often more powerful, technique is to estimate the demand and supply equations separately and then combine the estimated equations to obtain a set of forecasting functions called "solved structural equations". He also suggested that structural estimation would be a fruitful line of investigation for many countries who are large producers and consumers of paper and have the necessary price data available.

3.3.5. Market Models

Market models originally were developed for providing a greater capability for policy analysis and a broader array of information on potential policy impacts in the forest sector (Haynes and Adams 1983, p.9). The purpose of this type of model is to combine all relevant elements of the branch within a single framework to enable studying the simultaneous effects of demand and supply relationships on equilibrium quantities and prices of different products. In principle the system resembles simultaneous econometric techniques, since consumptions, productions and prices are all determined within the same procedure, but it uses mathematical programming instead of statistical methods for solving the equilibrium. Mathematical programming can provide a suitable framework for modeling trade flows from one region/country to another.

The *U.S. Timber Assessment Market Model* (TAMM; Adams and Haynes 1980) was the first important application of market models to the forest sector. This model was a spatial equilibrium model including several regions in North America and allowing trade flows between these regions. Spatial equilibrium in these markets was determined by a process that explicitly considered transport costs. The analysis was thorough for the softwood lumber and plywood sector, but consumption of paper and board in the model was projected simply by using income-consumption relations for the entire U.S..

Relatively soon after the 1980 TAMM was completed, efforts were initiated to include the pulp and paper sector in a more sophisticated way into the model. Buongiorno and Gilless (1983) developed a regionalized model of pulp and paper production and trade compatible with TAMM. The pulp and paper model is a global model dividing the world into six to eight U.S. regions, two Canadian regions, Western Europe, Japan, and the rest of the world. Paper products include three groups: newsprint, other printing and writing paper, and other paper and paperboard. The model is a partial-equilibrium model in that many variables, such as income and production costs, are treated as exogenous (Buongiorno and Gilless 1983, p.58). Demand is introduced into the model through price-responsive demand functions. Demand modeling itself does not include anything new – each demand function in the model is based on econometrically-estimated elasticities – but is interesting in that the supply-side effects on consumption levels are considered by determining equilibrium price and quantity simultaneously. Supply and demand are integrated by a mathematical programming algorithm where the objective function to be maximized is the sum of consumer surplus and producer surplus, which Samuelson (1952, p. 288–289) called ***the net social pay-off***.

The same approach has been used in later studies by Gilless (1983), and Buongiorno and Gilless (1984). A market model based on mathematical programmming and Samuelson's (1952) approach to solving for the competitive equilibria in spatially separated markets was used by Greber and Wisdom (1985) for analyzing roundwood product interdependencies. The framework created by Buongiorno and Gilless (1983) was in principle followed also by the IIASA Forest Sector Project when analyzing long-term global trends in production, consumption and world trade in forest products (see Dykstra and Kallio 1986). The main result of this project was a global forest sector model, more commonly referred to as the Global Trade Model (GTM), which is a partial market-equilibrium economic model cast in a nonlinear programming framework, with linear constraints and a partially nonlinear objective function. The model includes altogether 18 different world regions and 16 forest products, including four paper grades, namely newsprint, printing and writing papers, household and sanitary papers, and packaging paper and board. The main focus of this model is in modeling production and global trade flows in a sensible way, and consumption is represented in the system by a price (or inverse consumption) function, (see Dykstra and Kallio 1984, p.6):

$$\pi_{ik} = \lambda_{ik} \, C_{ik}^{-\gamma_{ik}} \tag{22}$$

where π_{ik} is the price of product k in region i, C_{ik} refers to the demand of product k in regions i outside the forest sector, $\frac{-1}{\gamma_{ik}}$ is the price elasticity coefficient and λ_{tk} is the level parameter for the demand curve, thus representing the effects of all demand shifters.

Berglund (1981) used a different approach in his study on pulp and paper markets in the EEC. He constructed a partial-equilibrium model for two product aggregates, namely total paper and board, and total pulp, and the model included in its final form seven equations and seven endogenous variables. These endogenous variables were (Berglund 1981, p.30):

P_{pb} = price of paper and board in the EEC;
Q_{pb}^{E} = equilibrium quantity of paper and board sold by producers in the EEC;
Q_{pb}^{NO} = equilibrium quantity of paper and board exports to the EEC by Nordic producers;
Q_{pb}^{NA} = equilibrium quantity of paper and board exports to the EEC by North American producers;
P_{pu} = price of pulp in the EEC;
Q_{pu}^{NO} = equilibrium pulp exports to the EEC by Nordic producers; and
Q_{pu}^{NA} = equilibrium pulp exports to the EEC by North American producers.

The important features of the model are that it tries to take into account the competitive interaction between different suppliers of paper and board as well as pulp, and that the interdependencies between pulp and paper and board markets are included in the same model. However, a major drawback is that this model is built only on a theoretical level without any attempts at empirical estimation, though the effects of changes in exogenous variables are evaluated by means of comparative static analysis.

The demand modules of all the above market models are very simple, and all the factors other than price that affect consumption levels are exogenous. With the exception of the model of Berglund (1981), demand modeling requires separate estimation with traditional means outside the system, and it is important that the few parameters in the demand equation are of correct magnitude. It can be argued whether or not a simple treatment of demand as in (22) is a sufficient representation of the whole demand system with reference to the dynamic and complex nature of the paper business today. Since the main concern of the market model has been in modeling international/interregional trade and supply-side mechanisms, much less attention has been paid to demand modeling. And it should be considered whether or not the partial-equilibrium framework excluding other economic sectors, which was applied to all the market models cited above, is the best choice for analyzing paper and board demand that is closely connected with developments in the surrounding economy and society.

3.4. Methods with Derived-Demand Approach

3.4.1. Use-Factor Approach

The use-factor approach has been included in the category of derived-demand models in this paper since the theoretical basis of the approach is clearly nearer to the producer theory than to the consumer theory. The aggregate market demand is split into various end uses and these end uses, which may differ from each other in many respects, are analyzed separately in terms of use factors.

A general use-factor model may be written as follows (see Adams and others 1982 p.23):

$$U(e,t) = C(e,t)/A(e,t) = f(P, P_s, P_{EP}, \varepsilon_e) \qquad (23)$$

$$C(t) = U(1,t) \cdot A(1,t) + \cdots + U(E,t) \cdot A(E,t) \quad (24)$$

$$e = 1, \ldots, E$$

where $U(e,t)$ is use factor, measuring consumption of some forest product per unit of activity in end-use sector e in period t, $C(e,t)$ consumption of some forest product in end-use e at time t, $A(e,t)$ a measure of activity in end-use e at t, P price of the forest product, P_s price of substitutes, P_{EP} price of end-use products, E total number of end-use categories, and $C(t)$ total consumption of the forest product in period t.

