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FOLIA FORESTALIA 101

METSÄNTUTKIMUSLAITOS · INSTITUTUM FORESTALE FENNIAE · HELSINKI 1971

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IUFRO, SECTION 31, WORKING GROUP 4

FORECASTING IN FORESTRY AND TIMBER ECONOMY. Preliminary report

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FOLIA FORESTALIA 101

Metsäntutkimuslaitos. Institutum Forestalia Fenniae. Helsinki 1971

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FORECASTING IN FORESTRY AND TIMBER ECONOMY

IUFRO, Section 31, Working Group 4

Preliminary report

6682--71/80

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CHAPTER I

1. INTRODUCTION

11. Purpose and Objectives of the Working Group

The program of the Working Group was outlined in continental meetings of the members and by correspondence in 1962–64. It was then agreed that the main objectives of the Working Group were:

(1) to list and review the major kinds of forecasts carried out in the field of forestry and forest products;

(2) to review the purposes for which forecasts are used and can be used, and to determine the requirements of a successful forecast;

(3) to define the basic concepts and terms of forecasting in the field;

(4) to study what models – including the selection of variables – can be successfully used for forecasting in various fields of forestry and timber economy;

(5) to find out whether there are any major gaps to which special attention should be paid in future research work.

12. Definition of Forecasting

Since this report is to deal with forecasting, little can be accomplished until this term is defined satisfactorily within the context of meaning accepted by the committee. THEIL (1958, p.l) defined forecasting as signifying "a statement concerning unknown, in particular future event." Among the several definitions given by WEBSTER the one most pertinent would seem to be: "to calculate or predict some future event or condition usually as a result of rational study and analysis of available pertinent data; esp. to predict weather conditions on the basis of correlated meteorological observations . . ."

As used in this report, the term forecast will be defined as a *quantitative estimate of some specified future condition or event, made as a result of rational study and analysis of available pertinent data.* Unless otherwise stated the term will be confined to conditions and events of an economic nature, and to those concerned with forestry and forest products (Forst- und Holzwirtschaft).

13. Use and Importance of Forecasting

The value of forecasting has long been recognized in practically all sections of economic activity. Virtually every economic decision made by private enterprises or public agencies rests upon some assessment of future conditions. To be sure, the past offers guides; sometimes very specific ones: cost records, performance records, sales records, experience of all types and levels. These are all important, but if economic decisions are to be significant they must be made with respect to future events. As soon as the word "future" is introduced one necessarily encounters an element of uncertainty. Forecasting aims at reducing the area of uncertainty regarding the assessment of future conditions, thus providing as accurate a basis as possible for making economic decisions.

STREYFFERT (1957, p. 72) was probably correct when he wrote that "there is hardly any other section of economic life which requires forecasting future development more urgently than forestry." One must observe, however, that this view is scarcely universal among foresters, a good many of whom would no doubt argue that long range forecasts are valueless – that they assume a knowledge of the future that is "ridiculously presumptuous." It seems, however, that such arguments miss the fundamental point. Timber production is, by its very nature, a long-term undertaking. Any advocate of continuous forest management, of thinning, of planting, or of any of the myriad of production practices that are common to the forestry profession, either implicitly or explicitly *forecasts* that there will be markets for the product of his labor.

Behind these rather elemental types of forecasts are a host of others, forecasts that are frequently overlooked in the preoccupation with timber production, but are never-the-less basic to the conduct of all forestry enterprises. The forest owner, for example, must make a specific forecast before deciding upon the species to be grown, the area to be devoted to production, the rotation and form of management, etc. Forest-based industries require forecasts in both short- and long-term planning. In the pulp and paper industry production units are large and involve heavy long-term investments. Their planning presupposes forecasts of long-term development of the market for pulp and paper and of the long-term supply of raw materials. The more reliable these forecasts are, the more likely it is that the investments will be successful.

Important though forecasting may be to private enterprise, it is probably even more important to those public agencies and authorities who are responsible for formulating public forest policy and for moulding economic policy in general. Rational policy decisions can only be made if future developments are carefully assessed – this means forecasting. One might argue long and loudly about the accuracy of the forecasts made (for example) by FAO in its path-breaking study "World demand for paper to 1975," but few would contend that these forecasts have not played a significant role in the expansion of this industry, especially in the Nordic countries and in North America. And anyone even vaguely familiar with the changing policy picture in the United States is well aware of the part played by the Copeland Report, the Reappraisal Reports, the Stanford Report, and the recent Timber Resource Review – all studies which attempted to foresee the changing role that timber might be called upon to play in the developing nation.

In a later section dealing with methodology it will be necessary to deal more directly with the *purpose* of forecasting, for the purpose often dictates the method most applicable. For the present, however, the point has been sufficiently stressed; forecasting is a necessary – in fact an inescapable – part of forest economics in the modern and changing world of today. It behoves the profession to study the techniques most applicable to their peculiar problems.

14. Requirements of a "Good" Forecast

Any analysis of forecasting methods presupposes a certain level of agreement on the requirements of a forecast. Before proceeding further we must try to answer the question: what are the requirements of a "good" forecast, and of a "good" forecasting method? They are believed to be five in number.

1. *A good forecast will be accurate in concept and in terminology.* This requirement applies, of course, to all scientific work. It seems worth stressing in this connection, however, since a number of published forecasts have used terms such as "demand", "supply", "requirements", "consumption", etc. in a variety of meanings and without explicit qualification. A later section on terminology (Section 3) will attempt to provide a basis for eliminating some of the present confusion on this score.

2. *A good forecast is assumed to give correct predictions.* The aim of forecasting is, in most cases, practical rather than theoretical. Hence its practical value depends mainly on how well it predicts the condition or event in question. An industrialist deciding on alternative investments in paper-production facilities, for example, is little interested in the correlation between GNP and the demand for paper as such in a specific nation or group of nations. He may, however, be extremely interested in the probable paper consumption of the same nation, in

the predicted price, and the possible new paper products which will be consumed. He will also probably be quite interested in predictions of the relative availability of raw materials needed for his particular operation and for the operation of his competitors — either local or foreign.

This requirement — that a good forecast yield accurate predictions — means that the assumptions underlying the prediction itself must correspond to facts. This applies to the model used, to the choice and quantification of the variables, and in fact to the whole construction of the forecast.

This does not mean that alternative sets of assumptions should be avoided. Rather, the forecaster should state explicitly the assumptions underlying his forecast and indicate the combination and values of variables believed most probable. Such a forecast usually implies that the forecast is a "conditional" one, that the event or condition in question is contingent upon values of certain "independent" variables, the values for which must also be forecast (although not necessarily in the same manner, or by the same individual). But even with the most carefully specified set of assumptions allowance must always be made for the casual, random, unforeseen factors which cannot be taken into account.

3. *A good forecast will be non-subjective.* This requirement is implicit under the definition of forecasting given earlier. By defining a forecast as "a result of rational study and analysis of available pertinent data", any crystal-ball techniques are clearly excluded. The selection of the method may well be the result of individual consideration on the part of the forecaster, but the method itself should be non-subjective; anyone with sufficient knowledge of forecasting technique should be able to use the method and achieve approximately equal results.

4. *A good forecast must rest on sound economic considerations with assumptions being explicitly stated.* Again, this requirement is implicit in the definition previously cited, but needs stressing simply because it has been frequently violated in the past. The requirements could be stated differently by specifying that "the model used must be consistent with economic theory and with the political and social realities of the situation". In addition, the model must possess "internal consistency". This latter specification is, in forestry, somewhat more difficult to assure than in many other types of enterprises because of the time spans that are involved. A forecast of consumption, for example, should not only take into account the conditions specified concerning both supply and demand, but should also be in accordance with the pattern of consumption that leads up to the specific period. If this is not the case then the assumed pattern should also be specified. As an illustration one might take the case of a national forecast of consumption for (say) the year 2000. The forecast might be phrased in terms such as, "if the timber producers undertake the required intensity of production, the supplies of sawlog-quality timber would be sufficiently large to permit a per capita consumption of one cubic meter of sawnwood annually". But in this forecast a number of assumptions concerning market events during the period are implied. One of these assumptions will be that the preceding consumption has not passed certain limits.

5. *A good forecast method will cost no more than any other yielding equally good results.* Given the wide variety in methodology it follows that there is apt to be considerable variation in costs of forecasts. Unfortunately, the results of two different methods are often difficult to judge on purely objective grounds. We feel it important, however, to indicate that costs of forecasting are important, and that frequently the choice of method may depend upon alternative costs.

2. REVIEW OF LITERATURE

The appendix lists the main forecasts in the field of forestry and timber economy, which are known to the members of the Working Group. The coverage of the list is not complete since only the studies which have been either printed or published in mimeographed form are included. The list therefore covers mainly those forecasts which have been conducted by international organizations, official or semi-official research institutions, and research workers. It does not cover the work done by individual firms and their organizations for their own use. It is probably correct to say, however, that the list contains the major portion of those forecast studies in the field which are of methodological interest.

Examination of the list shows that forecasting is, with a few exceptions, a rather recent but very progressive field of study in forest economics. It can also be seen that a very great part of the work in question has been done by FAO, sometimes in collaboration with other international agencies. In the series of "Timber Trends Studies" FAO has contributed greatly to the development of forecasting methods and probably even more to the fact that the whole world has gradually been covered by these studies. This is not intended to under-estimate the work carried out by various research institutions and individual persons.

3. TERMINOLOGY

It is common knowledge that the terminology of forestry forecasting is confused. This confusion leads to numerous and severe problems. One of these is that often the same word has been used with different meanings, resulting in misunderstanding and confused discussions.

A second problem arises from the fact that many of the terms used are part of the every day language of the businessman as well as belonging to the professional language of the forester and the economist. Each of these groups may attach a particular and different meaning to the same word. The term "demand" is a perfect example. We all speak of "the demand for lumber" or "the demand for pulp and paper" in very general terms and with relatively little confusion. Even when we speak of "forecasting the demand for lumber" many of us mean simply estimating the quantity that will be taken by the national market at some future date. Professional economists, however, consider demand to be a specific factor, though not necessarily having the same concept.

It would be presumptuous to try to change the common usage of such familiar terms as demand, supply, and consumption. Nevertheless, it is hoped that all research workers who deal with forecasting in the fields of forestry or forest products will try to use the terms precisely and consistently. This section on terminology is offered in this spirit and with the hope that all who work in this area of research will find it possible to use the terms in the particular way suggested here.

1. *Demand:* The quantity of a commodity which consumers and other buyers are willing to purchase in a given market in a given period of time.

Usually, demand (and supply) is expressed in some form of price-quantity relationship. A *demand schedule* shows in table-form, a *demand curve* in diagram-form, and a *demand function* by mathematical equation how the demand (the quantity demanded) varies with the price of the commodity, other factors being equal. It is also possible to relate quantity demanded to variables other than price.

A forecast of demand, therefore, means an estimate of purchases in some specified market during a specified future period of time. Definitions of forecasting the demand schedule, the demand curve and the demand function will be the same as that for forecasting demand when applying the preceding definitions.

The term *demand* has often been qualified with adjectives such as projected, potential, forecast, etc. Some of these combinations have been given specific meanings in publications. It is suggested, however, that wherever the term *demand* is used, whether combined with qualifying adjectives or not, it should be used in the generally accepted economic sense outlined above.

2. *Supply:* The quantity of a commodity which producers and other sellers are willing to offer for sale in a given market in a given period of time.

A *supply schedule* shows in table-form, a *supply curve* in a diagram-form and a *supply function* by mathematical equation how the supply (the quantity supplied) varies with the prices of the commodity (or with some other factor affecting the supply), other factors being equal.

A forecast of supply, therefore, means an estimate (or a prediction) of the quantity that producers (or other sellers) are willing to sell in some specified market during a specified future period of time. Definitions of forecasting the supply schedule, the supply curve and the supply function will be the same as that for forecasting supply when applying the preceding supply definitions.

3. *Sales:* The quantities sold from sellers to buyers in a given market during a given period of time. A quantity is considered sold at the time when the ownership of a commodity has passed from seller to buyer.

A forecast of sales may be derived – in some way or other – from the intersection of inter-depending supply and demand curves. Because of quantity restrictions, etc. the quantity sold is not necessarily equal to the quantity specified by the intersection of supply and demand curves.

4. *Consumption:* The amount of a specified commodity used in a particular area in a specified period of time. Consumption of fuelwood, for example, is the quantity of fuelwood burned; consumption of lumber is the quantity of lumber utilized in construction, ship-building, etc.

Consumption may differ from sales in at least two respects: (1) a sale can be made in a market, but consumption is deferred to some later time period; (2) consumption may and often does occur without any sale – for example, in a non-market economy or when a farmer cuts and uses fenceposts, fuelwood or lumber from his forest.

5. *Requirements:* This term has been used extensively (but not consistently) in forecasting. Technically speaking requirements represent consumption, but with the understanding that supply and price implications can be ignored.

A forecast of requirements, therefore, means a quantitative estimate (or prediction) of the amount of some commodity that would be taken in a specified market area without weighting this estimate in any way by the price implications that are involved. Unless otherwise specified the term requirements will always imply a perfectly elastic supply curve and, therefore, a constant price. Usually, the supply curve is assumed to be maintained at some current level. A number of members of the Working Group question the validity of the requirements concept.

6. *Physical supply:* The entire existing stock of a particular commodity. When applied to standing timber it means, therefore, the entire amount existing at the moment specified. Measurement units, merchantability standards, sampling techniques and other factors all effect the quantitative determination of physical supply.

Certain difficulties inherent in using *supply* in a purely economic sense, and *physical supply* in a strictly non-economic (or physical) sense, are recognized. Nevertheless, because most people will continue to use supply in both meanings, it will be helpful if this distinction is specifically recognized.

7. *Allowable cut:* The volume of timber that may be cut during a given period under specified management plans and management intensity levels.

The FAO/ECE Statistical Working Party has suggested (in 1968) replacing the term allowable cut by potential cut to be defined as follows:

8. *Potential cut* is the volume estimated to be available for felling based on the species, age classes and growth rates found in the forests and assuming a pattern of prudent and realistic forest management and exploitation, at the same time taking account of policies concerning the protective, recreational and other functions of the forest. The potential cut can be estimated for any particular year or period of years. This can be done for periods up to 20 years and even longer. It can be revised whenever necessary to take account of changes in the forests or in the circumstances governing their management and exploitation.

9. *Growth goal:* A production goal for a specified forest area necessarily involving more than one instant of time. Hence, a growth goal is a planned pattern of output over time.

A growth goal for a nation normally represents a major plank in the forest-policy platform for that nation. There is no reason, however, why growth goals could not be established by states, firms, or even for particular forests.

10. *Short-run:* An economic term referring to a period of unspecified duration during which a fixed or group of fixed factors is

operative. For example, plant capacity, area of forest land, etc., might be fixed during the short-run. The short-run should not be confused with calendar or clock time.

11. *Long-run:* An economic term often contrasted with short-run (see above). A period of time characterized by the change of any fixed factor of production.

12. *Short-term forecast:* Normally this means one would not have to consider changes in a secular trend but only cyclical or seasonal changes.

13. *Long-term forecast:* Normally a long-term forecast necessarily considers the secular trend, and very frequently can ignore cyclical or seasonal fluctuations.

4. APPROACHES TO ECONOMIC FORECASTING

SPENCER, CLARK and HOGUET (1961) mention four groups of forecasting methods classified according to the forecasting technique applied:

1. naive methods
2. barometric technique
3. opinion polling
4. econometrics

1. *Naive methods* include forecasting based on mere guess or simple extrapolation of historical data. In the latter type of projection the underlying assumption may be that there will be a continuous development of the variable in question ("continuity type of model"). Hence, the last observed variable serves as a prediction of the future. Or future development may be predicted by projecting past trends into the future ("trend projection"). This is probably the most common method used by business firms.

Simple trend projection omits short-term fluctuations in time series. Hence, cyclical models may be constructed in short-term forecasting; for example, by removing the trend from annual series of data and by analysing cycles in the remaining data. Here again, several methods can be used. It is hardly justified to label all methods in this group "naive" ones. Firstly, some of them, like trend projections, are as objective as many other methods and are often successfully used for forecasting. In fact, they must be used in many cases at least as a subsidiary method, because of the lack of adequate statistics or other data. Secondly, methods which are considered to be more advanced can also have "naive" features when applied mechanically and without sufficient economic judgement.