Two different sub-categories can be separated based on how equation (23) is treated and they can be called:

a) use-factor models with exogenous estimates of price elasticity, and

b) use-factor models with endogenous estimates of price elasticity.

In the former group (a) the equations (23) are not estimated by any statistical means from historical data at all. It is assumed that if historical trends in the relative prices of forest products and substitutes were to continue into the future, the general historical trends in use factors $[U(e,t)]$ will continue as well. The product of projected use factors and exogenously projected end-use activity indicators $[A(e,t)]$ gives the projected demand volume at trend price. The result is a set of individual price-quantity points, one for each of the time points in the projection period. Demand functions, to assess demand levels at other than trend prices, are determined by applying demand-elasticity estimates, derived from other sources, to each of the several price-quantity points under some specific assumption about the form of the demand function, e.g. linear or constant elasticity (Adams and others 1982, p.24).

This approach has been applied mostly in the United States for mechanical wood products by the U.S. Forest Service (e.g. see USDA 1973, 1980) and this was also the demand-modeling concept used in the market model by Adams and Haynes (1980). The basic consideration in defining use factors is to isolate the part of consumption that is price-sensitive from the parts that are not, so that price and other influences on demand would be more accurately identified. The estimation of use factors involves little or no statistical processing, and therefore the approach may be used for making rough estimates of consumption relationships in situations where more detailed efforts are impossible or infeasible, e.g. because of a lack of or unreliability of data.

Recently the use-factor approach was employed in the new European Timber Trends and Prospects study by ECE/FAO Timber Committee (FAO/ECE 1986). The end-use analysis included sawnwood but pulp and paper products were excluded from this approach.

Use-factor models with endogenous estimates of price elasticity have been extensively used by Data Resources Inc. for both mechanical wood products and also paper, board and pulp products in the United States, Canada, Japan and selected countries in Western Europe (see Cardellichio and Veltkamp 1980, Veltkamp and others, 1983). In these models, the coefficients in equations (23) are estimated by statistical means from historical data. The model (called FORSIM) for softwood lumber includes altogether eight end-use sectors, and use factors are estimated from the equation (see Veltkamp and others 1983, p.249):

$$U(e,t) = f(T, P_R, P_{EP}, E_e) \quad (25)$$

where T is time factor, P_R own-price relative to the price of major substitutes and P_{EP} own-price relative to either the overall price level, or to the price of the end product.

The use factor approach, especially in the latter case, requires a substantial amount of detailed data on different end uses. This is possible only in a limited number of countries, including the United States, and for selected products. Statistical data on paper and board end-uses is generally very difficult to obtain and when it is possible, maybe only some of the important end-use sectors are covered. It is possible to gather end-use information through market surveys, but normally this material refers to only a certain point in time and the use factors can be estimated only *ad hoc* and not by statistical means.

The primary advantage of the use-factor approach is that market research and other first-hand information, which is largely ignored when using traditional econometric techniques, can be fully utilized when estimating use-factor developments. The aggregate market consumption of a forest product is divided into a set of end-use categories which may be relatively homogeneous in their structure and behavior. It is also argued by the proponents of this approach that most of the advantages of use-factor analysis are preserved even though only a few of the most important end-use sectors are covered. It is clear that this method is best applicable with relatively narrow product category definitions. Practical studies have also shown that it is difficult to distinguish between the effects of changing relative prices and other factors such as changing user preferences on the use factors. For international studies with cross-sectional data bases, the possibly different end-use structures of countries may cause further problems regarding the applicability of the use-factor approach.

3.4.2. Traditional Input-Output Modeling

The classical approach to analyzing demand for intermediate products is input-output modeling. The use of traditional input-output analysis for deriving demand for forest products has been discussed by Andersson (1984, p.1–4). If the interdependencies between different sectors of the economy are assumed to be represented by fixed coefficients, as in the classical studies by Leontief (1951) and many others, the forecasting problem can be presented as the following set of linear equations (in which all relative prices are assumed constant for the forecasting period):

$$X_i = \sum_j a_{ij} X_j + C_i + G_i \tag{26}$$

which means, for instance, that the total value of all sales from the paper and board sector (X_i) should equal the value of all purchases of raw materials and intermediary commodities ($\sum_j a_{ij} X_j ; a_{ij} = X_{ij} / X_j$, where X_{ij} is the input from sector i to sector j and X_j the total input of sector j), plus the cost of household deliveries of labor, capital and other services (C_i) and governmental costs (G_i).

In matrix form (26) can be written as

$$x = Ax + C + g \text{, where} \tag{27}$$

$$A = [a_i],\ c = \begin{bmatrix} C_1 \\ \cdot \\ \cdot \\ \cdot \\ C_n \end{bmatrix} \text{ and } g = \begin{bmatrix} G_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ G_n \end{bmatrix}$$

and the solution can be computed as

$$x = (I - A)^{-1}(c + g) \tag{28}$$

where $(c + g)$ are normally treated as exogenous parameters and are forecasted independently. The expression $(I - A)^{-1} = I + A + \cdots A^{r-1}$ indicates that interdependencies cascade through the whole economic system (Andersson 1984, p.3–4).

Input-output analysis and end-use studies can be seen as related techniques. Traditionally, input-output analysis has been used to assess the impact of a change in final-demand sectors such as households and government or the structure of inter-industry demands. Conventional end-use studies focus on one sector of the economy at a time, e.g. what is the effect on paper and board consumption of the output of a particular sector increased by a given amount. If, however, the investigator wishes to assess what would happen to total paper and board consumption in the whole economy due to an increase in GNP, for example, input-output analysis may be used to trace the effect of this increase on the output of each sector and on paper and board consumption (McKillop 1971, p.13).

Input-output analysis is seldom used for analyzing changes in paper and board demand. Åberg (1968) used input-output techniques to investigate the impact of changes in final demand on paper and board consumption in Sweden. He noticed, however, that the share of paper and board of all inputs was only 1–2 per cent in both industry and private households (Åberg 1968, p.40). Therefore, it is questionable whether input-output analysis can be a valuable tool for paper and board analysis. Another drawback to the use of this analytical technique is the lack of input-output data in sufficiently detailed form. In the case of an individual paper grade, say newsprint, it is not possible to find the necessary input-output statistics from official sources. Furthermore, it was shown by Andersson (1984, p.5) that the input demand structure is changing over time, indicating that the inter-sectoral coefficients are not constant as the classical input-output model assumes. It can be concluded that for practical forecasting purposes with an international scope, traditional input-output analysis is not a useful tool.