2. *Barometric technique* is based on the idea that future development can be predicted from certain happenings in the present by using statistical indicators – selected time series – as a "barometer". Two methods are commonly used: leading series and pressure indexes. The former method involves the selection of a set of leading indicators of an economy, such as building contracts, new orders for manufacturers' durable goods, etc., which together are used as the basis for prediction.

The latter method is based on the idea that amplitude differences play a significant role in the analysis of business cycles. Various ratio and difference measures – "pressure indexes" – have been developed to be used as guides for forecasting. Thus, the difference between the rate of family formation and the growth rate in the inventory of houses and apartments may constitute a pressure indicator of the long-term demand for new housing.

3. *Opinion polling* is a sample survey designed to ascertain such factors as businessmen's intentions regarding investments in new plants, consumers' buying plans, etc. The basic assumption is that certain attitudes affecting economic decisions can be defined and measured with sufficient accuracy in advance so that predictions can be made of future trends in business.

4. The most advanced forecasting method at present is the application of *econometrics.* Econometric-forecasting technique is based on the idea that changes in economic activity can be explained by a set of mathematical relationships between economic variables. After sound theory has been developed on these relationships a mathematical *model* is specified to express the nature of the relationships between the variable to be explained (dependent variable) and a set of explanatory (independent) variables. The parameters of the model will

then be estimated on the basis of time series or cross-section data.

The model thus takes the form of an equation or system of equations that seems best for describing the observed set of relationships and is in conformity with economic theory and statistical analysis. The *future* course of the dependent variable will then be predicted on the basis of estimated relationships. This method, of course, requires that the independent variables are observed or predicted (in advance) before the dependent variable can be estimated.

There are various principles according to which econometric models can be constructed. Since probability is the underlying concept, three important features **combine** to form the analytical framework of modern statistics in the field of forecasting models (SPENCER, CLARK and HOGUET 1961, pp. 42–43):

1. Statistical inference. All economic relationships, particularly from an econometric standpoint, are regarded as *samples* from an unknown infinite population of all possible economic relationships and statistical methods are employed to arrive at numerical estimates.

2. Randomness. Basic to the science of statistical inference is the assumption of a randomly determined or *stochastic* variable. This is a variable that can assume a number of values with given probabilities. Randomness may, in other words, be interpreted so that any given value of the variable is *independent*.

3. Point estimation. This means that the problem is to predict a single figure as an estimate of the unknown quantity. There are two commonly used methods to this end:

a. method of least squares
b. maximum likelihood method

In the former method an estimate is chosen which minimizes the sum of the squared deviations from the chosen value. The method of maximum likelihood, on the other hand, estimates the value which makes the probability of the occurrence of the estimate a maximum.

The tool for accomplishing these principles may be correlation and regression analysis. Since the number of independent variables in a model usually is more than one, methods using mainly multiple correlation analysis are employed. Two important coefficients deserve special mention in connection with multiple correlation analysis:

a. coefficient of partial determination
b. coefficient of multiple determination

The former (partial correlation coefficient squared) measures the proportion of variation in the dependent variable (Y) explained by variations in the independent variable in question (X_1), assuming the other independent variables to be constant. The coefficient of multiple determination (R^2) gives the percentage variation in the dependent variable which is explained by all independent variables in the model (SPENCER, CLARK and HOGUET 1961, pp. 61–62).

Rapid development of regression analysis and the introduction of electronic computors have greatly increased the possibilities of employing econometric models in forecasting. This method of forecasting, therefore, requires particular attention in the discussion which follows.

From the practical point of view two major problems suggest themselves in the construction of econometric models: the choice of the type of model and the selection of the variables. They are not separate parts of model construction but rather two different aspects of it.

5. FORECASTING DEMAND

51. Short-term (Päiviö Riihinen)

51.1 Purpose and concept of short-term forecasting of demand

Short-term forecasts perform a special role in an economy. Most often they are made for the purpose of understanding any one of a whole array of economic problems (cf. Vaux 1967, p. 67) in order to facilitate decision-making in the short term. These decisions may relate to budgeting, personal income or expenditure, production output, procurement of raw material, provision of labour force, employment situation, etc. Thus forecasts of short-term demand are a concern of private people and business firms, as well as of governmental agencies and co-operative bodies. This paper is concerned with the short-term forecasts of demand in forestry and the timber economy.

The demand for a timber product is a schedule indicating – for a specified time period, place, and economic context – the quantities of the product which would be taken by consumers at different price levels. Demand may thus be defined in terms of the product taken at different prices at specified times, together with measures of the major economic factors associated with the amount taken – called demand shifters –, such as income, availability and price of substitutes for the product, and costs of other related goods and services.

By short term is meant a time period long enough to take into account the effect of one business cycle on the demand in the forecast period, but not long enough to be seriously affected by the secular trend. Accordingly, a short-term forecast of demand is a future demand schedule for a specified commodity in a given market area when the base-period demand has been projected into the future, taking into account the probable cyclical changes in the demand shifters and in the price elasticity of demand between the base period and the forecast period.

Since there are also the concepts of short and long run we consider it worth while to define these in order to avoid confusion. Economic analysis dealing with short run assumes that the amount of fixed input factors (plant capacity, area of forest land, etc.) and the technology are constant. Contrary to short-run analysis, long-run analysis assumes changes in fixed input factors and/or in technology. Thus the distinction between short and long run is not made in terms of historical time but in terms of certain general production conditions. It is obvious, therefore, that short term may relate to either short or long run.

While the concept of demand forecast takes into account the functional nature of demand, a future demand schedule, there are forecasts which are based on only one point along the demand schedule. We then speak of forecasts of consumption, either actual or potential, depending on the particular assumptions of supply and/or demand. The abscissa of the intersection of the future demand and supply curves gives a forecast of actual consumption. Thus there is no difference between the method of forecasting actual consumption and those of forecasting demand and supply. Forecasting potential consumption calls for a less ambitious procedure. Here, the consumption expected is determined on the basis of a statistical relationship between past consumption and certain predetermined variables. The demand and supply curves need not be taken into account. In other words, the point determined is that which corresponds to the intersection of the theoretical demand and supply curves under given circumstances. If future consumption is estimated as the abscissa of the intersection of the demand curve and a supply curve, which is assumed to be a horizontal line at a given price level, this, too, is termed a forecast of potential consumption. Accordingly, a forecast of potential consumption, which is sometimes called potential requirements, has two slightly different connotations: it refers (a) to forecasts that have been made without the knowledge of either demand or supply curves, and (b) to forecasts developed on the basis of a known demand curve, assuming that goods can be supplied at a given price.

If we adhere to one and the same system of reference, it is difficult to introduce concepts other than the above. Some may find it desirable to make a distinction between the forecast of consumption and that of sales or of output. These can be objects for forecasting, but they are just statistical refinements of forecasts of consumption. If we include stocks with appropriate lags in the model, we attain these refinements. The same result can also be reached by using output or sales series instead of consumption series (Riihinen 1963, p. 7).

51.2 Econometric vs. Survey Approach

The question can be raised whether forecasts ought to be based on econometric or on more conservative, mainly quantitative methods, since sometimes these two major approaches may be considered mutually contradictory. More often than not the argument advanced for econometrics is that the method used should provide a basis for testing the economic theory implicit in the method used. Similarly, it may be maintained that a purely qualitative relationship assumed between certain variables does not offer means of improving this relationship. On the other hand, some may defend qualitative approach by arguing that there are always special unquantifiable factors which cannot be taken into consideration without making arbitrary changes in the equations. Others have pushed their argument to the point of saying that quantification may draw one away from a close study of the most often limited and unsatisfactory data through the pleasures of model-building.

In fact, the distinction between these two principal approaches is often exaggerated. Furthermore, neither one alone is likely to provide adequate forecasts for every instance. The use of econometric models is gaining ground, but their application may be different; some forecasters use them just to test the validity of their theory in empirical data, while others rely upon them in the forecasting procedure itself. Again, we should like to point out that there are special situations in which one may aim at a careful specification of the model, whereas an 'intentions survey' may employ a much less ambitious frame of reference in taking its inventory. Many of the problems are likely to be of a composite nature and require a combination of the different methods. The selection of the approach may also vary according to whether one is interested or not in future transactions. A newsprint seller is more likely to use an economic model than the newsprint purchaser. But even the latter may need some information of possible income and price of newsprint, which he intends to carry forward to subscription and advertising rates. We shall not elaborate this topic further; it would be difficult to exhaust it even in a long paper.

51.3 Aggregate vs. Single-commodity Models

As previously mentioned, the problems of forecasting in forestry and the timber economy are often of a composite nature. We may sometimes prefer to consider product aggregates instead of separate products. Paper is not a single commodity but a group of commodities with differing economies. Sawnwood consists of an even greater number of commodities having diverse end uses. The question then arises as to how far it is possible to forecast the short-term demand for product aggregates instead of for single commodities.

Grayson (1969, pp. 8–9) draws attention to this problem, without being interested in demand, and cites examples of studies in which a single-product approach has been chosen. But he also puts forward points that may be used to defend the choice of product aggregates as observation units. For example, those engaged in timber growing are likely to be interested in information on aggregates. In general the appropriate approach depends on one's objectives. The concept of demand implies that we are dealing with structural parameters which can hardly be estimated for a heterogeneous group of commodities. In avoiding this difficulty it is sometimes feasible to split large aggregates into more homogeneous groups. If there is a wide time variation in the product composition of such groups, one may substitute as independent variables in the models the relative shares of the principal product components.

An interesting means of determining to what extent it is justified or how arbitrary it is to form product aggregates is introduced by Simula (1968). In carrying out a timeseries analysis of sales of printing and writing paper in Finland he avoids the product-by-product construction of econometric models by applying "theoretical combination". He draws a schematic diagram of the factors affecting the purchasing decision for each paper product and then combines the products having substantially similar diagrams. The models which result provide, in general, a satisfactory basis for forecasting potential consumption but not necessarily demand.

51.4 Specification of Short-term Models

Whether we intend to forecast with the aid of a mathematically formulated model or by one that is only implicit in the method used, it is advisable to specify the set of hypotheses underlying the forecast to be made. In other words, we ought to spell out the economic-statistical relationship in our model in order to be able to judge the theoretical foundations of the forecasting procedure. By specification we usually mean expression of an economic theory in mathematical form, but here it refers to any explicit statement of the frame of reference. It is to be noted that formal logicality of a forecasting model cannot be tested by mathematical testing; instead we can find out by empirical analysis which of the theoretically equally defensible models is best suited to empirical data. This is a prerequisite for any economic forecasting.

In short-term forecasting, however, specification of the model may differ somewhat from that in general forecasting. In long-term forecasting the model may often be conditioned by several advance requirements, especially if the forecast is to be of the fictitious type. In short-term forecasting, instead, we are interested primarily in gaining an insight into what will result if no special measures are taken on the side of either demand or supply. In other words, a short-term forecast of demand for a forest product is likely to deal with short run with no normative bias. It tends to forecast facts rather than provide a program, but facts as such may affect the decisions on the supply side. However, at the second stage, a short-term model of demand may be used for policy decisions; otherwise, we should hardly assume the ambitious task of forecasting demand instead of potential consumption.

The non-mathematical methods do not usually provide a tool for identifying the demand function *a priori*. The specification of the model thus consists in stating the relevant relationships to be quantified. Simultaneous estimation of the parameters of such models is replaced by an assessment of the effect of one variable at a time. Formally, one may finally end up with two or more points along one or more demand schedules, so that there would after all seem to be a way of evaluating price elasticity at, say, different levels of income. It is obvious that this type of forecasting procedure may have application in fields where the variables are of an aggregate nature, e. g., in sector forecasts. But then the question arises whether demand forecasts proper can be made at all for large groups of commodities, or whether in such cases they have real significance; it is useless to speak of short-term price elasticity of demand for forest products in general. Thus it would seem that non-mathematical methods other than 'intentions surveys' in short-term forecasts of demand have less application than they do in long-term forecasts. Of course, we are always interested in, say, how many building permits have been issued for the coming year, because permits provide a useful component of the demand forecast for sawnwood. Similarly, it may be of interest to know how many annual newspaper subscriptions have been made for the following year because this serves as a basis for estimating the newsprint consumption for that year.

If we desire especially to specify a short-term model in a mathematical form, certain theoretical considerations are necessary to direct our thinking to a model having a basis in reality. These considerations offer valuable guidance in forecasting by non-mathematical methods also. It is advisable to start the specification of a model from an exposition of the type of competition prevailing in the market of the commodity in question. This gives us a picture of the position of certain key variables, especially as to price. Thus we can infer whether price is predetermined with respect to quantity, or vice versa. Also, by examining price (or total expenditure) in relation to the consumers' disposable income we may draw some conclusions about the expected price elasticity of demand. All this information is useful for a more detailed consideration of a 'full-information model' underlying demand for a specific commodity.

A detailed analysis of all economic variables affecting demand can be drawn up as a decision scheme where no attention need yet be paid to lags between the variables. This

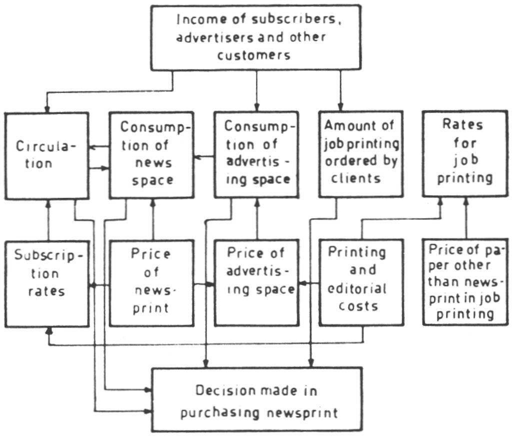

Fig. 1. Hypothesis of the factors affecting decision making in purchase of newsprint. The arrows indicate the assumed direction of the influences. (Riihinen 1962, p. 21).

can perhaps be illustrated best by means of a demand model for newsprint in Finland. The scheme in Fig. 1 shows most of the factors affecting the decisions made by newspapers in purchasing newsprint. Some of the variables may not be very significant. Assuming that a newspaper – after duly circulating the news and guiding opinion – takes profit maximization (or minimization of loss) as its secondary objective, newsprint purchases are then affected by the variables that determine the paper's total revenue and expenditure. Of these, the most significant are the ones with the greatest influence on total revenue and costs. Among the most important are those which vary with output (variable costs).

It may be impossible and, in short-term forecasting, inappropriate to use all the information available. Some of the variables included in the specification may have no observed values, or they may be erroneous and have properties undesirable for estimation. If we have especially to depend on least squares techniques in estimating the parameters of the models, multicollinearity may suggest a drastic limitation of information. True, maximum likelihood estimation is becoming widely applicable with the development of computer programs.

By way of example, we shall endeavor to select from Fig. 1 the most significant variables and to examine the time lags with which these affect each other according to the rhythm of decision-making at all stages. The price of newsprint which, in this case, is determined by a bilateral monopoly can be taken as the point of departure in this examination.

Once a newspaper publisher knows the price of newsprint, he can immediately make a decision regarding the rates for advertising space. On the other hand, the subscription rates for the year to which the newsprint price applies cannot be modified, since they will have already been decided upon. It will be possible only to take the modified newsprint price into account in the subscription rates for the following year. Most newspaper subscriptions are annual. The decisions of the advertisers are mainly influenced by the purchasing power of the public in the period affected by the decision. Hence the consumption of advertising space in any one year is associated with the income level in that year (in the short term,

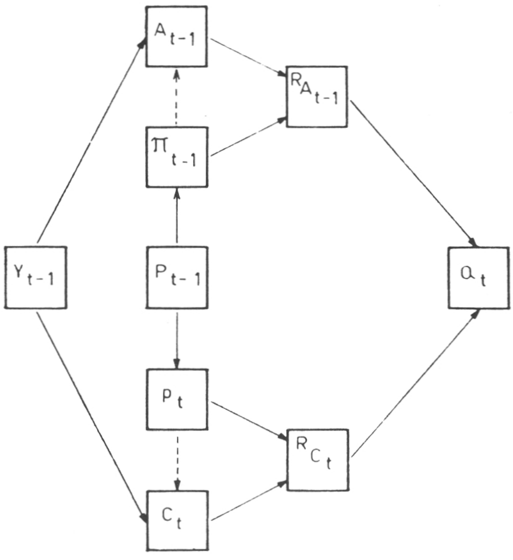

Fig. 2. (Riihinen 1962, p. 23).

Symbols used in Figure 2:

Y_{t-1} = income level of subscribers, advertisers and other customers in the year $t-1$
A_{t-1} = consumption of advertising space during $t-1$
π_{t-1} = average unit price of advertising space during $t-1$
P_{t-1} = price of newsprint in $t-1$
p_t = average (annual) subscription rate during t
C_t = circulating during t
$R_{A_{t-1}}$ = revenue from advertisements during $t-1$
R_{C_t} = revenue from subscription in t
Q_t = quantity of newsprint sold during t.

this does not apply to announcements independent of the business cycle). Circulation, on the other hand, can only be affected by changes in the purchasing power of the public with a lag of one year, because subscribers make their decision for the year t in the light of their income during the year t-1 (and assume that their income will continue to be the same in the year t). All subscriptions for one year must be paid either at the end of the preceding year or at the beginning of the year in question. Fig. 2 has been drawn on the basis of these facts.

51.5 Problems of Identification

It follows from the definition of demand that we are dealing with structural estimation, not with the coefficients of a 'mongrel' equation where demand and supply influences are interwoven. Only in the exceptional case in which the demand function exhibits no or little variation, the supply function being subject to a wide variation, no identification problem proper occurs; in no other case can the demand function be estimated by a single-equation approach. By securing a proper specification of a demand model we can ensure formal identification.

The need for identification arises from the fact that single points in time or space, representing quantities consumed or exchanged and prices actually paid, are understood as intersections of the appropriate demand and supply curves. It is thus suggested that in a simplified demand-supply model we must have at least two structural equations: one representing demand and another representing supply. We usually add yet another (non-structural) equation stating the equality between the quantity demanded and that supplied. The model as a whole may thus read as follows:

$$
\begin{aligned}
& q_{(d)t} = \alpha_0 + \alpha_1 p_t + u_t, \\
(1)\quad & q_{(s)t} = \beta_0 + \beta_1 p_t + v_t, \\
& q_{(d)t} = q_{(s)t},
\end{aligned}
$$

in which

$q_{(d)t}$ represents the quantity demanded at time t,
$q_{(s)t}$ represents the quantity supplied at time t,
p_t represents price at time t,
u_t, v_t are random disturbances,
α_0, α_1, β_0, β_1 are statistical parameters.

This model as such, however, does not permit identification of demand, because the structural equations contain the same variables and the variances of the random variables (u_t and v_t) usually do not differ enough from each other to provide identification (var u_t ought to be much smaller than var v_t). The same conclusion may be drawn more generally from the fact that, by linear combination of the above equations, it is possible to derive another equation that contains the same variables as the demand equation. We say that the demand equation (as well as the supply equation and hence the model as a whole) is underidentified.

To provide identification it is necessary to add variables (called shifters) to the above system of equations, so that the number of variables in the demand equation either is equal to or exceeds the number of structural equations in the system less one. These shifters, of course, ought to have a realistic basis in economic theory and possess desirable statistical properties. Thus, after substitution of a supply shifter, say any exogenous variable limiting physical supply, model (1) might read as follows:

$$
\begin{aligned}
& q_{(d)t} = \alpha_0 + \alpha_1 p_t + u_t, \\
(2)\quad & q_{(s)t} = \beta_0 + \beta_1 p_t + \beta_2 z_t + v_t, \\
& q_{(d)t} = q_{(s)t},
\end{aligned}
$$

where z_t is an exogenous variable limiting physical supply. Depending on the circumstances in each country, it may be difficult to find shifters of short-term supply in forestry and the timber economy. If the above model is to be used for forecasting, one or more demand shifters may be needed. Then the number of supply shifters must also be increased in order to comply with the above rules for identification. Identification is more thoroughly discussed in several textbooks of econometrics.

51.6 Problems of Estimation

Theoretical considerations may lead to either one of two principal types of multi-equation models. A multi-equation model can either be recursive or simultaneous. In a recursive model there is only one current endogenous variable in the first equation, and only one new such variable at a time can be added as the number of equations is increased. Lagged endogenous and exogenous variables are not limited in number in so far as they have desirable statistical properties. A recursive model forms a causal chain and is characterized by lack of simultaneous two-way influences between any pair of variables. As far as the specification of a recursive model is concerned, it lends itself to least-squares estimation, one equation at a time. The value of the endogenous variable can be calculated from the first equation and substituted in the second equation, which gives the value of the second endogenous variable. Proceeding this way, the values of the endogenous variables in the last equation can also be calculated.

By endogenous variables we mean variables that are determined in the equation system itself, whereas exogenous variables are considered as determined from outside the equation system. Lagged endogenous and exogenous variables are jointly called predetermined. In the least squares estimation we must select the non-lagged (current) endogenous variables as dependent. Consistent and efficient estimation of the parameters requires that the residual term complies with certain *a priori* requirements. For instance, the residual term must follow some probability distribution (if this is normal, the estimate will be one of maximum likelihood), and its values must be independent of the values of the explanatory variables. In practice, especially with small samples, only the randomness of the residual term can be tested. Apart from stipulations set on the residual term, another *a priori* requirement for an efficient estimate by the method of least squares is that each explanatory variable should be composed of series of known (not random) values that are free of observation errors (cf. Foote 1958, pp. 58–59; Riihinen 1962, pp. 14–15).

Simultaneous models also consist of systems of equations. They differ from recursive models mainly in that they contain simultaneous influences between pairs of variables and that a single equation can include more than one non-lagged endogenous variable. The parameters of simultaneous models can be estimated by the method of least squares, provided that the models can be transformed into the reduced form, from wich the values of all the non-lagged endogenous variables are calculated as functions of all the predetermined variables in the system. But to obtain the reduced form of the simultaneous model it must be possible to solve the equations for each endogenous variable in such a fashion that each endogenous variable appears as a linear function of the predetermined variables alone. Since this is not nearly always possible, one must consider various other methods, such as the instrumental variables method (Klein 1953, pp. 122–5), Theil's (1954, 1958) two-stage method, or the maximum likelihood methods proper, either that of full or of limited information.

51.7 Certain Aspects of Data

The question is sometimes raised whether in short-term forecasting data containing the secular trend should be used, or be eliminated. By definition, we are dealing with short-term – more exactly, cyclical – influences and not with trend. Here again, we have the possibility of reconciling practical and theoretical aspects, depending on their respective weighting. If the trend is not very steep, it may not have a significant influence upon the forecasts. If the trend is steep, the parameters of the short-term model are 'biased' by long-term influences, and short-term projections may also become weighted by the trend. In such cases it may be desirable to eliminate the trend.

There are several methods of eliminating the trend, which can be divided into two major categories: the trend elimination methods proper, and those based on absolute or logarithmic differences of observations. The trend elimination methods proper have the disadvantage of being based on a computed trend which seldom, if ever, can be theoretically motivated. Instead, if we transform the data into a certain order of arithmetic or logarithmic differences, the new series has a definite significance: it represents periodic changes in absolute or in relative terms. Relative changes in variables containing the business cycle may often logically correspond because of acceleration effects, etc.

Transformation of observations may often be necessary also because of multicollinearity – quite apart from the fact that we are interested in short-term relations. By comparing the parameter estimates obtained from transformed data with those containing the trend we may infer the source of multicollinearity.

It would also seem possible to avoid the adverse effects of multicollinearity by factoring the independent variables before the regression analysis. If the factoring method is orthogonal, the factors obtained will be uncorrelated and provide explanatory variables whose parameter estimates are mutually unaffected. However, it is obvious that the efficiency properties of variables formed in this manner may be somewhat less than adequate.

51.8 Using Structure-identifying Models for Forecasting Short-term Demand

Sometimes it is possible to be satisfied with forecasting by means of an equation assuming that values of the structural parameters in the forecast period remain the same as in the observation period. Such an assumption may prove correct, but it is clearly arbitrary unless it is based on a study of probable future trends in the structural parameters. If we are dealing merely with short-term influences, it is quite likely that some of the structural relations will change.

Before using the model for 'mechanical forecasting' it is always desirable to carry out a structural analysis. On the basis of this analysis it is possible to adjust the parameters of the model to correspond to changes in the structural relations between the observation period and the forecast period. It may seem that here one might like to reconsider subjectively the objective values of the parameter estimates obtained from the observation period data. This subjective element is indeed present in the forecasting procedure itself, but it can hardly be avoided unless we have a model where all the independent variables are lagged, and the forecast relates to the period which is only one time unit from the base period.

52. **Long-term** (Dwight Hair and H.R. Josephson)

The formulation of public forest policies and programs, or decisions on long-range commitments such as construction of wood-using plants, must be based on some expectation concerning future timber demands, supplies, and prices. Expectations about the future may be intuitive in the sense that they are derived without formal analysis. Or they may be based on elaborate and detailed studies of the multiple variables that affect timber demands, supplies, and prices.

In the past several decades there has been a number of published studies of this latter kind, all designed to guide legislators, public land managers, directors of forest industries, forest landowners, and others concerned with the longrun timber situation.

52.1 The nature of demand projections and the relationship to supply projections

Most of the recent studies have developed estimates of the potential consumption of timber products under certain explicit or implicit assumptions about determinants of demand, such as populations, economic activity, technology, institutional changes, relative prices of timber products, and availability of timber supplies. The projections derived in this way have not been regarded as "forecasts", but rather as "conditional" estimates of the amounts that consumers would purchase under the specified or implied assumptions.

In most studies it was assumed, as an initial step, that there would be no significant change in the price of timber products relative to competing materials in the projection period. Such a simplifying assumption meant in effect that (1) future supply schedules for timber products would be highly elastic (i.e., small changes in prices would lead to large changes in quantities supplied), over the range of amounts specified in the demand projections or (2) increases in costs of supplying additional quantities of competing materials would match cost increases for timber products, or (3) some combination of these possibilities.

The demand projections developed with such assumptions have then been compared with projections of timber supplies that might be realized under explicitly or implicitly defined forest management programs. Such comparisons provide a means of identifying possible future imbalances between supply and demand, prospective changes in prices, and an indication of the types of forestry programs that would help balance demand and supply at some price goal.

This use of demand and supply projections is illustrated in recent Forest Service appraisals of the timber situation (1958, 1965, 1969). These studies indicated that future demands for timber products, assuming approximately stable relative prices, would rise substantially over the projection period. On the other hand, projected timber supplies to be expected with the levels of investment in forest management prevailing at the time the studies were made soon would fall increasingly short of projected demands.

This in turn would mean increasing competition for available timber supplies, rising prices of stumpage and wood products, and greater use of competitive materials with lower consumption of wood products than indicated by the initial demand projections. As an alternative action could be taken to (1) increase timber supplies by such measures as accelerated management to grow more timber, (2) improve utilization of available timber and wood fiber supplies, or (3) increase imports beyond the amounts assumed. Such a change in supply conditions would dampen price increases for timber products and permit actual consumption of timber to approach the demand projections more closely.

It is increasingly recognized that such simulations of longrun trends in timber demand and supply under alternative assumptions help to identify the type and scale of forestry programs that would balance future timber supplies and demands at some target price level. Such a target might be (1) to achieve a price level that would cover costs of timber production or (2) to maintain a given price relationship between timber and competing materials.

As a step toward such objectives several studies have contained alternative projections of both demand and supply, based on different assumptions about the important determinants of these variables.

52.2 Elasticity versus shifts in demand

The development of alternative projections of timber demand requires in effect estimations of both the location and the slope (i.e., elasticity) of shifting demand schedules. There are, however, a number of practical difficulties involved in quantitatively defining those schedules.

Several studies have indicated that "short-run" Marshallian demand schedules for most timber products are inelastic, at least near the intersection with supply schedules, i.e., price changes have relatively little effect in the short-run on the quantity consumers are willing to buy [1]. Although there is little quantitative information available on this point, the inelasticity of timber demand seems to have been confirmed by events. For example, the spectacular increases in softwood lumber and plywood prices in 1968–69 apparently had little effect on the demand for these products.

Over a period of time, however, general observation of timber markets also indicates that a sizeable change in the price of a timber product relative to prices of competing materials has important delayed effects on demand. Such a change in relative prices appears to act as a demand shifter, inducing in time greater use of available substitutes, changes in consumer tastes, and possibly the development of technological and institutional changes, all of which result in the movement of the shortrun Marshallian demand schedules to the left or right [2].

This phenomenon might also be described in terms of an elastic "longrun" demand schedule. However, there is a great deal of uncertainty about the definition of longrun demand or supply shedules (Tomek and Cochran 1962). Because of this uncertainty, the apparent non-reversibility of such longrun schedules, and the fact that each part of such a schedule involves a different time period, the concept of price changes acting as a demand shifter appears to be a somewhat better description of events.

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1) Marshallian demand and supply schedules describe the relationship between price and quantity at a given time. They provide no mechanism for showing how a price induced change in a demand determinant such as technology will affect the schedule.

A demand schedule is considered to be inelastic when the ratio between the percentage change in the quantity demanded and the percentage change in price is less than unity.

2) This kind of change is illustrated in statements prepared by hardwood furniture manufacturers for recent Department of Commerce hearings on fine hardwoods (Public Hearing to Consider the Possibilities of Controlling Domestic Consumption of Fine Hardwoods, October 11, 1967, Washington, D.C.). These statements contain repeated references to gradual adjustments such as increased use of imported woods and substitute materials, and changes in design and manufacturing practices, resulting from a rise in domestic hardwood lumber prices in the mid-1960's.

Thus, for longrun projections of demand for timber products, estimating price elasticities of shortrun demand and supply schedules does not appear to be the important issue. The chief problem is to determine how price changes induce shifts in the demand schedules for timber products.

52.3 Principal demand shifters

In most studies population has been considered a significant determinant of demand, or demand shifter, for timber products. It is a measure of the number of consumers of such goods as houses, furniture, and paper products. Population is also the major determinant of labor force which, with labor productivity and hours worked, determines the level of economic activity.

Economic activity, as measured by gross national product, or some component such as construction or manufacturing, has usually been considered a major determinant of demand, not only for timber products but for other materials as well.

Technology has been considered important because it is a basic determinant of the productivity of the labor force and hence of the level of economic activity. Changes in technology also influence the substitutability, availability, relative cost, performance, and "saleability" of timber and competing materials in various end uses.

Institutional factors, such as shifts in the rural-urban distribution of the population, and zoning or building codes, likewise have major impacts on demand for many timber products. For example, increasing urbanization has contributed to a large increase in the proportion of multifamily dwelling units in the housing mix. This has had a major impact on the consumption of lumber and plywood, because the use of wood products per unit of multifamily construction averages only about two-fifths that for single-family units.

Growth in economic activity and population tends to increase the demand for most timber products, i.e., demand curves are shifted to the right. Some technological and institutional changes have reduced demand for products such as fuelwood and mine timber. In other cases, such as the development of new woodpulp processes and products, improvements in plywood, and new materials-handling techniques utilizing wood pallets, new technology has resulted in major increases in demand for timber.

52.4 Projecting independent variables

In practice the projection of demand for timber products has involved such problems as the major uncertainties associated with the projections of future changes in the demand shifters and inaccuracies in historical data. The first of these difficulties may be illustrated by population projections made during the past few decades. In the early 1940's, for example, a leading demographer projected a U.S. population of around 175 million in 2000. This figure was reached in 1958. In the early 1960's median projections of the Bureau of the Census and projections adopted by other agencies indicated a population of from 325 to 380 million in 2000. Current trends in fertility rates now indicate that population in 2000 will be around 280 million.

As in the case of population, accepted projections of gross national product, residential construction, and other measures of economic activity also have differed from actual trends. In most cases growth of the U.S. economy has been underestimated and projections of raw material requirements consequently have generally been conservative. Likewise, many technological discoveries and institutional changes have not been accurately forseen.

Data on new housing starts published by the Bureau of Labor Statistics in the 1950's illustrates, hopefully in an extreme way, former inaccuracies in a major economic series that is an important demand shifter for many timber products. Studies by the Bureau of the Census showed that the BLS series understated new housing starts by about 24 percent in the 1950–56 period and by 13 percent in 1959.