3.4.3. Production and Cost Function Approaches

The starting point for this approach is the firm with one or more production plants. A commodity like paper is used as one of the many inputs $(q_1, \ldots, q_n)$ to be transformed by the use of the fixed production facilities to generate a set of outputs $(y_1, \ldots, y_s)$. This production process can be mathematically expressed as (see Andersson and others 1984, p.6):

$$F(y_1, \ldots y_s; q_1, \ldots, q_n) = 0 \tag{29}$$

It is also assumed that the firm's objective is that of profit maximization or cost minimization. One way of specifying F is by assuming that the firm produces one output (y) only. Then it is possible to write an explicit *production function*, i.e.:

$$y = y(q_1, \ldots, q_n) \tag{30}$$

By using different assumptions about factor substitutability and elasticities of substitution, different production functions can be specified. Typical production functions used are the traditional Cobb-Douglas (CD) production function, the constant-elasticity-of-substitution (CES) function, and the variable-elasticity-of-substitution (VES) function and the translog production function (e.g. see Simula 1983).

Profit maximization and the existence of a mathematically well-behaved production function are general assumptions required for deriving demand for inputs. Although profit maximization is a reasonable assumption at the level of firms, constrained cost minimization has certain advantages from a general theoretical point of view (Shephard 1953; see also Andersson and others, 1984, p.16). It may also be an alternative and probably better assumption at the level of individual production plants within large corporations. Assuming cost minimization, the optimal input mix (q_i) can be solved from:

$$\underset{q_i}{\text{minimize}} \sum_i p_i \, q_i \tag{31}$$

subject to

$$y^0 = y(q_i), \tag{32}$$

where p_i is the price of production factor i (price of input) and $y = y^0$ a given level of output. The optimality conditions for the resulting Lagrangian function L are:

$$\frac{\partial L}{\partial \mu} = 0 \text{ and } \frac{\partial L}{\partial q_i} = 0 \quad \text{for all } i\ , \tag{33}$$

where μ is the dual multiplier for constraint (32).

A generalized form of the Cobb-Douglas production function can be written as:

$$y(q_i) = a \prod_i qi^{\beta_i} \tag{33}$$

where a is a scaling parameter and β_i is an input coefficient ($\Sigma \beta i = 1$). It can be shown that demand for input j can be derived from the equation (for derivation, see Kallio and others (1984, p.2-3)):

$$q_j = (y^0 / a) \prod_i \left[\frac{pi / \beta i}{pj / \beta j}\right]^{\beta i} \tag{34}$$

In the CES case the production function can be written as:

$$y(q_i) = b\left[\sum_i \gamma_i \, q_i^{a}\right]^{\frac{1}{a}} \tag{35}$$

where b is a scaling parameter ($b > 0$), γ_i's are input coefficients ($\gamma_i \geq 0$, $\sum_i \gamma_i = 1$) and a is a parameter defining the elasticity of substitution ($a \leq 1$). Similarly to the CD case, it can be shown that the demand for input j is to be calculated from (Kallio and others 1984, p.3–4):

$$q_j = (y^0 / b)\left[\sum_i \gamma_i \left[\frac{pi / \gamma_i}{pi / \gamma_j}\right]^{a/(a-1)}\right]^{-1/a} \tag{36}$$

Both equations (34) and (36) were used by Kallio and others (1984) for studying the substitution effects between wood products and other inputs in the Canadian construction sector in the period 1961-1978. It should be noted that the parameters of equations (34) and (36) can be calculated from one-year data only, or then year by year from time-series data to consider possible shifts in the parameter values over time. From a statistical point of view, the significance of the estimated parameters from formulas (34) and (36) cannot be directly tested.

Another possibility is to utilize the strong duality between production and cost functions demonstrated by Shephard (1953; 1970, p.159-177). When starting from the generalized CD production function (33), and assuming three inputs K,L and E, the production function becomes:

$$Y = bK^{a_1} L^{a_2} E^{a_3} \cdot \mu \qquad (37)$$

and the associated cost function can be written as:

$$C = P_K \cdot K + P_L \cdot L + P_E \cdot E \qquad (38)$$

where C is an index of the cost of producing Y while P_K, P_L and P_E are price indices of the inputs. The conditional factor demand for a production factor K can be derived, when assuming cost minimization and the production technology described by (37), from the equation (see Chou and Buongiorno 1984, p.159–160; Andersson and others 1984, p.16–17; Varian 1978, p.15):

$$K = b_0 \cdot P_k^{b_1} \cdot P_L^{b_2} \cdot P_E^{b_3} \cdot Y^{b_4} \cdot \varepsilon \qquad (39)$$

where

$b_0 = (b\ \alpha_1^{-\alpha_2-\alpha_3} \cdot \alpha_2^{\alpha_2} \cdot \alpha_3^{\alpha_3})^{\frac{-1}{s}}$

$s = \alpha_1 + \alpha_2 + \alpha_3$ = economies of scale elasticity,

$b_1 = -(\alpha_2 + \alpha_3)/s$

$b_2 = \alpha_2/s$

$b_3 = \alpha_3/s$

$b_4 = 1/s$

$\varepsilon = u^{-1/s}$

The coefficients b_1, b_2, and b_3 are the input elasticities, of which the own-price elasticity b_1 is negative while the two cross-price elasticities b_2 and b_3 are positive. It can also be seen that $b_1 + b_2 + b_3 = 0$, i.e., the conditional demand is homogeneous of degree zero in prices so that given a certain level of output Y, the demand for K does not change if all prices change by the same proportion (Varian 1978, p.31). The elasticity b_4 is positive and measures the shifts in demand arising from changes in output Y.

This approach was used by Chou and Buongiorno (1984) in their study of U.S. forest products demand in the European Economic Community (EEC). They derived a ***dynamic neoclassical model of the derived demand for imports*** from the U.S. by using model (39) and dynamized it based on the partial adjustment model suggested by Nerlove (1956). Their basic model was of the following type (Chou and Buongiorno 1984, p.160):

$$U = a_0^{\lambda} (PU)^{\lambda a_1} \cdot (PW)^{\lambda a_2} (PQ)^{\lambda a_3} \cdot Y^{\lambda a_4} \cdot U_{t-1}^{1-\lambda} \cdot \varepsilon^{\lambda} \qquad (40)$$

where U is the demand for a U.S. forest product, PU, PW and PQ are, respectively, indices of the price of the U.S. forest product in an EEC country, the price of the same product originating from other countries, and the price of all other inputs used in producing the output Y. λ is a coefficient with a value between 0 and 1 measuring the speed of adjustment ($\lambda = 1$ corresponds to an instantaneous adjustment). The model was applied to several forest products, including newsprint, other paper and paperboard, pulp and waste paper using pooled time-series data from the EEC countries.