Such deficiencies are not confined to housing statistics. A recent work by Morgenstern points out that most of the commonly used economic series have "error components of unexpected magnitude" (Morgenstern 1963). In addition, information on consumption of timber products in such important end uses as nonresidential construction and upkeep and improvements is limited. There are few data on in-place costs of using various timber products and competing materials. Price data for timber products also are limited, consisting mostly of wholesale prices for selected species and grades of lumber, selected grades of plywood, and selected pulp, paper, and board items.

Thus, considerable judgment has been necessary in establishing statistical series for wood consumption and the independent variables, and in developing timber demand-supply-price relationships. More accurate statistical data fortunately are becoming available. This should result in improved analyses, and hopefully more useful projections.

52.5 Models for projecting longrun demands

A number of models are available for making conditional projections of timber demands, including: (1) graphic models, (2) single equation models, (3) multi-equation models, and (4) input-output models.

1. *Graphic models,* i.e., charts, showing the relationship between variables provide a simple, and widely used way of projecting longrun trends. Effective use of graphic analysis requires considerable judgment as to the probable effects of changes in demand shifters and prices on demand for various timber products and competing materials. For some products, projections developed by an experienced analyst using graphic techniques may be as meaningful as any that can be derived from complicated mathematical models. Under some circumstances, as when data are insufficient to permit determination of mathematical relationships, a graphic model may be the only practical choice.

2. *Single equation (regression) models* of the general type Y = F (X) have been widely used in projecting longrun trends in demand for many timber products (Guthrie and Armstrong 1961). These models are well suited for projecting historical relationships between the detailed time series data that are available for consumption of some timber products and demand shifters such as population, gross national product, or other measures of economic activity. They provide insights on behavioral relationships. They can be used for making longrun projections without computers or other elaborate data processing equipment. They are generally understood by researchers and decision makers in government and industry. These models can utilize one to several independent variables, but they provide projections for only one dependent variable.

3. *Multi-equation* (two-or-more equations) *models* have been receiving increasing attention because they can be designed to provide simultaneous projections of demand, supply, and price-information needed, for example, to specify an economic goal of balancing timber supplies with demands. 3)

Use of multi-equation models at this time is limited by a lack of suitable data. There are also some serious structural faults. For example, any distortions in relationships among variables caused by random influences in the time period used as the base for a projection will be magnified through the projection period (Crom and Maki 1965). Cumulative effects may be very large over an extended period of time. In addition, there is no practical way of estimating elasticity coefficients for the longrun demand and supply schedules which implicitly underlie such a model.

The use of both single and multi-equation models for longrun projections is based on the assumption that a relatively few variables in the economy are the key determinants of demand, supply, and price for timber products. Frequently this appears to be the case. Changes in many sectors of the Nation's economy affect demand for a given product, however, and theoretically a system of equations in which all sectors of the economy are included would thus be the most logical projection model. 4)

4. *The input-output model* is the common name for such an inclusive system of equations. This model shows interrelationships among all sectors of the economy through the medium of

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3) A multi-equation model with this information output has been developed by Gregory (1960, 1965) for shortrun forecasting in the hardwood flooring market. Gregory also proposed the use of a multi-equation model for making longrun projections of timber demands and supplies in an early paper on the subject (1955). McKillop developed a multi-equation model for projecting consumption and price for various timber products (1967). This study illustrates both the techniques and problems involved in using multi-equation models. Holland's study (1955) was a pioneering work in the use of such models.

4) An interesting and different inclusive model – a dynamic simulation model – in which economic and noneconomic forces influencing timber demands and supplies are included has been suggested by Robert S. Manthy (1966).

input-output tables. The links among the sectors of the economy provide a useful tool for calculating shortrun effects of a specified change in gross national product or other determinants on demand. These effects are shown in terms of the value of output of any sector of the economy, such as the sectors producing timber products. By using supplementary data on physical output per unit of value, it is possible to convert value output data into physical units such as board feet of lumber or tons of paper.

In using an input-output model for longrun projections, it is necessary somehow to derive longrun estimates of both (1) final demand in the economy, and (2) changes in the coefficients which link final demand to the sectors of the economy for which projections are made. Research to develop basic techniques and data for using the input-output model in making longrun projections is underway but at this time data are not available to provide a basis for estimating future changes in linking coefficients. The input-output model consequently is not yet considered a practical choice for making longrun projections of demand for timber products.

52.6 Uses of longrun projections of demand for timber products

In spite of the various problems encountered in projection analysis, projections of some type are essential for guiding forest policies and investments in programs whose effects extend into the longrun future. And despite the uncertainties involved, historical evidence indicates that past long-range studies of timber demands and supplies have provided effective guidance for forestry programs and for investments in forest management and timber processing facilities.

The importance of such evaluations of the longrun timber supply-demand situation was specifically recognized by the Congress in 1928 in the McSweeney–McNary Act, which authorized funds to enable the Secretary of Agriculture to cooperate with States, private owners, and other agencies:

"In making a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States, and of timber supplies, including a determination of the present and potential productivity necessary in the determination of ways and means to balance the timber budget of the United States."

The various appraisals of the U.S. timber situation made over the years have been widely used in developing forest legislation and in obtaining funds to carry out forestry programs. Such use of the findings of the Capper Report (1920), one of the early landmark appraisals of the timber situation, is illustrated by the following statement of Charles L. Pack, President, American Tree Association, during hearings on the Clarke–McNary Act:

"The Select Committee of the Senate, with which Congressman Clarke collaborated to a great extent, did a great work. It has established a foundation of facts and figures on our forest situation (The Capper Report). It presented to Congress a report which shows unmistakably that we are using our forest assets far faster than we are building them up; that we are allowing more than 80,000,000 acres of natural forest land to exist as a liability economically; that fires are exacting an enormous toll; . . ."

Passage of the Clarke-McNary Act led to effective fire protection and cooperative reforestation and management programs. These programs have contributed in a major way to the build-up of timber growth in the United States and have made possible such important developments as the large expansion in the southern pulp and paper and plywood industries that has occurred in recent years.

Other appraisals of the timber situation have likewise played an important role on the development of forestry in the United States – both for public agencies and for the forest industries that have invested billions of dollars on the basis of some type of estimate of demand and supply prospects.

It also seems clear that the series of studies of U.S. timber demands and supplies did for the most part correctly appraise the trends of the times. Even the "timber famine" that was believed to be on the horizon when some of the early studies were made was undoubtedly in prospect. A famine did not develop because studies of the U.S. forest situation identified consequences of current policies and helped to determine and justify the kinds of programs needed to change the course of events.

This success illustrates a final point about longrun projections. Insofar as they are effective on revealing prospective problems, and in stimulating effective forestry programs, they generate the improved conditions which in retrospect may make the original projections appear unrealistic. This clarification of alternatives and the consequences of action or inaction is the basic aim of projection analyses.

6. FORECASTING SUPPLY

61. Short-term (Rolf Sæther)

61.1 The Purpose of Short-term Forecasting

Short-term forecasts or projections of supply are usually made to establish a basis for prediction of different factors or factor combinations.

Projection of the supply of timber in a given market may serve a wide range of useful purposes. For example, it might be used to predict labor requirements in forestry. Provided the projections made are fairly reliable, short-term planning of employment may be possible. It may also prove useful to forest industries, dependent on timber supply from nonindustrial forest land. In such cases a projection of the supply of industrial wood may furnish a planning basis for operation of the industry. Having information about the probable magnitude of timber supply some time in advance, the administrative staff will thereby gain a corresponding period of time for preparing decisions with respect to market policy.

In making short-term forecasts of supply, one of the fundamental and introductory questions is: What factors determine or affect the magnitude of supply? And further if supply-affecting factors are established: How may the dependency between the quantity of supply and the factors of significance in determining it be described? Finally, one serious question is always present: How precice can a projection be made, and what sorts of limitations and provisions are included when a forecast is presented? In this paper most of the discussion and examples are confined to short-term supply of industrial wood.

61.2 Some basic definitions

A short-term forecast or projection is, in this paper, limited to forecasts in which only cyclical or seasonal changes, and not secular trends, are considered. The season in this case will be one year. Although 'supply' and 'demand' are well-used terms, considerable confusion exists over their precise definitions, mostly because the terms are defined in different ways. Consequently, a statement of the intended meanings here is considered warranted.

Demand: the quantity of a commodity which consumers, and other buyers, are willing to purchase in a given market in a given period of time.

Supply: the quantity of a commodity which producers and other sellers are willing to offer for sale in a given market in a given period of time.

From these:

a *demand curve* shows diagrammatically how the demand varies with the price of the commodity (or some other factor affecting the demand), and

a *supply curve* shows how the supply varies with the price of the commodity (or some other factor affecting the supply).

Many factors affect both supply and demand, so that with factor changes over time, the two curves are continually changing in slope and position, and, thus, in their intersection point.

A key feature of the definition of supply is that the term deals with the amount that sellers are *willing* to offer. It is obvious, then, that supply and *sales* (the quantity sold from sellers to buyers in a given market, during a given period of time) are not necessarily the same. If quantity restrictions are imposed by marketing organizations, or if severe weather conditions occur, forest owners may be prevented from delivering the amounts that they are willing to sell under the market conditions in existence. Both these factors have, during the operational season, caused reductions in the quantities that forest owners in Norway offered for sale in the fall, after roundwood prices have been set. This means that the quantity relationship between supply and sales may be expressed as

supply = sales + quantity reduction caused by weather conditions (1) and by organizational restirictions (2).

61.3 Factors Affecting Short-term Supply

61.31 *Classification and nature of supply-affecting factors*

The preceding definitions imply that those supply-affecting factors which are considered to be fixed during the period under study may be omitted from a short-term forecast. At the same time these factors may be of major importance for a long-term forecast. Such factors might include: the area of forest land in the market under study, the net growth of the growing stock, and the land-use pattern.

Before discussing the specific problems of short-term supply forecasting in forestry, it may be in order to consider some common misconceptions with respect to the term supply in the general economic sense. First of all, the term supply is per definition an expression of the attitude of the individual supplier. In other words, the supply term refers to an abstraction, existing only in the minds of those who are potential sellers of the actual product. Though it may generally be expected that a change of attitude among suppliers is a result of a change in unit product prices or in unit operation costs, it is easy to imagine that the market attitude of suppliers may change without contemporary changes in these factors. A change in the present alternative rate (i.e. opportunity costs) required from the growing stock is likely to produce short-term effects in supply. This means, in fact, that one or more factors affecting supply have not been taken into consideration. In a number of market studies, however, a curve based on corresponding unit prices and quantities sold is called the supply curve without reservations. In addition to production prices and costs, anticipated prices and costs, opportunity costs, general market conditions, and institutional factors may contribute to an explanation of the supply procedure. However, one or more of the relevant factors may be difficult to measure. The important point here is that supply of any product derives from the attitudes of individual suppliers, accordingly one of the crucial points in research is to find out what these attitudes of the sellers are, or to understand what governs their market behavior. This means that a supply study, limited to observations of contemporary unit prices and quantities supplied during a specified period, could give useful information about real supply relations under but one condition – that unit price variations reflect corresponding supply attitude variations. If such is not the case, a constructed supply schedule will be something other than it purports to be.

It is necessary to make another qualification. Most short-term supply functions are based on observations of corresponding quantities and unit prices over time. For purely statistical reasons, such time series data have to contain a certain number of observations, which means that the series must represent a certain range of time. Thus the reliability of the supply function can usually be improved when the number of observations is increased. Supply functions consequently contain an element of long-term factors, the degree depending on the length of the period investigated. However, keeping functions up to date will certainly reduce the problems involved, and may also give information about systematic changes over time.

It may be argued that this problem is a technical calculation problem, and hence not relevant in a theoretical, philosophical approach. All the same, in most short-term supply studies this problem has presented real difficulties in the establishment of a supply expression of contemporary validity.

However, in the following exposition those factors which are supposed to have the most influence on short-term (or annual) variations of supply will be given individual attention.

61.32 *Production costs and product price*

As a rule, to raise production requires increasing total costs. Inasmuch as different production functions will induce costs to increase at different rates when production is increased

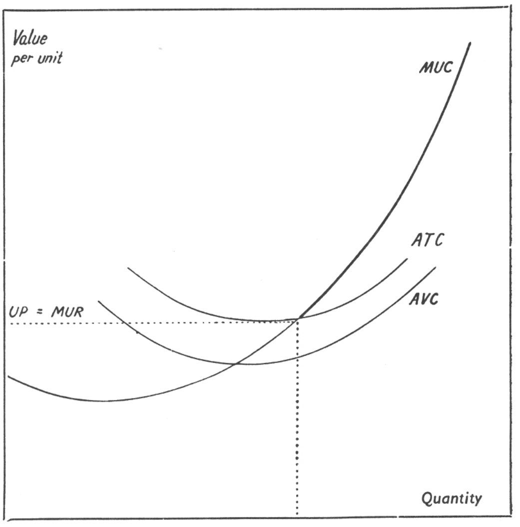

Fig. 1. The marginal unit cost curve, MUC, is supposed to constitute the supply curve. If all production costs should be covered, only the part of the marginal unit cost curve above the intersection with the average total cost curve, ATC, may be expected to give supply responses. The minimum price, UP, which in a full competition market is equal to the marginal unit revenue, MUR, corresponds to the interesection between the two curves mentioned above. If only variable costs are to be covered, supply responses may be expected down to the interesection between the marginal unit cost curve and the average variable cost curve, AVC, which consequently requires a lower minimum price.

(fixed costs will not increase), product unit costs among producers will also change at different rates as production is changed. Thus a producer or a supplier of a product has to compare a given market unit price for his product to the unit costs involved in reacting at a certain level of production. In economic theory it is assumed that the curve for marginal unit costs, extending upward over a range of production, from a certain point (intersection point between the marginal unit costs curve and an average unit cost curve), constitutes a basic expression of the supply curve. A schematic illustration of this theory is given in Figure 1. The structure and the development of functional costs from one production level to another will consequently give the supplier information about what his supply responses should be to different marginal unit prices. This information will only be relevant to supply responses when other supply-influencing factors in addition to production costs and product price are unchanged from one production level to another. Further, if the supplier has specified his profit maximization objective with regard to time, it follows that he should be guided by the cost curve for the same period. If, for example, long-run profit maximization is his objective, he has to forecast gross prices and production costs for the long-run period in question. Thus a supply curve derived from a unit marginal cost curve anticipated for a specified future may differ from a supply curve based on present cost conditions. The structure and development of functional costs which derive from changing output levels will, as seen from the preceding description, yield a theoretical supply.

As the unit price for the product supplied under free market economies is largely determined by ordinary supply-demand considerations, it may be said that the quantity supplied will be determined by the total internal cost situation, on the one hand (both apparent and non-apparent costs), and external market factors, on the other. This kind of interaction is depicted in Figure 1, where product price UP is the lowest price capable of creating any response from the supplier. For this unit price the supplier is able to cover all of his total costs by selling quantity Q.

In forestry, very few suppliers of roundwood would be able to furnish cost curves like those in Figure 1. and it should not be difficult to explain why. Sophisticated research work would be required to establish a production-cost relationship comparable to those shown in the graphic illustration. And because production costs will change almost continually, frequent review of costs would have to be made if shifts of the supply curve are to be anticipated.

Despite all of the difficulties outlined above, it may be justified to think of the marginal unit cost curve as the basic explanation for the location of the supply curve.

61.33 *Expectation of future costs and prices*

It was stated above that the short-run marginal unit cost curve may serve as a short-run supply curve, if profit maximization during the period in question (for example 1 year) is assumed to be the objective of forest owners.

However, in forestry a widely accepted economic goal would be the maximization of profits during a long-term period. This means that long-run considerations cannot be neglected when deciding a short-term supply. The problems of making reliable supply estimates for the short-run period are further complicated by the fact that if a seller of roundwood anticipates future changes in costs or prices, these expectations may influence the current supply of roundwood.

Some of the problems in estimating supply arise from the fact that the timber is easy to store in the form of timber-growing stock. And storing costs, mainly in the form of interest costs in the timber-growing stock, may be easy to overlook.

In the Norwegian market for industrial roundwood, for example, expectations of future roundwood prices appear to have influenced the quantities supplied. For example, in years when unit prices for pulp have shown tendencies to increase, the quantities of roundwood supplied were generally smaller than one would predict on the basis of the current price-cost situation.