In a study on mechanical wood products, Rockel and Buongiorno (1982) used a translog cost function for residential construction with U.S. monthly data for the period 1968-1977. The translog average cost function used was (Rockel and Buongiorno 1982, p.209):

$$\ln(\bar{C}) = \alpha_0 + \alpha_Q \ln Q + 1/2\alpha_{QQ}(lnQ)^2 + \alpha_t\, t + \frac{1}{2}\, \alpha_{tt}\, t^2 + \sum_i \beta_i \ln P_i$$

$$+ \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \sigma_i \ln P_i\, Q + \sum_i v_i \ln P_i \cdot A \qquad (41)$$

where $\bar{C}$ is the unit cost of residential construction, Q is the number of units built, P_i is the price of the i-th factor input, and t is a time trend used to capture technological and other changes not reflected by the price and output variables. All α's, β's, γ's, σ's and ϑ's are constant such that $\gamma_{ij} = \gamma_{ji}$ and, for a fixed level of output, $\sum_i \beta_i = 1$, $\sum_i \sigma_i = 0$, $\sum_i \vartheta_i = 0$ and $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$. The corresponding general equations for derived demand can be written as:

$$X_i(\underline{P},Q) = (C(\underline{P},Q)/P_i)(\beta_i + \sum_j \gamma_{ij} \ln P_j + \sigma_i \ln Q + \vartheta_i\, t) \;\; \forall i \qquad (42)$$

where X_i is the demand for input i. Four additional cost models were developed by simplifications of (42), of which one was the cost function of a generalized CD production function. It was noticed that the dual cost function of the generalized CD production function described the data adequately. Consequently, the derived demand function (42) simplifies to:

$$\ln X_i = \alpha_0 + \alpha_t\, t + (\alpha_Q + 1)\ln Q + (\beta_i - 1) \ln P_i\; e \sum_{j \neq i} \beta_j \ln_j \;\; \forall i \qquad (43)$$

A further type of cost function, a generalized Leontief cost function, was introduced by Diewert (1971). This function in its simplified form is quadratic in the square root of prices and directly proportional to output (see Doran and Williams 1982, p.134):

$$C(p,y) = y \sum_{i=1}^{m} \sum_{j=1}^{m} \beta ij\, (p_i\, p_j)^{0.5}\,, \quad \beta_{ij} = \beta_{ji} \qquad (44)$$

With this cost function, the demand for input i is given by:

$$Q_i = y \sum_{j=1}^{m} \beta_{ij} \left[\frac{p_j}{p_i}\right]^{0.5} ,\beta_{ij} = \beta_{ji} \qquad (45)$$

where p's refer to the prices of different inputs, y to the output level, and β_{ij}'s are unknown parameters to be estimated by using either ordinary least squares (OLS) or seemingly unrelated regression (SURE) techniques. Both methods yield consistent and unbiased estimates, but SURE is more accurate and efficient because there is the symmetric constraint ($\beta_{ij} = \beta_{ji}$) and there is more than one equation.

Doran and Williams (1982) used this approach for analyzing the demand for domestically-produced sawnwood in Australia. Andersson and others (1984) applied the Diewert cost function to the Canadian construction, furniture, office, and printing and publishing sectors. A major advantage of the Diewert cost function over the Cobb-Douglas cost function is that the Diewert-type function allows for complements and differences in substitution elasticities between different inputs.

Production and cost function approaches have some advantages but also drawbacks in the demand analysis of forest products. The advantages include:

1) The approach is well grounded in economic theory, and the functional form and the empirical estimates of each derived demand function necessarily flow from the cost function (Rockel and Buongiorno 1982, p.218).
2) The approach focuses on the relationships with different inputs and involves system estimation as opposed to single-equation estimation (Doran and Williams 1982, p.146).

The main disadvantages are:

1) The cost function may be misspecified if all important inputs are not taken into consideration, leading to biased elasticity estimates (Doran and Williams 1982, p. 146).
2) The approach requires detailed data which are only seldom available on a sufficiently detailed level (Rockel and Buongiorno 1982, p.210).
3) Prices are determined exogenously, and price forecasts have to be made separately.
4) Prices are used to explain the whole substitution process although other variables related to the input factors may also be important determinants as well.
5) In the case of paper and board, there are several different end uses, which may have production/cost functions clearly differing from each other, and these functions may be extremely difficult to be explicitly expressed. Estimation of model parameters is impossible because of the lack of empirical data.

3.5. Subjective Assessment Methods

3.5.1. Use of Human Judgment in Forecasting

The work on subjective judgmental forecasting methods, which are also often called qualitative or technological forecasting methods, was not started until the 1950s when these methods were applied mainly to government situations (Wheelwright and Makridakis, 1980, p.268). Later on, a number of large companies also began to employ these methods primarily for their long-term corporate planning. There are two obvious situations which usually require a qualitative approach to forecasting:

1) When data are scarce - for example, when a new product is first introduced into a market. Human judgment and rating schemes are used to turn qualitative information into quantitative estimates (Chambers and others 1971, p.49).
2) When analyzing what exceptional occurrences, structural changes, new developments and discoveries can be expected in a specific area (Wheelwright and Makridakis 1980, p.267).

The dependence of formal forecasting on human judgment has been stressed in recent research and literature on forecasting. Human judgment affects several phases of forecasting: acquisition and generation of inputs, diagnoses, model building and information processing, and interpretation and formulation of outputs (Eerola 1986, p.14; Hogarth & Makridakis 1981, p.117).

The value of judgmental forecasting methods lies in the fact that they can often be used to supplement quantitative methods. Fitting a model to past data is still the standard procedure followed by statisticians, economists and other model builders, but empirical evidence has shown, however, that more accurate fits often do not improve post-sample forecasting accuracy. Alternative ways of minimizing post-sample forecasting errors may include utilizing more information from the past data, and combining the results of quantitative models with judgmental forecasts in an effective way (Makridakis 1986, p.37).