A general expectation of an increasing demand for roundwood should give similar effects.

61.34 *Opportunity costs*

When forest owners have alternative uses for their capital and their labor, each owner's alternative rate of return derived therefrom offers a guide to the owners with respect to choice among existing alternatives. The alternative rate is thus the opportunity cost, set by the best of the forest owner's alternative opportunities.

If the alternative rate is based on capital investment opportunities, and the prospective alternative rate is increasing compared to the rate of return being earned on forest growing stock, a reduction of the growing stock would be indicated for such owners, leading in turn to a rising short-term supply.

The alternative rate may also be based on spending opportunities, the rate set by subjective evaluation of current versus future consumption.

For owners of small forests the alternative use of labor may influence short-term supply. Increasing rates of return from labor outside the small forest would tend to decrease the short-term supply of roundwood, because labor opportunity costs have increased.

61.35 *General market conditions*

Demand relations, organization of market institutions, channels, and methods may be of considerable importance for short-term supply. If the buyers of pulpwood in a market increase their pulping capacity at a more rapid pace than the producers of roundwood increase their production, the suppliers would improve their bargaining position. Most likely this situation would result in rising unit prices for roundwood, as a consequence of an increasing demand. Market institutions and established channels for sale of forest products are undoubtedly of major importance for supply (and demand) conditions. Sellers' organizations, for example, may take over a good deal of the work and the responsibilities involved in the marketing of roundwood. As the case is in Norway, for example, sellers' organizations may themselves engage in logging operations on behalf of owners of smaller forest properties. One likely effect from such activities will be decreasing unit costs of operation and consequently an increase in the supply of roundwood. Thus, co-operative logging among small forest owners may have immediate effects on the quantity of roundwood supplied.

Established rules and procedures for the requirements on quality, measurement, and delivery of the product are also important for the supplier.

61.36 *Institutional factors*

These factors will be described as factors outside forestry and forest industries of significance for short-term supply of forest products. One example of these social factors is forest taxation. If the government in a country wished to raise the supply of roundwood, one means of achieving such a goal might be to raise taxes for mature stands and lower taxes for young stands and cleared forest land. Other legislative measures could be employed to produce the desired effects.

61.4 An example from the Norwegian market for industrial roundwood

61.41 *Supply-affecting factors*

In an attempt to predict annual quantities of industrial softwood that may be supplied in the future, the Norwegian Institute of Forest Economics instituted a series of studies to examine the factors affecting the supply of Norwegian softwood.

This first part is rather aggregative, dealing with the total Norwegian supply of softwood over various time spans within the period 1918–1965 (Sæther, 1964, 1966, 1967).

A second part of the series is currently under way. In this, inquiries are being made into the supply relations for different forest owner groups, classified according to geographical area, productive forest area held, the net increment of this, the area of farm land under the same ownership, and the degree of occupation on the farm and forest land. The discussion that follows refers to the first part of the series.

In the initial work, the principal questions asked were: Which factors determine, or affect, the annual quantities of softwood delivered for sale, and how may they be best described?

As the sales volume of Norwegian industrial hardwood is only about five per cent of the total volume sold, these questions can be considered, for practical purposes, to refer to the total volume of industrial wood produced and sold in Norway.

During the course of the study, ten supply-affecting factors were considered, namely:

1. The unit price for spruce pulpwood delivered at roadside or river.
2. The unit logging costs (factors 1 and 2 = unit stumpage value).
3. The general price level, expressed by indexes of wholesale and consumer prices.
4. The expectations of future price changes.
5. The cut for the preceding year.
6. The date on which sellers' and buyers' representatives finally set prices.
7. The organizational influence on quantities delivered.
8. The weather conditions during the operational season.
9. The agriculturally based section of the national income.
10. Time, as a trend factor.

61.42 *The supply model*

It may be expected that the supply curve would be curvilinearly increasing in slope, so as to place an eventual limit on the amount offered for sale, as implied by the marginal unit cost curve (Figure 1).

From a practical point of view, however, a linear model may be well justified on at least two considerations. First of all the interval of range, within which the observations are made, may be along an almost linear part of a theoretical curvilinear supply curve. And secondly, a linear function should facilitate an easier solution than a curvilinear one.

In most cases a linear model should at least provide a reasonable first approach to developing a supply function, while at the same time one must not forget that a curvilinear model might be a more ideal final approach.

The first part of the studies are based on linear relationships between annual volumes of industrial softwood delivered for sale and the supply-affecting factors considered. Curvilinear functions, expressed by log-values of the variates, are also computed and compared with the linear functions. Functions based on first differences between annual values, are also established. For prediction purposes the curvilinear functions and the functions of first differences do not improve the results given by the linear equations for the period 1918–1960. However, the discrimination between two (Hunter & Reiner 1965) or more statistical models (Box & Hill 1965), is a tricky problem. The examination of the relationships between the supply-affecting factors mentioned and the annual volumes delivered for sale was carried out by means of multiple regression techniques.

61.43 *Main conclusions* in the paper, published in 1964 (Sæther, 1964), show that:

1. There is a most significant correlation between the annual quantities cut and the prices for pulpwood.
2. The introduction of unit conversion costs makes a significant contribution to the explanation of the annual variation in quantities delivered for sale, as does also,
3. the introduction of the variation in the purchasing power of the Norwegian krone.

These factors correspond to those on the top of the list in the chapter of the supply-affecting factors considered. The tests of significance are based on functions of three variables, presented as orthogonal functions. Confidence limits are determined to have the prob-

Table I. *Some results of analysis-of-variance, testing the improvement of estimated regressions by introduction of annual operation costs and figures of the wholesale price index. Period 1918-1959 (war years excluded)*

Variate	Sum of squares	DF	Variance	F
x_1	43.34	1	45.34	33.59
x_2 corrected for x_1	9.91	1	9.91	7.34
Rest	45.82	34	1.35	
x_2	51.85	1	51.85	62.50
x_3 corrected for x_2	20.85	1	20.85	25.12
Rest	28.37	34	0.83	

x_1=price for mid-measured spruce, current value.
x_2=operation (conversion) costs, current value.
x_3=figures of wholesale price index.
F_0 or tabulated F=4.45, when P=0.95 and DF=1 and 17.

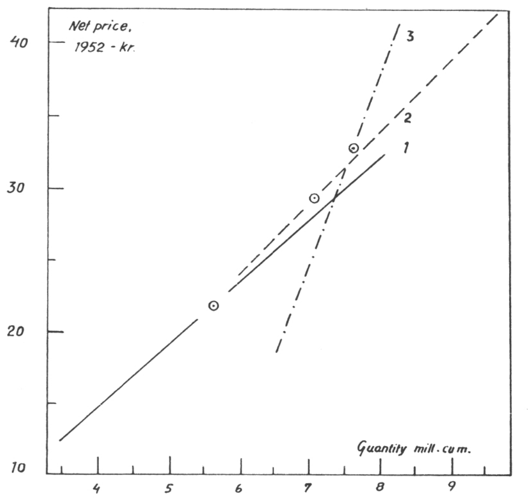

Fig. 2. Linear supply functions for three different periods:

1. 1918-1939: $\hat{x}_0=1.29+0.1936\ x_1$
2. 1945-1954: $\hat{x}_0=1.19+0.2000\ x_1$
3. 1955-1964: $\hat{x}_0=4.99+0.0814\ x_1$

$\hat{x}_0$ is the estimate of the quantity supplied in million cubic metres.
x_1 is calculated net price in 1952-kroner.
Periodical averages of quantities supplied are indicated by circles.

ability of 95 per cent, including the true value of the term in question, upon the hypothesis that the expected value of this term is zero.

Table I gives the results of the tests of significance, presented as F-values.

The factor listed as No. 4, the expectations of future price changes, is very close to making a significant contribution to the annual quantities delivered for sale, according to the 95 per cent confidence limit. It seems likely that the expectation of price and cost changes is a factor that is taken into consideration by the forest owners. The question of significance in a statistical meaning of the term might first of all be a question of having the relevant statistical data.

Factor No. 7, the organizational influence on quantities delivered for sale, has been quantified according to information from The Norwegian Forest Owners' Association. After 1959 the organizational influence, appearing as requests from the Association to the forest owners to reduce their supply of industrial wood, has not been in operation.

The factors listed from No. 5 to No. 10 did not contribute to the explanation of annual changes in quantities supplied. The lack of evidence for maintaining an assumption that these factors are influencing supply may well be due to the scarcity of observations, or that observations are incomplete.

In addition to the conclusions already stated, the studies published in 1964 showed that:

4. the variations in the annual quantities cut during the period 1918–1960 gave a standard deviation equal to 25 per cent of the arithmetic mean,

5. annual fluctuations of both quantities and prices of industrial wood are larger than the fluctuations of the general price level,

6. computed elasticities of supply, with regard to deflated, calculated net prices per cubic metre, show values about 1.0,

7. elasticity has declined after the Second World War, compared with the period between the two world wars,

8. bringing functions up to date improved their precision in forecasting, measured by differences between time series of residuals.

Figure 2 shows how the elasticity of supply has declined. Compared to Figure 1, the linear curves in Figure 2 may well be imagined as tangents to a curvilinear marginal cost curve, as presented in Figure 1.

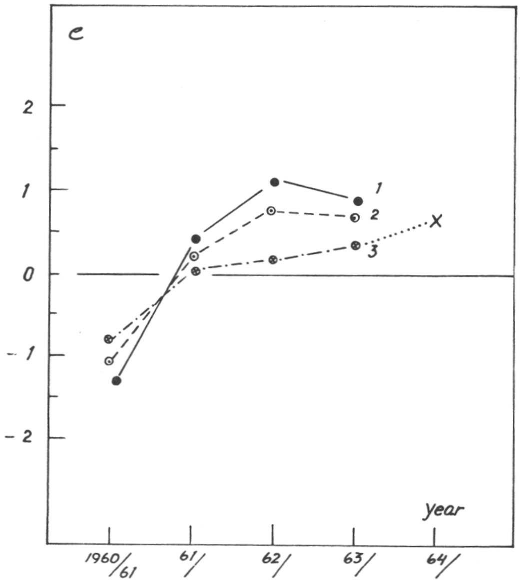

Fig. 3. Series of residuals ($e = x_0 - \hat{x}_0$) derived from three different functions, all of them applied on the years 1960-1963.

1. $\hat{x}_0 = 1.06 + 0.2066\ x_1$, observations 1945-1959.
2. $\hat{x}_0 = 2.14 + 0.1707\ x_1$, observations 1945-1962.
3. $\hat{x}_0 = 4.03 + 0.1103\ x_1$, observations 1954-1962.

$\hat{x}_0$=estimate of the quantity of industrial softwood supplied, million cu.m.

x_0=quantity of industrial softwood offered for sale.

x_1=calculated net price in 1952-kroner.

Residual predicted for 1964/65 is marked by a cross. This value was added to the estimate derived from function 3.

61.5 Application of the supply functions for predictive purposes

The supply functions thus established were tested officially in 1964/65 and in 1966/67. The first control was made in a paper, written in November 1964 and published in *Norsk Skogindustri*, No. 2, 1965 (Sæther, 1965). A complete description of this approach may serve as an example of how to make practical use of the theories established.

Supply functions were estimated for three different periods, of which the dependent variate gives the quantity of industrial softwood supplied ($\hat{x}_0$). The independent variable (x_1) is expressed by a calculated net price in 1952–kroner. The correction of the price level was made by means of the index of wholesale prices. The residuals, or the differences between the actual and the functional values ($x_0 - \hat{x}_0$), were calculated for all three functions and drawn up in a diagram. In Figure 3 the estimated values of the functions and the trends of residuals are presented. From the trends of residuals it was concluded that function 3 should most likely be preferable in forecasting:

$$x_0 = 4.03 + 0.1103\ x_1 .$$

As the calculated net price in constant 1952-kroner turned out to be 27.19, the values of $\hat{x}_0$ amounted to 7.03 million cubic metres.

By means of the trend of residuals an additional quantity was added to the function estimate (additional quantity appearing as a cross in Figure 3), resulting in a final forecast of 7.7 million cubic metres. The quantity of industrial softwood offered for sale in the Norwegian market was 7.55 million cu.m. The second attempt to make use of the supply functions in an actual forecast took place in the fall 1966, as a result of a consultant statement to the Norwegian Forest Owners' Association concerning the probable quantity offered for sale falling from the operational season 1966/67. The function applied for this purpose was based on price and quantity values for the period 1955–64, giving series of lower residuals than any of the other functions so far tested:

$$\hat{x}_0 = 4.99 + 0.0814\ x_1$$

where $\hat{x}_0$ = estimated quantity supplied (in million cu.m), and x_1 = calculated net price for mid-measured spruce in 1952-kroner.

From Figure 4 it appears that there is a striking difference between the series of residuals emerging from the functions covering the two periods 1955–64 and 1945–46, especially so for the last 4–5 years. The negative residual for 1965/66, following a trend of increasing positive residuals, was supposed to originate in the severe winter conditions during that season. Having some information on the magnitude of industrial wood which was cut but not delivered for sale in 1965/66, and supposing that the trend of residuals would continue in the same way as after 1960, the residual for 1966/67 was estimated to be 0.5 million cu.m.

The net price in 1952-kroner was calculated to have a value of 16.20, resulting in an estimated quantity equal to 6.3 million cu.m. (x_0 = 4.99 + 0.814 · 16.20). Adding the estimmated residual to this figure, the final forecast of the supply of industrial softwood for sale in 1966/1967 amounted to 6.8 million cubic

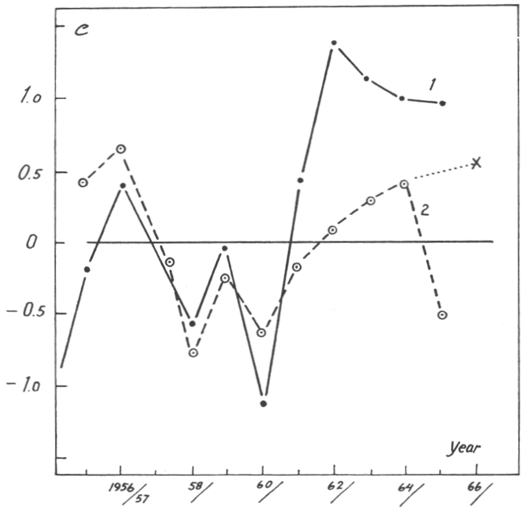

Fig. 4. Series of residuals ($e = x_0 - \hat{x}_0$) derived from the functions:

1. $\hat{x}_0 = 1.19 + 0.2000\ x_1$ (observations 1945-1964).
2. $\hat{x}_0 = 4.99 + 0.0814\ x_1$ (observations 1955-1964).

$\hat{x}_0$=estimate of the quantity of industrial softwood supplied, mill. cu.m.,

x_0=quantity of industrial softwood offered for sale, mill. cu.m.,

x_1=calculated net price in 1952-kroner.

Residual predicted for 1966/67 is marked by a cross. This value was added to the estimate derived from function 2.

metres. The last official report gives a record of 6.7 million cubic metres. Previous experience, however, indicates that a smaller quantity has to be added to the official record, so the final volume offered for sale will probably be something between 6.7 and 7.0 million cubic metres.* In spite of the fact that the number of forecasts is limited to two attempts, the combination of function estimates and trends of residuals seem to be quite promising.

61.51 *Experience after 1960*

The estimation of cost and price data in the statistical analysis into the annual cuts for the period 1918–1958 (Sæther, 1964) presuppose by implication that change of the conditions for wood production and changes of production methods are fully expressed through changes of wage tariffs. The increase of productivity resulting in the reduction of the use of manpower in Norwegian forestry by about 50 per cent during the last ten years will only to a certain degree be reflected by wage tariffs. For example, changes in wood production conditions, as a decrease in hauling distance, will not ba taken care of by current wage tariffs. Nor have changing delivery conditions, affecting the ratio of one timber grade or quality to another, been taken into consideration in the studies, based on data up to the 1960's. In a recent study concerning comparative cost-revenue analyses in forestry (Jørgensen & Opheim 1966), based on data from publicly owned forests, the development after 1958 differs from cost- and revenue trends in the supply studies. In these comparative cost-revenue analyses first of all trends of conversion values are fairly constant compared to corresponding trends in the supply studies, in which they are distinctly decreasing. In other words, the increasing productivity of wood production, especially during the last decade, which is clearly brought out in the comparative cost-revenue analyses mentioned, has been only partly expressed in the supply studies. This fact may explain the trends of residuals, resulting from the supply functions, based on cost-revenue informations for recent periods (Figures 3 and 4). To the extent that the increase of productivity, resulting from changes in production conditions and methods, develops in a systematic or regular way, as indicated by the trends of residuals, quantity predictions may be sufficient reliable. On the other hand, supply-affecting forces and factors will be more and more difficult to trace. Thus it seems quite evident that time series of revenues and costs have to be built up on the dynamics of events that are really taking place in Norwegian forestry, if the supply studies are to keep pace with the times.

* The final quantity was 6.9 million m^3.

62. Long-term (H. J. Vaux)

Long-term forecasts or projections of supply might be made in order to understand any one of a whole array of different sorts of economic problems. For example, the supply of standing timber might be forecasted for an area for dates forty, sixty, or more years in the future in order to determine whether or not additional land area should be used for timber growing. Or, the supply for an area might be predicted for dates ten or twenty years in the future as one determinant of how much investment in timber processing facilities should be made. Or, in an undeveloped forest area, the supply might be predicted for a five or ten year period as a guide to the rate of development of primary timber access routes. Thus, the phrase "long-term forecasting" embraces a good many types of problems. For each of these several types, the time horizon to be used, the selection of essential variables for study, and even the choice of methodology may be different, depending on what is appropriate for the particular problem at hand.

Thus, in a five to ten year forecast of supply for an undeveloped forest area needed to guide a program of road development, timber growth within the forecast period will be both relatively secondary in total magnitude and relatively little influenced by timber growing inputs. Within such a time period, the *elasticity* of supply in response to such inputs will be small. At the same time, the elasticity of supply will be much greater with respect to inputs of road construction and related transportation facilities, if they will make operable previously inaccessible portions of underdeveloped forest area.

In contrast to this problem stands the one of forecasting timber supply over a fifty year period as a guide to timber growing policy. Over such a time span the supply response which can be obtained by physical development inputs is sharply limited by the finite size of the supply area, and indeed (except in underdeveloped areas) the elasticity of supply with respect to such inputs is negligible. But the supply response to timber growing inputs may be very substantial; it increases rapidly as the length of the forecast period approaches the length of rotation.

The preceding illustrations have been concerned with forecasting supplies of standing timber. Parallel problems in the supply of manufactured forest products could be cited to show the generality of the principle that the elasticity of supply response to different classes of inputs is highly correlated with the length of the time horizon being used so that the length of horizon influences strongly the nature of the factors affecting supply. Thus, stipulation of the time horizon is an essential initial step in long-term forecasting. This, in turn, provides the basis for analysis of input factors in order to select those whose influence on future supply may be significant.

Most frequently, long-term supply projections are under-taken in order to provide a guide to help choose between policy or program alternatives which affect wood production. Ideally, the whole range of alternatives may be projected, in which case the result is the supply function or schedule. In practice, the task of projecting may be so large that it may only be feasible to analyze a limited number of alternatives which suggest either the most likely probabilities or the range of possibilities.

62.1 Defining market area

The first step in forecasting supply is to define the market area for which supply is to be predicted. The purpose for which the forecast is to be made will, of course, provide certain criteria for defining the market area. However, the nature of available physical and economic data, the geographic distribution of the forest resource itself, and the location of major centers of consumption may also be of primary importance. In general, the task of forecasting is simplified if the supply area is chosen in such a way that it is bounded by sharp discontinuities in the physical characteristics of the resource and by changes in administrative jurisdiction which permit measuring flows into and out of the market area. The detailed nature of the existing (or potential) transportation network is obviously of great importance in delineating market areas useful for the analysis of supplies of roundwood and of standing timber.

62.2 Defining time horizon

The time horizon to be embraced by the projection must, as has been said, be selected in relation to the particular problem in hand. Thus, a projection to be used for evaluating the economic feasibility of expanding wood processing plants would usually extend to a horizon determined by the normal economic life of such plants; but a projection used to determine the optimum scale of planting programs would usually embrace one whole rotation. Time horizons of the latter order of magnitude may thus be dictated by the logic of the problem under study. Even though there may be major uncertainties about many aspects of such distant periods, they do not justify selecting a shorter, less uncertain, time horizon in defiance of the logic of the problem.

62.3 Factors affecting long-run supply

For any commodity, the factors influencing long-run supply are those which determine the costs of production at alternative levels of output. For roundwood these include the costs of timber growing, of timber harvesting, of extraction, and of transportation to the point where sales of roundwood are expected to take place. It should be emphasized that the relevant costs are all prospective. For example, if the time horizon appropriate for the forecast is thirty years, one must be concerned with harvesting, extraction, and transportation costs likely to be incurred thirty years from now, or at some appropriate intermediate date of harvest, not with those of the present. Similarly, the costs of timber growing must be estimated on the basis conditions which are expected to prevail at whatever date the timber growing measures in question are applied.

Predominant elements in the cost of growing timber are those related to the capital invested in growing stock. Thus careful measurements of present growing stock and accurate projections of the potential yields from it are essential as a basis for estimating costs of capital. Of coordinate importance is the determination of the interest rate which is appropriate as a measure of the cost of using capital.

62.31 *Inventory and growth*

National and regional forest inventories will usually provide information on growing stock adequate for long-term supply forecasting. Current inventories must of course be supplemented with information as to recent rates of stand reestablishment so as to insure a complete picture of the total available forest capital. Similarly, current surveys of national and regional levels of timber growth provide a starting point for estimating the physical productivity of the growing stock. Current surveys alone, however, furnish only a part of the information needed for long-term growth projections. They must be augmented by careful analysis of (1) how growth is likely to increase or decrease in the future, if the present dynamics of the forest are allowed to run their course, and of (2) how growth is likely to be modified either by variations in the future level of cutting or by the application of programs of management different from those which have produced current conditions.

The accuracy of growth information is a critical factor determining the reliability of long-run supply estimates. Because of the long time periods involved, even relatively small errors in estimates of current or prospective growth may become heavily compounded. Ordinarily, growth projections may be simplified by estimating net growth after deduction of expected mortality and losses from forest enemies.

62.32 *Interest rate*

Estimation of the interest rate appropriate for calculating capital costs also is critical for reliable results because of the compounding of such costs. The rate which is appropriate will depend upon the problem in hand. For example, if the question concerns supplies of timber that private owners will place on the market in the long run, the most important guides to interest rate will be the long-term rate at which such owners can borrow capital and the marginal rate of return to capital in alternative lines of private investment. But if the question is the normative one of analyzing timber production goals for the supply area as a whole, the long-term rate on Government borrowing or some overall estimate of the marginal efficiency of capital in the regional economy may be more appropriate guides.

Of particular concern is the treatment of risk and uncertainty. In short run and market period problems, it is often the practice to allow risk and uncertainty to be reflected in the interest rate. If used in long-term projections this practice is likely to exaggerate risk allowances to an inappropriate degree, due to the differential effects of compounding at different rates of interest. Unless there is clear evidence that risks do in fact compound annually, it is preferable to identify risk and uncertainty costs separately from the interest rate and to handle them as annual charges.

62.33 *Interdependency of outputs*

When any growing forest is analyzed over a period of decades, it is apparent that growing stock available in the later years is heavily dependent on the level of cutting (or output) in the earlier years, and that allowable cut in the later years depends heavily on current growth and level of growing stock in the earlier years. Recognition of such time interdependencies is essential if costs of production are to be estimated properly. How to treat such time interdependencies constitutes a major methodological problem.

In some cases, interdependency of outputs may be treated by use of the assumption of sustained yield. Wherever this assumption is appropriate (for institutional or other reasons), it serves to specify the way in which timber output in one period is related to that in others, and the interdependency problem disappear. In many cases, however, the sustained yield assumption may be inappropriate (for example, where the question to be studied is that of whether total growing stock should be increased, decreased, or maintained at the present level). In such cases simulation models (such as are described in Sec. 62.4 below) appear to provide the most effective methodological approach because of their large capacity for analyzing intertemporal relationships.

62.34 *Available forest area*

In the long-run, the area of land available for (or used for) growing timber may be subject to significant change. On the one hand, forest areas may be taken out of production in order to provide land for urban development, transportation facilities, or agriculture. Or, additional land may become effectively available as a potential supplier of timber because of abandonment of agricultural land, extension of transportation into previously inaccessible areas, or for other reasons. Accordingly, an evaluation of prospective trends and potentialities in land use should be made in order to provide estimates of how forest area is likely to change over time. Such estimates must then be included as one of the independent variables in the timber supply forecast.

62.35 *Forest management programs*

Over the long run, timber growth and levels of yield are responsive to the intensity of forest management. Thus, long-term supply projections must take account of the effects of alternative levels of forestry programs concerned with protection or silvicultural improvement of the forest. Costs of such program alternatives must be estimated and their potential effect on growing stock and yield must be determined. Where the purpose of the projection is to determine the most probable level of future supplies, it may be sufficient to project a single pattern of management programs, corresponding to the level of management which is expected to prevail. Where the purpose is to evaluate management alternatives, however, it is clearly necessary to envisage several different management regions and to project the costs and changes in output which will be associated with each.

62.4 Choice of a supply model

For long-run supply analysis, non-structural statistical models based on the extension into the future of regression relationships determined from historical data have limited applicability. Such models cannot take adequate account of the time interdependencies noted above. In addition, the length of long-run planning horizons is ordinarily such that many production relationships which have characterized the past are likely to be different in the future. (For example, in the short run, the impacts of increasing mechanization on the costs of output might quite properly be disregarded. But in the long run, explicit recognition of such effects is a vital part of the analysis.) Finally, in most countries, reliable statistical data covering inventories, growth, costs, and the like are available for a relatively limited period of past history. These periods are usually too short to reveal the longer run trends which are essential for the sort of supply analysis being considered here.

A more useful sort of model is based on the actual physical and economic structure of future supply. It simulates the various steps that lead to the generation of timber supply by tracing out year after year what would happen to such items as inventory, growth, and cost if specified management and cutting regimes were to be followed. Such models may be relatively simple, based on rather broad specifications as to forest growth, demand, and costs of factors. Or they may be quite complex, attempting to take account of many significant details as to growing stock, products demanded, sorts of management inputs, and the like. In the latter instance, the simulation model is only practicable if a computer is available to handle the manifold calculations involved with a reasonable degree of speed.

A brief description of the principle elements in a timber supply simulation model may help to explain this method of approach. A very simple situation will be assumed in order to stress methodological aspects.

62.41 *A representative long-term supply problem*

Consider a forest region of about two million hectares of accessible timberland, situated so that there are evident and substantial obstacles (either physical or political) to the import and export of forest products. The area includes substantial markets for wood pulp and sawn products. Let us assume also that all forest land is owned and operated by the central government and that only two species of timber are suitable for production in the area. (Much more complex assumptions as to ownership and species could be used without complicating the methodology.) Suppose, finally, that the central government is considering whether or not to expand output of pulp and paper products by investing in pulping facilities that will increase existing capacity by twenty-five percent. A projection of long-term timber supply useful in answering this question is required.

62.42 *Length of planning period*

The economics of the proposed increase in pulping facilities will depend on conditions throughout the life of the facilities in question. Therefore, the timber supply analysis must extend over a period at least as long as the expected depreciation period of the new plants. In the present case, this is judged to be 30 years.

62.43 *Terminal supply-demand conditions*

An important (and too often unanalyzed) element in the cost of producing timber is the residual one of impact of production on more distant future conditions. Thus, in the present case, costs of increasing wood output during the next 30 years will depend in part on the state of the timber supply-demand balance at the end of the period. Other things being equal, the long run costs of additional output during the next 30 years will be higher if they result in a severe supply-demand imbalance than if they do not.

In order to reflect properly this element in cost of production, the simulation method requires us to specify the terminal conditions of supply and demand which are expected (or desired) at the end of the planning period. Unless these terminal conditions *are* specified, the anticipated average unit cost of wood produced during the planning period is indeterminate and a statement of long-term supply in the economic sense cannot be made.

The specification of these terminal conditions must be made within the broader framework of forest policy considerations applicable to the problem in hand. In the present example, the most appropriate terminal condition might be an inventory sufficient to maintain output on a sustained yield basis at the level where average total unit cost of wood production equals expected average long-run price of wood. (One might readily imagine different terminal conditions which might properly be specified under particular circumstances.) Whatever the specific terminal conditions may be, however, they involve quantitative statements about the long-run conditions of (1) timber growth, (2) costs of production, and (3) the demand schedule for timber output. Each of these functional relationships must, of course, be specified in the light of conditions expected to prevail at the end of the planning period. Each must be the object of research which is carefully designed to estimate the proper function.

It may at first seem anomalous to state, as we have just done, that the long-term costs of wood production depend (in part) on the demand for wood. But this apparent contradiction is simply a reflection of the fact that a major element in the real economic cost of growing wood is the opportunity cost of foregoing consumption of wood in other time periods. The magnitude of this opportunity cost is influenced by the demand for wood in these periods. When we include the demand for woods as one of the factors defining the terminal conditions used to identify cost, we are simply recognizing the opportunity cost of using growing stock. The simulation model provides a practical way of sorting out the time interdependencies which arise out of the existence of these opportunity costs.

62.44 Initial inventory and growth

The simulation model must also include a detailed description of present inventory and of growth potentialities. The number of hectares of land and the volume of wood inventory, by species, site quality, and age and condition class of the forest may provide sufficient description of the inventory for supply projection purposes. In establishing the units and the standards to be used in measuring the inventory, care must be taken to insure that these are consistent with those likely to prevail in timber utilization practice throughout the 30-year planning period.

The timber supply model must also be provided with specifications as to future growth. These may be formulated either in the form of stand projections or by yield table methods. The choice may well depend on the comparative extent and reliability of the information available for use in each of these alternatives. Under either method, the growth analysis must be sufficiently precise so that the effects on future inventory and yield of a range of alternative forest management programs can be evaluated.

In the present illustration, the timber supply model provides the description of present inventory in the form of a tabulation of areas of forest land in the following forms. The tabulation is compiled separately for hardwood and for softwood:

Condition Class	Age Class I	II	III	IV	V	VI
A: Site I, unstocked						
B: Site I, 1–25 % stocked						
C: Site I, 26–50 % stocked						
D: Site I, 51–75 % stocked						
E: Site I, 76–100 % stocked						
F: Site II, unstocked						
G: Site II, 1–25 % stocked						
Etc.						

Inventory volumes are determined from knowledge of the correlation between the tabulated condition classes and cubic volume per acre.

The effects of annual growth under a particular management regime are specified in the model by including in it estimates of the proportion of the acres in each cell which will move to some other cell at the end of one year's growth. Similarly, the effects of one year's harvest cutting of a given amount and kind are simulated by providing the model with estimates of the shifts in area from one cell to another induced by such a cut. If the relevant information is programmed for a computer, the impact on inventory of different levels of cutting and of different management program over the next thirty years can be estimated quantitatively. This inventory/growth simulation will provide a tabulation in the above format for each year in the planning period.

62.45 Comparing management alternatives

Using the computing device outlined above, we may now compare the results of the various management alternatives which might be adopted over the 30 year planning period in order to provide a 25 percent increase in pulpwood output. The available management alternatives must, of course, be specifically defined for the particular problems in hand. In the present case, suppose that pulpwood output may be increased by either of the following alternatives:

(1) Planting unstocked (or understocked) softwood areas. If done immediately and on a sufficiently large scale, the terminal growing stock will be increased and cutting over the next 30 years can be expanded without violating the terminal sustained yield condition previously established. The inventory/growth

simulator of the preceding section provides the information needed to determine the extent of the plantings which will be required to permit an increase of 25 percent in the pulpwood harvest.

(2) Intensifying intermediate cuttings on the more heavily stocked sites. The inventory/growth simulator provides the information needed to determine the extent of intensified intermediate cuttings needed to secure the 25 percent increase in pulpwood harvest and states the effects of this on the residual growing stock. The additional management inputs, whether of planting or other measures, needed to regain the specified terminal growing stock may then be determined.