The use of judgmental methods for analyzing the future market outlook is rather recent in the world pulp and paper industry. The literature on subjective forecasting applications to paper and board products is relatively limited. It is obvious that judgmental assessment is used more by the paper industry corporations than one can conclude based on the literature, but often the use of expert opinions, etc. is intuitive and not made within a structural framework which could be documented.

In the following, some of the judgmental methods used, to the author's knowledge, by the paper industry are discussed. These methods include:

1) Delphi method
2) Expert panel consensus
3) Market research and end-use techniques
4) Visionary future judgment or scenario techniques.

3.5.2. Delphi Method

The Delphi method can be summarized as follows (Chambers and others 1971, p.55):

> "A panel of experts is interrogated by a sequence of questionnaires in which the responses to one questionnaire are used to produce the next questionnaire. Any set of information available to some experts and not others is thus passed on to the others, enabling all the experts to have access to all the information for forecasting. This technique eliminates the bandwagon effect of majority opinion."

The essential feature of the Delphi method is that the experts are not allowed to communicate so that their judgments will not be influenced by social pressure or by other aspects of small-group behavior. The Delphi method, unlike many forecasting methods, does not have to produce a single answer as its output. Instead of reaching a consensus, the Delphi approach can leave a spread of opinions, since there is no particular attempt to get unanimity. The objective is to narrow down the quartile range as much as possible without pressuring the respondent. Thus, justified deviant opinion is allowed by this approach (Wheelwright and Makridakis 1980, p.278-279).

The Delphi approach in its pure form is used rather seldom for the paper demand forecasts. Glass (1982) used this approach as an alternative method for forecasting printing and writing paper consumption in western Europe in 1990 by utilizing the expertise of industry experts at an international seminar. A comparison of the results received from traditional trend projection and GNP correlation analysis with the final results of the Delphi approach showed no significant differences (Glass 1982, p.20).

A second example of the use of the Delphi approach to paper demand forecasting is given by Oliver (1985). The approach was employed to assess the impact of cable television and interactive electronic home systems on newsprint demand. Baseline demand forecasts were made for each major world region using traditional regression analysis (GDP as the main explanatory variable), and then several experts separately estimated the impact of the new electronic media on the forecasts. The Delphi panelists on average adjusted the baseline projections downwards for western Europe and North America, but no adjustment was considered necessary for the rest of the world (Oliver 1985, p.49).

It is not known how strictly the Delphi approach was followed in the case Oliver (1985) reported. Often the first questionnaire is completed as the Delphi method suggests, but on later rounds free discussion is allowed and thus the method begins to resemble review panel techniques. As the above example shows, in paper demand forecasting the Delphi approach may be useful for analyzing the effects of factors for which no historical data exist but whose impact can be seen in qualitative terms. An advantage of the Delphi approach is that the experts can be both in and outside the company and that each expert need not be qualified in the same area. By using experts from different business areas, it may be easier to cover the whole problem area of interest.

3.5.3. Expert-Panel Consensus

The expert-panel consensus technique is defined by Chambers and others (1971, p.55) as follows:

> "The panel consensus technique is based on the assumption that several experts can arrive at a better forecast than one person. There is no secrecy, and communication is encouraged. The forecasts are sometimes influenced by social factors, and may not reflect a true consensus."

Review panels of paper-industry experts have been used to assess the proposed market outlook, e.g., by FAO (1977b). The preliminary forecasts of paper consumption prepared by using common quantitative techniques were assessed by an industry working party including members from several countries. The final consumption forecasts were obtained by combining the original proposal and the judgment of the experts.

The approach was also used by JAAKKO POYRY (JP 1982) to estimate the future effects on the demand for paper and board of substitution by electronic information systems, advances in packaging and declining grammages of paper. Judgmental assessment was used particularly for newsprint, sack paper and other kraft paper demand forecasting. For newsprint, subjective assessment of experts was used because there were no suitable data for estimating the possible effects of new information systems, and for sack paper and other kraft papers because the recent consumption history showed a maturation of the markets and an obvious turning point of the consumption series indicating that the past relations would no longer hold in the future. Due to declining grammages of newsprint, the demand forecasts of newsprint were prepared on an area basis and future average grammages were separately estimated by an expert team consisting of both paper-manufacture and graphic-arts-industry experts.

The value of the information gathered through review panels lies in the fact that it contains *a priori* insights of experts who are well familiar with the socioeconomic business environment. The use of expert panels improves the possibilities for evaluating future turning points and new influences on demand. Large deviations in expert opinions, which might be a problem for practical forecasting purposes when using the Delphi approach, can be more easily handled by the panel-consensus method allowing free communication of experts.

An important question is at which stage of analysis should expert opinions be taken into account. In the JAAKKO PORY (JP 1982) study, this was done at several stages of the forecasting process, starting from data analysis and ending with evaluation of the results. A second question is who should participate in the expert panels. It should be remembered that a review panel is a forum where social communication plays an important role. There is always a danger that one participant with strong opinions and/or high social status will be able to modify the panel consensus according to his/her own opinion.

3.5.4. Market Research and End-Use Techniques

The market research and end-use techniques can be described as being based on a systematic and conscious procedure for collecting data and/or opinions directly from all relevant market participants. The method is strictly market- and marketing-oriented; thus it is mostly applied by market research organizations, consulting companies and marketing planning departments of large companies/corporations. Field research plays a very important role and normally involves substantial costs.

The need for end-use forecasting turning periods characterized by technological change has become evident in several branches producing and marketing industrial goods or services, not only in the paper industry (e.g., see Fischler and Nelson 1986).

In the paper industry the importance of end-use analysis has been emphasized recently by Graff (1984) and Goldstone (1985). The complex nature of paper and board products discussed earlier has resulted in a growing interest in end-use analysis, the main aim being a better understanding of the market circumstances regulating the sales and consumption of paper and board grades. The basic phases of market research and end-use techniques for forecasting future demand are:

a) analyzing the market structure by identifying all important end-user groups, the quantities bought by each group, the number of buyers, and the prevailing price level by end-user group,

b) clarifying the main factors affecting the purchasing decisions,

c) collecting opinions and expectations of each important end-user group about the future growth of their business and arguments for the growth (driving forces),

d) identifying new possible threats and opportunities that might change the paper consumption pattern of the branch, caused by already known or foreseeable developments in the end-use industries,

e) evaluating the material collected from each end use, concluding the effects on paper or board consumption, preparing judgmental forecasts by main end use based on the fieldwork results, using possibly also some external indicators describing the growth of the end-use industries for comparison, and

f) comparing the results with forecasts received by some other (quantitative) methods, reviewing them within a panel of experts, discussing the possible bigger deviations and reasons for them and revising the results accordingly, if necessary.

There are naturally also other methods of end-use analysis, but the above list of phases represents a very typical means by which consumption forecasts are made based on the market-research approach. The subjective element in the forecasting process is essential, the personal judgment of the researcher is needed particularly when evaluating the fieldwork data. Since the effect of the forecaster's own opinions and understanding is to be seen in the results, it is important that the forecaster is well familiar with the end use industries in question. In practice this means that normally the forecaster has to do a considerable part of the fieldwork him/herself. For the same reason, sending mail questionnaires is often out of question; personal and telephone interviews have proven to be more reliable and effective ways for collecting information about the end-use industries and the major mechanisms and forces prevailing in the paper and board markets.

The market-research approach is widely applied in the practical forecasting work of paper companies, but the literature on the end-use technique is limited. This is understandable, since most studies in this category are intended for a certain purpose within the company and are often confidential. Additionally, econometricians and other scientists can with considerable justification label the method as non-scientific and therefore pay little attention to this approach. In fact, many of these scientists lack the necessary experience with the paper industry and markets, and thus are unable to use the method at all.

The market-research approach has been used in several multiclient studies prepared by market-research and/or consulting companies. Recent examples of this kind of study are JP (1984, 1986), BIS (1985) and RISI (1986). All these studies are based on substantial fieldwork by market experts. One reason for using end-use analysis is that the paper grade classification in the studies is so disaggregated that there is no statistical material available on the consumption, production, prices, etc. of these individual grades. However, a better understanding of market forces and interrelations between end-use industries and the paper industry is the main advantage supporting the use of the market-research approach.

End-use analysis is often used in combination with other techniques. For example, when using the earlier discussed use-factor approach, the past and future values of use factors may be determined based on the results of market research reports. This is discussed (for lumber consumption) by Spelter and Phelps (1984, p.35-36). End-use techniques can be used also for collecting data for other quantitative methods, though the data acquired through market research normally have a cross-sectional nature which restricts the use of the method for many quantitative modeling applications.

3.5.5. Visionary Future Judgment

Chambers and others (1971, p.56) define this approach in the following way:

> "A visionary forecast is a prophecy that uses personal insights, judgment and, when possible, facts about different scenarios of the future. It is characterized by subjective guesswork and imagination. In general, the methods used are non-scientific. Data requirements are a set of possible scenarios about the future prepared by a few experts in light of past events."

Scenario techniques can be classified into this group of forecasts. Different kind of scenarios about the future market status are frequently used by paper companies in their strategic planning to support decision-making. A typical example of scenarios applied to paper demand is, e.g.:

> "It is believed that newsprint consumption in Western Europe will grow annually by 2% on average in the next ten years, provided that the total GDP growth will average 2.5% per year during the same period."

Strictly speaking, scenarios are no real forecasts. They are rather rough assumptions about the future state of affairs whose purpose is to bring subjective expectations on a quantitative level and thus assist in the evaluation work in a decision-making process. For actual forecasting purposes, some other approaches have to be used.

An interesting procedure for managing strategic uncertainty is presented by Mason and others (1986, p.1-2) in their Future Mapping System. The system provides a structural framework for accessing, formatting and relating large amounts of diverse information about the business environment and developing changes in competitive dynamics. The purpose of the effort is to explore a set of diverse possible futures, define key events in the development of each alternative, and establish perspectives for developing strategic plans that are robust in the face of a variety of potential futures. The system tries to facilitate capturing structural change in advance of the competition and also provides a set of guidelines for the monitoring and development of alternative strategies over time.

The most interesting thing in the Future Mapping System is that it provides managers with a structured tool showing how to proceed with different scenarios into strategic decisions. The method also emphasizes the search for both current and future driving forces of the business and finding possible discontinuities which may simultaneously be both opportunities for and threats to the business. This is essentially the area where human judgment and qualitative forecasting methods have their biggest value. It is not known to the author whether this system has been applied by the forest industry companies.

3.5.6. Main Advantages and Disadvantages of Subjective Assessment Methods

The main advantages of the use of subjective assessment techniques for forecasting paper and board consumption can be summarized as follows:

1) It is possible to take into account the *a priori* insights of experts, which improves the possibilities for evaluating future turning points and new influences on demand and the market environment as a whole.
2) These methods can be used even if data are scarce (the methods are then often the only possibility for preparing any forecast).
3) They can be used as supplements to quantitative methods for making new data and variables available, for testing the acceptability of the model results, or for evaluating possible changes in time-dependent parameter values of quantitative models.
4) These methods are, in comparison with some sophisticated quantitative models, rather simple and easy to understand by decision-makers; this facilitates the interpretation of the results and thus increases the value of forecasts to the final users.

The main disadvantages of subjective assessment methods are:

1) They have little theoretical background and thus lack scientific acceptance.
2) The results are sensitive to the persons who are participating the judgments, and thus the involvement of a "peculiar" analyst may give exceptional results (particularly if using the panel-consensus method).
3) There are no possibilities to control the validity and reliability of the results by calculating confidence limits etc. by statistical means.
4) For long-term forecasting purposes, the opinions and expectations of experts or end users often reflect too much the latest market developments (cyclical behavior of the market), resulting in erroneous forecasts.
5) Qualitative methods often involve substantially high costs and take a lot of calendar time because of the use of experts and/or the gathering of unpublished data. This applies particularly to the market-research approach if the geographical and/or product scope of the research is wide.

4. CONCLUSIONS

4.1. Summary of Requirements for Long-Term Paper and Board Consumption Models Suitable for Practical Forecasting Purposes

The general requirements for practical forecasting models were summarized in section 2.2. When considering these and the specific characteristics of forecasting paper and board consumption, the following requirements for an ideal model can be listed:

1) The model should derive its framework consistenly from generally accepted postulates of macro- and microeconomic theories.

2) It should take into account the oligopolistic nature of paper and board markets and not be based on the simplistic assumption of perfect competition.

3) The product characteristics of paper and board should be considered in the model. Since end users or buyers of paper and board include both producers of different commodities and final consumers, the model should utilize elements describing the behavior of both buyer groups, i.e., consider both producer and consumer theory.

4) The model should describe the actual end-use markets for paper and board in an efficient way; when using a very abstract model there is always a danger of losing some essential information about the real business environment, and on the other hand, the value of a very detailed econometric model in practical forecasting is limited by the large number of explanatory variables whose forecast values should be available in advance.

5) The model should be a *consumption* rather than *demand* model; it should take into account also the supply-side factors affecting the price and quantity levels in the market system.