(3) Sawn wood production may be reduced by an amount sufficient
(a) to permit the 25 percent increase in pulpwood cut and
(b) to build up growing stock necessary to sustain the level of yields required by the terminal conditions.

Under alternatives (1) and (2) above, the additional pulpwood output is the cost of the new plantings or other management measures needed to offset the effects of the heavier cut. Under alternative (3) the cost of the additional pulpwood output is the net income foregone (opportunity cost) as a result of curtailment of sawn wood production. Whichever of these alternatives is least costly may be regarded as the appropriate measure of the cost of the required increase in long-term supply.

Using the same simulating device and techniques described above, one may estimate the cost of other changes in output in addition to the specific case discussed above. This family of estimates, showing the cost at which different alternative levels of 30-year pulpwood output can be secured from the existing forest inventory in the area, constitutes a statement of the long-run timber supply.

7. FORECASTING CONSUMPTION AND PRICE (G. Robinson Gregory)

For purposes of this report consumption has been defined as "the amount of a specified commodity used (consumed) in a particular area at a specified time". Price has not been defined – very probably because it is so universally accepted and because it is accorded the same meaning by economists as by almost all others. But since one of the purposes of this working group is to resolve terminological differences, a definition will be proposed: *price will be taken as the quantity of one thing, measured in money terms, that is exchanged or demanded in barter or sale for a specified commodity in a particular area at a specified time.*

In consumption (price) analyses, quantity (price) will be treated as the dependent variable, always under given conditions of place and time, and always with the commodity being carefully specified. The analyses are thus qualified, no doubt intentionally so, in much the same fashion as are the usual statements made with regard to analyses of demand and supply.

Before plunging into forecasting *per se* it seems desirable to take at least a brief look at the matter of product specification.[1]) One is interested in forecasting the price and quantity *of what?* To a considerable extent the objective of the forecasting exercise will determine how detailed product specification should be – but not in every case. Forecasts aimed at developing answers to questions such as "How much wood will be consumed by India in 1985?" for example, might only require identification of four or five major wood use groups. In preparing the World Indicative Plan, which asks precisely this type of question, FAO is using five major wood product groupings – sawnwood, wood-based sheet materials, pulp and paper products,

1) This point was discussed in a paper presented at the Sixth World Forestry Congress in Madrid. (Gregory: "Timber Trend Study Methods", 6CFM/G/CTX/9). The author apologizes for repeating some parts of his Madrid paper, but there seems no alternative at the moment since plans of making available the papers of the World Forest Congress are not yet fully settled.

industrial roundwood, and fuelwood. On the other hand, if interest is confined to a very narrowly defined sector of the forest economy there may be no need for product grouping. It would scarcely seem sensible, for example, for a newsprint manufacturer to suggest framing forecasts in terms of "pulp and paper products". Usually one can be assured that the more restrictively a product can be specified the more precisely the factors affecting consumption or price can be identified.

But product groups can serve quite another purpose. Frequently, forecasts for groups of products can be made more accurately than can forecasts for any single one of the group components. Thus it may be far better methodology to begin a forecast for plywood by studying the consumption of all wood-based panels, then proceed to analyse the factors that lead to substitution of particle board or fibreboard for plywood. Similarly, a producer of sheathing lumber might find it advantageous to begin a market forecast by studying consumption of sheathing products as a group, then to analyze the factors that lead to substitution of plywood or fibreboard for lumber within this group.

Once the product has been satisfactorily specified the job of forecasting can begin, with the variation in techniques (and the degree of complexity) ranging from the absurdly simple to the (almost) equally absurdly complex. Not all can be dealt with in a paper of this length, but an effort will be made to cover the major varients that have been used so far.

The simplest method of estimating future consumption, or price, of almost any product or group of products is to equate the future with the present: next year's consumption will be the same as this. For short term forecasts there is certainly much to recommend the method: it is easily understood, and if the forecaster is moderately lucky the predictions so derived are quite likely to prove as accurate as those made by more sophisticated methods. As a matter of fact, this procedure gives very good results for some products over considerable time periods. If one had attempted, for example, to forecast the price of newsprint in Canada and the U.S. at almost any time during the post-World War II period this approach would have produced quite acceptable results — and especially so if real prices had been used: deflated prices of this particular commodity have remained virtually constant.

But normally we need not be satisfied with a model quite this simple. Instead of saying that next year's consumption will be the same as this year's, the "trend" of past consumption (or price) can be projected. This is the procedure used in most of the so-called timber trend studies made over the past half century, and provided the forecasting period is not too long one should expect fairly good results. Among forest products, those from the pulp and paper field offer good examples of commodities for which consumption forecasts for periods of five years or so could have been made quite accurately by projecting past trends. Figure 1 provides a specific example of such trend forecasting and also permits illustrating some of the inherent difficulties. In this figure, data on paper consumption in the United States since World War II have been plotted. Quite obviously, providing the predictions were made for five year periods or less, consumption estimates based on past trends would have proved quite accurate. But if one tries to extend the forecasting period to (say) 1985, serious difficulties are encountered. What is the trend line?

In Figure 1 two lines have been fitted by regression techniques. The linear relationship is specified by the equation

$$C = -34.0 + 1.23t \qquad (r^2 = 97.3)$$

and the logarithmic relation (or curve) by the equation

$$\log C = -2.12254 + 2.09383 \log t \quad (r^2 = 96.4)$$

where C is consumption in millions of tons and t is time (1945 = 45, etc.). In both cases the regression coefficients are highly significant while the coefficients of determination seem reasonably acceptable (and not significantly different). The question posed is, very bluntly "How does one decide which of the two curves is "best" for making a forecast?". This is an important question, for the linear equation yields an estimate of 70.5 million tons and the logarithmic equation gives an estimate of 82.7 million tons. In terms of new production the first implies 24.5 million tons of new capacity by 1985 and the other only 36.7 million tons — a difference of fully 50 %! Clearly, trend analyses do not always provide unequivocal forecasts. And if another product had been selected even the short ferm forecasts of con-

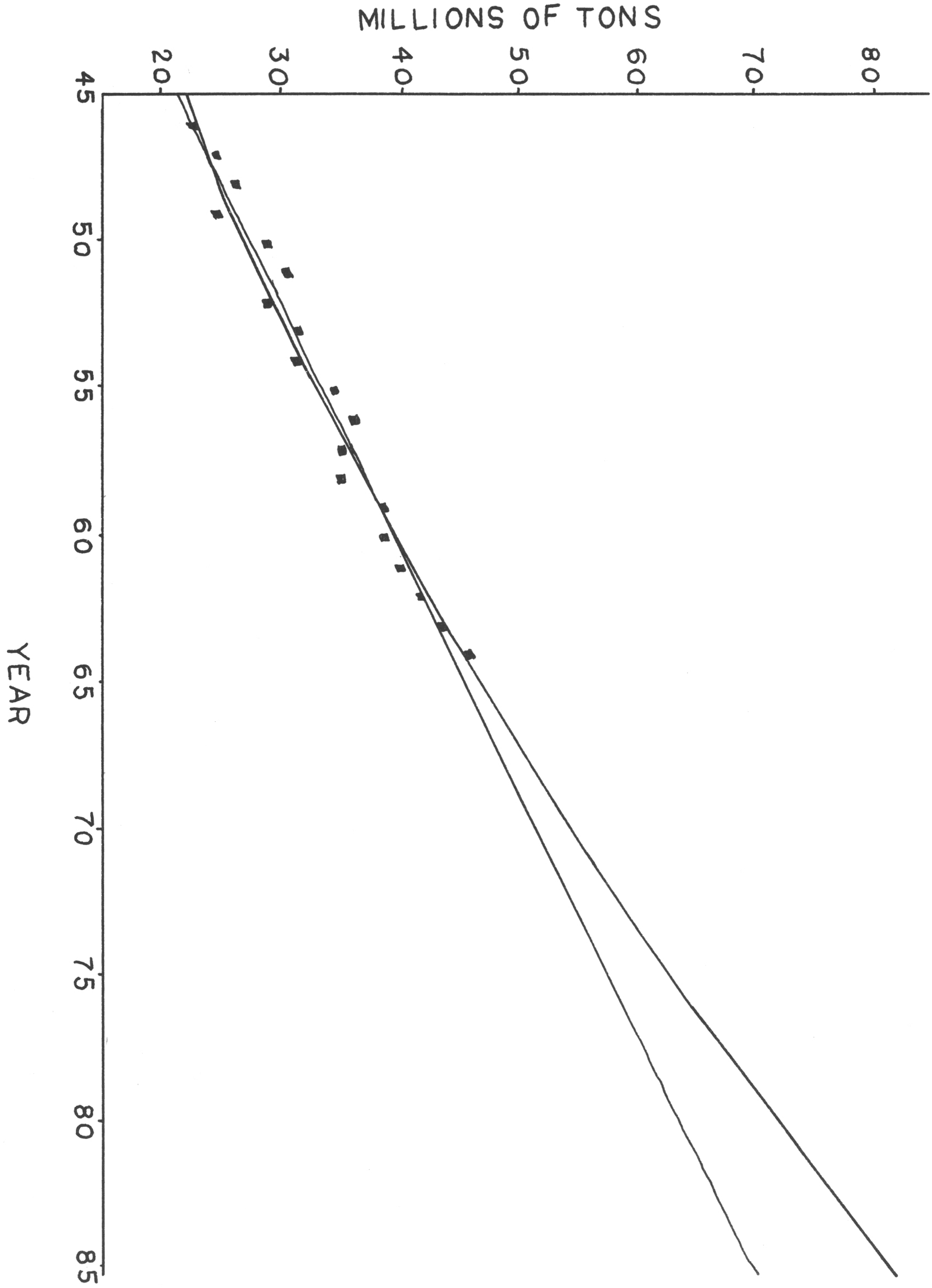

Fig. 1: Trend in annual consumption of paper in the United States. For details of the projections to 1985, see text.

sumption or price might have been quite deficient: lumber consumption or price in the U.S. since 1950, for example, has not followed any particular trend line very closely.

Another type of difficulty with trend projections may be illustrated by the current problem of forecasting future use of particle board. Here is a product in which use is increasing exponentially — but how long will the exponential trend continue? The product is so new that data on consumption extend only over the past few years. Scarcely enough time has elapsed to permit even the most optimistic to believe a simple extrapolation would give valid answer for anything more than two or three years in the future.

Part of the problem lies, of course, with the difficulties inherent in making a choice between the various types of functions that might be used. Each function implies certain assumptions about the behaviour of factors affecting consumption of price: will the changes in these factors continue to occur at the same *absolute* level, or will their *rates* of change continue in the future the same as in the past? Basically, however, the fault lies with the implicit assumption made in all trend analyses — that all those factors that produced the changing consumption observed over the past time period will continue to affect the dependent variable in exactly the same way through the future.

In the introductory paragraphs of this paper it was observed that consumption (and price) had been defined in a manner analogous to the usual definitions of demand and supply. Since consumption and price are almost always taken to be identical to the "quantity" and "price" indicated by the intersection of a demand and a supply curve, the analogy should be reasonable. And this parallelism permits specification of a somewhat more complex model for forecasting price and consumption — pictured in Figure 2.

DD and SS are (respectively) demand and supply curves for a specified commodity in a particular area at a given time. This is, clearly, the elementary short run model of price theory, showing the equilibrium marked price resulting from the interaction of short run demand and supply curves, with the commodity, time, and market place fully specified. The model shows plainly why consumption and price can be considered conceptually in the same frame-

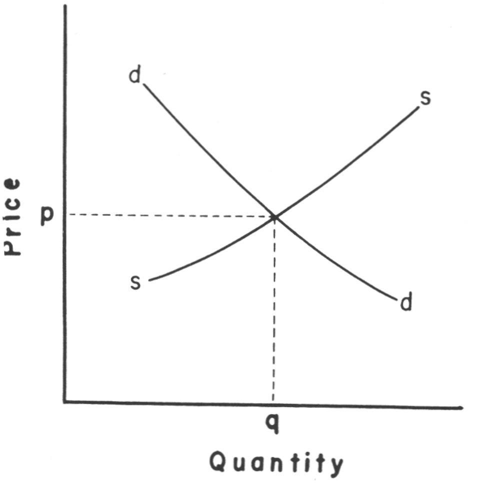

Figure 2. *The conventional short run supply-demand model.*

work, for even in this very simple model price and consumption are determined simultaneously. Price is not determined by the level of consumption, or viceversa: both are determined by the interaction of the entire set of forces determining the supply and demand curves.

To estimate either future consumption or price, therefore, it would seem reasonable to derive demand and supply schedules for the various types of forest products or for the product groupings desired. Then, by analyzing the factors affecting the position and shape of these two curves one could trace their movement over time. The intersections of the shifting demand and supply curves would identify both product price and consumption under the conditions specified for the two curves. Modern quantitative economics has developed techniques for derivation of statistical demand and supply functions that are fully as applicable to forest products as to those from other areas. Usually these methods of econometrics require description of both demand and supply equations in terms of variables generated by the system (endogenous variables) and those given to the system (exogenous variables). Various methods have been established for solving the resulting equations systems under different situations and a great deal of work is being done to make the methods more usable. To date, however, few studies involving forest products have utilized these analytical techniques (Gregory 1966). In most countries there is no doubt that the data available simply will not permit this type of approach. The fact that these models may be quite complex, however, should be no deterrent: the consumption of wood is not a simple problem and we should not shrink from employing models of whatever complexity we can manage and for which suitable data can be found. Modern computer technology has removed almost all constraints on computation: unfortunately it has done little to erase the difficulties imposed by lack of data.

But neither consumption nor price forecasting, even with the model illustrated in Fig. 2, necessarily require simultaneously solving demand and supply equations. Suppose, for purpose of illustration, we agree that one of the more important factors affecting the position of the curve for (say) paper demand in modern nations is the level of per capita income: as per capita income increases, the demand curve is expected to shift outward. Since three factors are now involved a three dimensional figure is needed to illustrate the result – as in Figure 3.

Here both the demand and supply functions are assumed to "shift" as income increases: the shifting demand (dd) and supply (ss) curves create "surfaces" which intersect. Under the conditions illustrated in Fig. 3 consumption rises with increasing incomes, and so does price. The effect on consumption is made clear by projecting the path of the supply and demand intersections on the base of the diagram, yielding a relationship similar to that shown in Fig. 4 – *a two* variable relationship between *consumption* and per capita income. Quite obviously, a similar projection could be made on the other

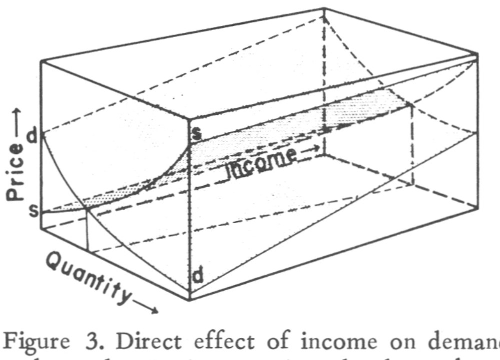

Figure 3. Direct effect of income on demand and supply. As income rises the demand and supply curves (dd) and (ss) shift, creating the intersecting surfaces shown here.

Figure 4. The two-variable relationship of consumption and income derived from Figure 3.

(price) surface which would yield another two variable relationship, this time between *price* and per capita income.

The effect of income on consumption provides a convenient illustration, but other factors could also play important roles. To include additional factors requires a multi-dimensional model, most easily represented by generalized equations such as

Consumption = b_1 (population) + b_2 (income) + b_3 (wood availability) + b_4 (price of other fibers) + b_5 (wage rates) + b_6 (literacy rate) + b_7 (production costs) + b_8 (. . . etc.)

where the b's are weights appropriate to each variable. Again note that while demand and supply appear to have been by-passed, this is strictly a demand/supply model: each of the selected variables affects consumption (or price) by "shifting" either the supply curve, the demand curve, or both.

Models of this type have been used frequently during the past few years, although generally they have purported to estimate "demand" rather than consumption. In nearly all cases income has been the only variable utilized, even though relatively few attempts have been made to *measure* the effect of either income changes or income levels on consumption of forest products, and even fewer to examine the effect of other variables[x]) (Gregory 1955).