6) All essential information available *a priori* about the end-use industries, product innovations, technological advances and other factors related the market environment should be utilized in the model. This information covers both statistical "hard" data and "soft" data resulting from judgmental assessment, which should be based on a well-managed, structured procedure.

7) The model should be statistically consistent so that the reliability of the results could be assessed mathematically.

8) A good forecasting tool should allow for structural variability of the system, i.e., show dynamic properties of adaptation to changes within the time horizon of forecasting.

9) Generality of the model is essential. It should be applicable with small modifications to several forecasting situations and not be a tailor-made model for one product and one country only.

10) To ensure that results from use of the forecasting model are actually used by decision-makers, the model should have an understandable structure and a relatively simple formulation avoiding highly mathematical expressions. In the worst case the forecasting method is considered as a "black-box method" by decision-makers, and thus the whole credibility of the forecasting system and its results are endangered.

4.2. Major Drawbacks of the Present Paper Consumption Models

There is no international long-term model for forecasting paper and board consumption which would be superior to all others. Most of the research work has used different direct-demand approaches, although recently the derived-demand approach has also been applied with increasing frequency. However, for several reasons (stated earlier in this paper), the latter approach has not proved to be a better choice than the traditional models. Major drawbacks of the present models can be summarized as follows:

1) In most international paper consumption models, demand is forecast separately from supply, though both quantity and price are solved simultaneously as a result of the interaction of supply and demand. Instead, prices are often included as exogenous variables which in a forecasting situation means that they should be determined in advance. When using the assumption about perfect competition underlying all these models, this is not justified from theoretical point of view unless the price level is controlled by authorities or is otherwise given outside the supply-demand mechanism.

2) The assumption about purely competitive markets for paper and board is a simplification of the actual market situation; the nature of competition also varies according to the product group in question. In consumption modeling, competition types other than perfect competition have seldom been assumed; an exception was the study by Muller (1978) where a price-leadership assumption was made.

3) Most international models analyze the markets with overly aggregated product categories and use some very general economic variables like GDP/GNP or industrial production as explanatory variables without trying to clarify the actual driving forces for the demand for individual products/product groups. Within these aggregates (e.g., printing and writing papers), the changing structure of the product group over time is also ignored, though the effect on average prices and end-use markets might be essential (e.g., the breakthrough of LWC paper in the 1970s).

4) The starting point for paper and board consumption models has been either consumer theory or producer theory, from which the consumption models are derived by simplistic and often ambiguous means, and then the model is applied to the paper sector with more or less violent assumptions about market behavior. How well the model structure corresponds to the actual market picture is seldom evaluated or even discussed.

5) So far, substitution effects for paper and board have not been properly taken into account. Efforts have been made to include substitute prices in demand equations, but the choice of price series has been in many cases arbitrary because of the lack of data and/or analysis of substitution mechanisms. For reasons discussed elsewhere (Uutela 1984, p.15 and 21), it is evident that prices of different materials as such are not the only decisive factors for buying or consumption decisions for paper and board; there are many intervening variables such as labor intensity, installation or user cost, flexibility of use, and product performance, which together determine the choice of materials. It is a question of *system substitution* rather than *product or price substitution*.

6) There is a lack of additional explanatory variables which would be able to explain the residual variance between countries after the impacts of general macroeconomic variables and prices have been considered. Often, countrywise dummy variables have been employed to improve models from a statistical point of view, but this procedure does not necessarily improve the forecasting properties of the model at all. A dummy variable may represent the net sum of several omitted variables affecting model outcome in different directions and with a different time horizon, thus making the determination of the future value of the dummy variable extremely difficult or impossible.

7) The models do not normally allow for structural variability of parameters within the forecasting horizon.

8) The forecasting properties of the models are seldom emphasized. The analysis is often stopped after the estimation of parameter values from past data. However, it was shown by Baudin (1985a) that the confidence limits for individual forecasts from a statistically acceptable model may be so broad that its use for practical forecasting purposes is very questionable.

9) Too little attention has been paid by researchers to data aspects. The main focus has normally been on the formulation of the model structure and its theoretical background, and the data needed for estimating model parameters have been taken from sources easily available to the researcher, mostly international statistical publications. Unfortunately, the quality of data in these compilations is varying, and use of these data often requires a critical evaluation of data quality. In many cases, it is possible to have several alternative data sources which could be used to replace questionable time series.

10) Most models include only the statistical analysis of past relations between variables but no evaluation of possible changes in the future model environment. Statistical models are not able to utilize material other than "hard" data on facts about the past. Forecasting should be seen as an iterative process where statistical analysis forms only one, though very important, part of the whole forecasting procedure.

4.3. Suggestions for Improvements and an Approach

Based on the above review and assessment of different paper and board consumption models the following conclusions for improvements in further research are suggested:

1) The modeling work could be started with a detailed description of the market structure of the paper or board grade in question, including identification of all relevant end-user groups, main driving forces for demand in each group, buying and distribution practices, price formation mechanisms, non-price factors affecting buying decisions, supply structure, production technology of suppliers, and factors determining changes in production levels. A schematic overview of how the market system could be described is given in Figure 1.