[x]) The African Timber Trend Study made by FAO also took wood availability into account but the mechanism for so doing was not specified. FAO studies of "paper demand" have been based on income elasticity, usually derived from a combination of cross-

Most often, models of this general type use estimates of the elasticity of consumption with respect to income[xx], couple these to forecasts of per capita Gross Domestic Product or Personal Consumption Expenditures, and thus produce forecasts of future consumption on a per capita basis for the target date. By multiplying these per capita consumption forecasts by estimates of population, forecasts of total consumption are produced.

Leaving aside questions regarding the suitability of the basic approach, one can criticize forecasting models of this type on at least five counts: (1) the estimate of income; (2) the estimate of population; (3) the estimate of elasticity; (4) the functional form chosen to make the per capita consumption forecast; (5) the complete omission of other variables. The first two items can be ignored at this time since we are primarily concerned here with forecasts of forest product consumption and price. Population and income estimates are admittedly highly important to the success or failure of the quantitative prediction, but the techniques of forecasting income and population are not believed to lie within the scope of this paper. The other three points, however, deserve comment.

Attempts have been made to estimate the elasticity of consumption with respect to income for some forest products through both cross-sectional analyses and by use of time series data. In FAO's major study of future paper consumption (1960) the elasticity estimates were usually made from cross-sectional studies, then checked whenever possible by time series. Unfortunately, data for deriving elasticity estimates for other forest products are very poor, and especially so if time series data are wanted. What little work has been done leads one to doubt very seriously the existence of any strong relationship between income and the consumption of sawnwood, roundwood, or fuelwood, while wood-based panels are (as observed earlier) a product that has encountered such far-reaching technical changes that any correlation of consumption with income deserves little weight in forecasting.

Both cross-sectional studies and those utilizing time series data are subject to strong theoretical criticisms – criticisms sufficiently well known as to preclude any need for repetition here. At the same time one should bear in mind that if elasticities are to be estimated either time series or cross-sectional studies must be used as the basis for their estimation: no other bases seem available.

A wide variety of functional forms have been used to forecast consumption from estimated elasticities. In "World Demand for Paper to 1975" the log-normal function was introduced and has been used by FAO for most forecasts of paper consumption since that time. Other commonly used functions include the very simple linear function (seldom used for elasticity-based forecasts), the semilogarithmic, the logarithmic, the log inverse, and of course polynomials of various degrees. Each has certain characteristics that favor its adoption for certain purposes, probably the most important *being the implicit behaviour of the elasticity over the time of the forecast.*

Table 1 may aid in clarifying some of the assumptions implied by functions of particular use in making forecasts by elasticities. The three equations shown have been re-written so that the assumed elasticity can be entered directly into the equations. Clearly, use of the logarithmic form implies that the elasticity remains constant throughout the forecasting period, while the semi-logarithmic and the log-inverse forms imply that elasticity is constantly decreasing over the forecasting period. The log-inverse function also possesses the characteristic of being asymptotic – implying an eventual saturation level.

Each of these three functions requires three parameters for making a forecast: the elasticity, the consumption during the base period, and the index of change in income ($\frac{x^1}{x}$ in the table). With these, any estimate of income can be used to yield a corresponding estimate of per capita

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sectional and time series analyses. Recently an adjustment has been added – a "time trend factor" – but this seems to be an effort to correct the forecasting equation by introducing an error term rather than an attempt to achieve a better understanding of underlying factors.

[xx] Elasticity of consumption with respect to income is defined as

$$= \frac{\%\ \text{change in consumption}}{\%\ \text{change in income}}$$

Usually the % change is calculated on an annual rate of change basis and, if periods of several years are involved the rates should be compound.

Table 1: Nature of three functions of use in projecting consumption. 1)

Function	Elasticity Coefficient	Increase in Per Caput Demand
Logarithmic $\log_e y = a + b \log_e x$	b	$\log_e \frac{y^1}{y} = \log \frac{x^1}{x}$
Semi-logarithmic $y = a + b \log_e x$	$\frac{b}{y}$	$\frac{y^1}{y} - 1 = 2.3026 \log_{10} \frac{x^1}{x}$
Log-inverse $\log_e y = a - \frac{b}{x}$	$\frac{b}{x}$	$\log_{10} \frac{y^1}{y} = 0.4343 \quad \frac{(1 - x)}{x^1}$

x, y, and refer respectively to per caput Gross Domestic Product, per caput consumption, and elasticity coefficient at the base period. x^1 and y^1 refer to the corresponding values at the end of the projected period. The coefficient 0.4343 corresponds to the transformation of decimal into natural logarithms (or its inverse, 2.3026) corresponds to the transformation of decimal into natural logarithms.

1) From Table 1.9, page 34 of the FAO publication "Agricultural Commodities-Projections for 1975 and 1985", Vol. II, August 1966. CCP/3. Not available for distribution, but prepared for the Committee on Commodity Problems, Forty-First Session.

consumption when the values of the three variables are known for the base period.

The log-normal function used in the paper study referred to previously requires an additional parameter – the so-called "t" value, based on the saturation level. This value is usually obtained by making a series of successive approximations through graphic means (FAO 1960, Annex. B, p. 95). There is little doubt that commodities such as cereals and starches have a saturation level: the human body seems to have a quite clearly defined "saturation level" at about 2,030 calories – and there are many other examples. The appropriateness of using such a function for estimating consumption of forest products, however, is open to serious question since it requires an additional parameter, and especially when this parameter must usually be approximated and when the resulting coefficients can thus not be subjected to usual statistical tests. The argument that consumption tends to "flatten out" as income increases does have empirical backing, but there are many functions having this characteristic yet requiring no additional parameters. The log-inverse, illustrated in the table, is one such function and is the one being used (March 1967) in the IWP work for virtually all forest product forecasting.

The final model to be mentioned here is the one introduced by A. Wald – the recursive model – which Gregory used in an investigation of red oak flooring. Since this study has been reviewed by Josephson in this same series of working papers there seems no need for additional detail. Normally this model would seem best adapted to short-term forecasts of price. The model assumes a lag between production decisions and sales, that an equilibrium price already exists between supply and demand equations, and that price is altered in the market because (a) production must precede consumption, (b) producers under-estimated or over-estimated the realized demand, or (c) production (supply) suffered some unforeseen change. Price therefore results from the difference between producer's expectations and the realized market equilibrium. Changes in stocks are necessarily closely related to price changes – a fact readily substantiated in many (though not all) markets.

Unfortunately, this paper must leave far more unsaid than said about price and consumption forecasting. But after being responsible for making consumption forecasts of forest products for FAO's Indicative World Plan the author feels compelled to end on a pragmatic note.

Consumption and price data for most forest products, and for most variables that seem of propable significance in determining consumption and price, is woefully inadequate in the majority of countries – developed as well as developing. How many *reliable* price series (to take just one example) have been assembled for lumber, or plywood, or for that matter – for paper products? Our production data are not much better: in a good many developing countries one finds himself asking, NOT "are these data reliable to within a plus or minus 20 percent?" but "Should I multiply this production figure by 5 or by 10?".

Forecasting models and techniques are important, but good forecasts must begin with reliable base data. We in forestry, along with those working in the forest-based industries, badly need to set our statistical houses in order!

8. SUBSTITUTION AS A PROBLEM IN FORECASTING (S. L. Pringle)

This note deals with substitution as it relates to the forecasting of demand or consumption. It does not deal with substitution among factors of production as it might affect the supply function directly.

In recent years competition (a) between forest products and products of materials other than wood and (b) among different forest products has been a major concern of foresters and forest industries in estimating future market positions for their output. The term substitution, initially used in commerce in the derogatory sense of replacing a desired product with another, often of inferior quality, has now become commonly used to refer to replacement of one good or use by another for one of a variety of reasons. Examples of these replacements affecting forest products, especially over the past half century or so, have been numerous and are becoming more frequent and often more rapid in their impact. Wooden sidewalks and wooden paving blocks have essentially disappeared and been replaced by cement or asphalt. Wooden shingles have given way to asphalt or asbestos roofing tiles. Fuelwood in more advanced economies is replaced by other fuels for normal heating and cooking although wood for fireplaces or charcoal cooking may be a luxury item. In other uses such as mining timbers, wall siding, panelling and flooring in building construction and furniture, wood continues to compete with other materials, sometimes paper products may have nearly replaced other materials, e.g. glass milk bottles, hemp sacks, but in turn are being replaced or combined in these uses with plastic products.

Among forest products, competition and substitution is continually taking place. Boxes made of lumber, except for special tasks such as packaging heavy machines, are nearly completely replaced by plywood boxes, veneer crates and paper and paperboard boxes, and these in turn are competing heavily with containers of plastic. Plywood, particle board and fibreboard have replaced sawnwood in many of its uses and now compete among themselves for these markets.

In some instances, replacement of a forest product may occur because the end product or service becomes obsolete or for some other reason gives way to an alternative product or service. For example, replacement of railway services by those of aircraft have adversely affected the volume of use of wood products.

Economic theory deals with substitute (and complementary) products by means of the concepts of maximizing utility, minimizing expenditures, diminishing marginal rate of substitution and cross-elasticity of demand, which may be expressed through the devices of utility and outlay indifference curves. Theory puts emphasis on the utility pattern of commodities used simultaneously, on relative levels of prices, and on the impact of changes in prices or income. Although this body of theory assists in understanding the interplay of forces, it has little possibility of application to forecasting.

Experience suggests that many actual cases of substitution related to forest products have come about through development of new competing products, or at least adaptation of products with different and superior characteristics and that price considerations are often less important than properties of the product. As most forest products are producers' goods they tend to be non-elastic with respect to price and the same is, of course, true of many of goods competing with forest products. Hence, cross-elasticity of demand in response to change in price may often be of secondary importance in explaining substitution.

The problem of dealing with substitution, when forecasting demand or consumption of a forest product, differ according to the phase of development in the competition between the commodity under study and the alternate products. It may be well to distinguish three phases:

(a) continuing competition between established products
(b) active initial replacement of one product by a new competitor with a former competitor that has a new and substantial advantage
(c) effective competition not yet under way, but prospective replacement from a potential new competitor is anticipated.

When two established products compete in the same market, changes in their relative consumption may result from relative price shifts which might be either of a short term and reversible nature or of a more permanent long term sort. If the competing commodities have the relationship of inferior and superior goods, then income change may be the factor bringing about consumption shifts.

In either of these cases the competitive or substitution aspects may be included in models developed from historic data by including the consumption of price of the competing material and income as variables related to the consumption of the product beign analysed. Corresponding price and income assumptions about the future are, of course, necessary in forecasting with these models.

McKillop (1967) has used both (a) current price of competing materials and (b) ratios of past prices of a competing material to the commodity being analysed, as variables in demand equations which were developed for several commodity groups. The results, although interesting, are not in all cases sufficiently convincing to argue that price effects have been important causes of substitution.

There are a number of reasons why this type of approach may not be adequate to deal with competition and substitution. As has been said, new competing products may have markedly preferable qualities to the traditional product and here price competition may not be most important. Consumption of the competing commodity may thus be a preferable variable.

A most obvious case of substitution occurs when a new or greatly improved product, or a product which, because of some technical or economic development, has become considerably cheaper, actually replaces a traditional produce in one or several uses. A specific example is the replacement of glass milk bottles by a variety of paperboard containers and these, in turn, by simple plastic sacs used in conjunction with a reusable rigid container. In the same category is the replacement of national advertising in newspapers by radio broadcasts which adversely and seriously affected newsprint consumption in the 1920's (Pringle 1954). Other examples of such replacements or shifts that have taken place are well documented in the USFS reporting on wood products used in single family houses and in a study of use of plastics in Finland (Runeberg 1967).

In such cases methodical problems may arise in forecasting. In many instances, there is clearly a maximum of replacement that can occur without further growth in the use itself. Thus, there is an initial increase and corresponding decrease in the consumption of the two competing commodities to new levels from which changes will continue in a more modest fashion. Any measurement of the rate of change in consumption during the period in which replacement is taking place is, therefore, dangerous to project without accounting for the level to which actual replacement is expected to take place. Otherwise, the traditional product may be projected to too low a level while the future consumption of the replacing commodity may be overestimated. Regression coefficients determined for a model derived from historical experience of competition between commodities must, thus, be subject to careful scrutiny prior to applying them to the future.

When replacement is still actively taking place at the time forecasts are made, for example because new products are replacing traditional ones or because of a continuing price decline in the new product or continued price increase in the one being replaced, subjective adjustments to, say, income elasticities may be made to allow for a levelling out of the impact. Such a device was used in a world outlook for panel products which applied, for future periods, successive reductions from the apparent income elasticity derived historically.

An even more difficult problem is to foresee new replacement which is just commencing or has not yet come into play. Here one must depend on some type of simulation model which presupposes conditions which may develop. These assumptions must, however, be based on background technical knowledge.

Major studies directed largely to competition between forest products and other commodities are very few. Some consideration is given to timber and to paper and paperboard products in a UN Economic Commission for Europe study although no forecasts are made. Plastics, as a material competing or combined with forest products, were examined with emphasis on Finland by Runeberg (1967) who made time trend projections to 1975 for consumption of plastics used in conjunction with timber paper and paperboard.

A most interesting methodology was developed by Steenberg et al (1969) in a study where several forest products including a number of paperboard, hardboard, plywood and sawnwood were considered in their competition with a number of other materials, e.g. plastics, glass, aluminium and steel plate in their use for rigid packaging. The stiffness quality range of the material was related to its relative price per unit area. On this basis the forest product and especially corrugated boards showed as being generally the cheapest for a given stiffness range. Other analyses were made in a similar fashion. The price per unit volume of containers actually on the market were related to the container size. The weight of the material which might affect shipping costs was examined in relation to stiffness quality. Finally, relative price per unit area was compared to stiffness over density. In all cases, the forest products and especially corrugated board gave performance superior to their competitors in the appropriate range.

The study could not take into account the possibilities of obtaining rigidity through tension as in shrink plastic containers or by combining reusable rigid containers in conjunction with disposable liners. Nevertheless, studies such as this do much to explain the technical factors affecting the structure and shifts of consumption patterns.

In summary, substitution problems relate to forecasting of demand and consumption in a number of ways and may be dealt with varying facility according to their nature:

(a) when established products compete, allowance may be readily made for substitution in forecasting models by introducing as variable price or consumption of the commodities which compete with that being studied. When the competing products comprise superior and inferior goods, income, normally included as an independent variable, may explain some substitution.

(b) When replacement of a traditional product by a new product or by a product made less costly by technical or economic developments, special devices, possibly of a subjective nature, must be used to allow for the limits of replacement and to estimate consumption during the return to a more balanced competition.

(c) For useful forecasting, some form of simulation model is necessary to allow for substitution which may be foreseen but which cannot be based on historic econometric data. Here technical analyses are especially useful.

CONCLUSIONS

1. Forecasting plays an ever increasing role in forestry and in the timber economy, and literature dealing with forecasting now occupies an important position in forest economics.
2. Methodology in forecasting has made considerable progress since the beginning of the 1950s. This is largely due to advances made in the field of general economics and particularly in econometrics. Forest economics itself, however, has also contributed to the development of forecasting techniques suited to its particular problems.
3. Despite the advances made, there are a number of problems which deserve attention in the future. One of them is confusion in terminology. Further efforts are required to develop a consistent structure of concepts and definitions which will serve to minimize misunderstanding of research results in the field.
4. Thus far research work has been concentrated mainly on forecasts dealing with the demand side of the timber economy. Greater efforts in both supply and demand forecasting are needed as a basis for investment decisions, for land-use allocations, and for other long-term policy purposes.
5. In the field of demand forecasting a number of problems remain to be studied, among which are: the validity of saturation theory, the nature of demand functions, more precise and inclusive specification of variables other than income and population in the demand model, the influence of wood substitutes, and the development of methods for appraising the probable accuracy of forecasts.
6. It is important to bear in mind that timber-trend studies conducted and published by national and international organizations have greatly improved information among governments, producers, etc. regarding trends in the various sections of forestry and the timber economy. A producer of pulp and paper, for instance, has from these sources far better information concerning the development of consumption as a basis for his investment decisions than existed 20 years ago. Information has become more generally available. Therefore it can be expected that publication of a forecast will have some general influence on public and private investments.
7. Long-term forecasts are based on many uncertainties (including "uncontrolled" changes in technology). Therefore it is important to repeat timber-trend studies at fairly frequent intervals.

APPENDIX

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