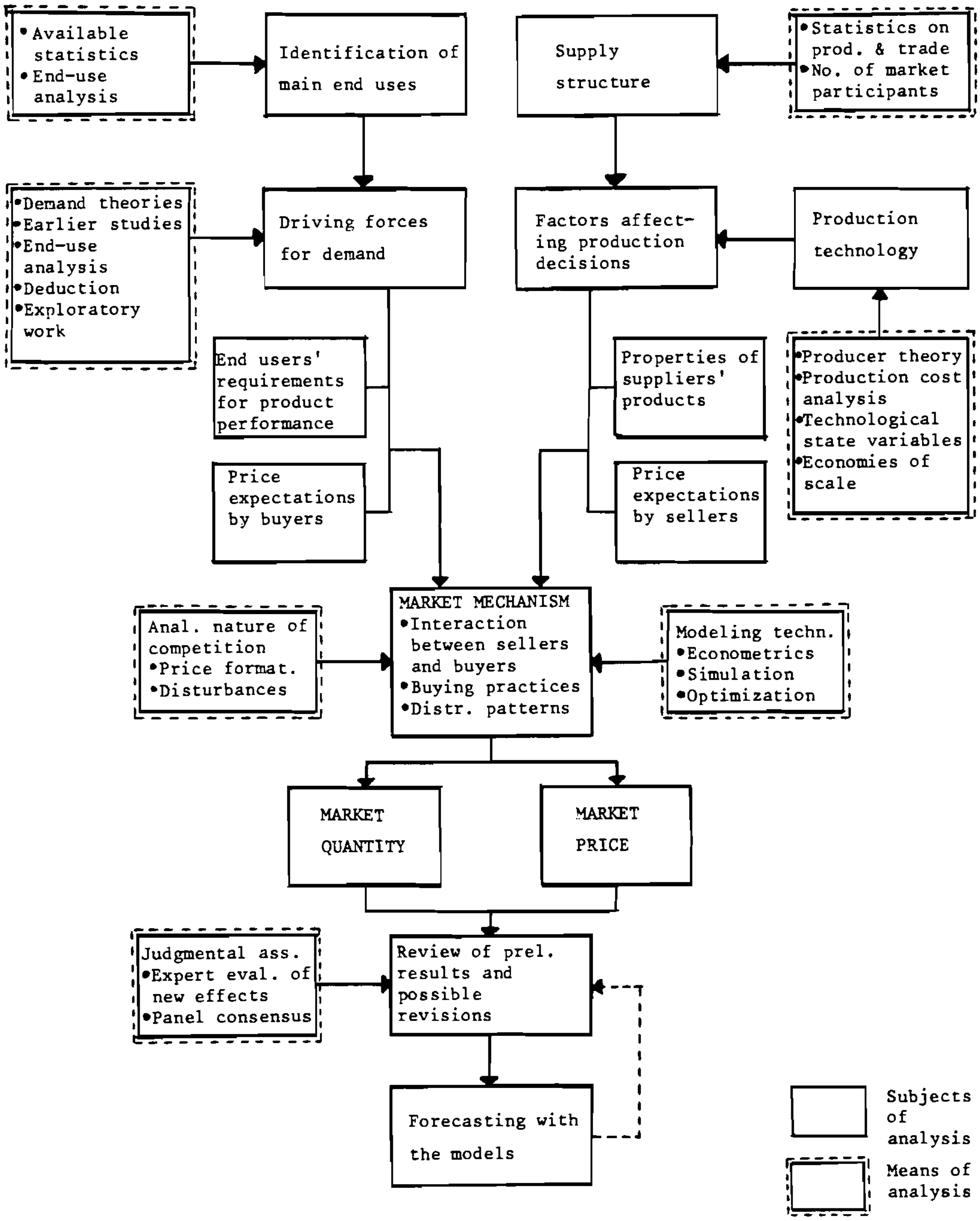

Figure 1. A hypothetical framework for modeling paper and board markets for forecasting purposes.

forecasting purposes.

2) It would be possible to analyze the driving forces for demand much more thoroughly than before by starting from the end-use distribution of consumption, mapping the main factors affecting the developments of each end-use sector, searching for variables representing these factors satisfactorily and combining them into a structurally reasonable framework. At this stage, much effort should be directed to the identification of suitable variables and data concerning the end-use industries, as well as testing the quality of data in advance. There are several means for doing this, as suggested in Figure 1.

3) It is evident that the supply side cannot be excluded or considered at recursive phases of forecasting, as most current paper and board forecasting models do. Interaction between buyers and sellers (i.e., negotiations) determines finally the quantity and the price level in the market. The general producers theory provides only a theoretical starting point for this analysis; another approach, departing from the industry itself and its main problem areas by analyzing the cost structure, variables describing technological state and changing production conditions, may contribute to the supply modeling. With regard to the high capital intensivity of the pulp and paper industry, the effects of economies of scale have to be considered in the models.

4) It might be possible to introduce some variable(s) describing non-price factors, e.g., product performance to allow for a limited product differentiation due to a different raw-material basis, production technology or branding in the model. One simple possibility would be to use dummy variables for describing these differences between products originating from areas/producers with clearly different quality standards.

5) More attention could be paid to the nature of competition in the markets. Most consumption models assume perfect competition; however, in models addressing price formation in the pulp and paper industry, other types of competition have been applied. Muller (1978) used a oligopolistic model for the Canadian newsprint industry but a competitive model for the pulp industry. He was criticized by Schaefer (1979), who concluded that a competitive model would also be a better representation of the newsprint market. Price leadership models based on oligopolistic market assumptions (and mark-up pricing) have been used also by Dagenais (1976), Buongiorno and others (1983) and Singh and Nautiyal (1984). In an earlier paper, Buongiorno and Gilless (1980) assumed that monopolistic competition generally prevails in international pulp and paper markets. Since there is no common agreement on which type of competition would be the most realistic assumption for paper and board markets, the market behavior should be analyzed and the price formation system tested separately for each product group in question. A framework for empiricaly testing the hypothesis of price-taking behavior is provided by Appelbaum (1979).

6) Substitution analysis could be extended. Instead of strictly applying the principles of price theory, the non-price factors relating to substitutes and paper and board products should be taken into account. Though construction of these variables is certainly complicated, a thorough analysis of the critical properties in each end use may produce new possibilities to consider substitution effects in the models in a more realistic way.

7) The effects of technological change in the pulp and paper industry could be taken into account in consumption models, too. Within a time perspective of 15-20 years, several important changes have occurred in the past. Examples of how technological change can be modelled are given by Buongiorno and Gilless (1980), Stier (1983, 1985), Wibe (1983) and Spelter (1985).

8) Econometric methods have predominantly been employed in building forecasting models. The use of other techniques, particularly simulation and optimization methods, may sometimes be more effective ways for producing applicable forecasting results.

9) The models could be built so that they allow for varying parameter elasticities due to technological innovations, product maturity, etc. Possibilities for modeling structural variability have been discussed recently by Westlund and Zackrisson (1986a). Applications to the forest sector include studies by Spelter (1985), Baudin and others (1984), Baudin and Westlund (1984) and Westlund and Zackrisson (1986b).

10) As Figure 1 suggests, forecasting could also include methods other than pure statistical analysis. The use of human judgment in the interpretation of the results and evaluation of new possible factors in the market is important, particularly because many paper and board segments are showing signs of maturity and rapidly changing product requirements.

It is clear that all of the above-listed suggestions for improvements cannot be immediately implemented when building a new consumption model. Many of the problem areas where improvements are needed are complex and difficult to analyze thoroughly. Data and measurement problems facing researchers are also substantial. The purpose of this paper was to show how much work on paper and board consumption models is still needed rather than to provide a ready solution. The approach suggested in this paper is more practice-oriented than approaches proposed in most earlier studies, and thus it is believed that it can be used as a good starting point for further research. The next few years will show how efforts building new paper and board consumption models for practical forecasting purposes based on such an approach will succeed.

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