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FOLIA FORESTALIA 124

METSÄNTUTKIMUSLAITOS · INSTITUTUM FORESTALE FENNIAE · HELSINKI 1971

MARKKU SIMULA

AN ECONOMETRIC MODEL OF THE SALES OF PRINTING AND WRITING PAPER

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FOLIA FORESTALIA 124

Metsäntutkimuslaitos. Institutum Forestale Fenniae. Helsinki 1971

Markku Simula

AN ECONOMETRIC MODEL OF THE SALES OF PRINTING AND WRITING PAPER

PREFACE

One of the basic tasks of forest economics is the determination and forecasting of timber supply and demand while attempting to determine the forest-policy means by which a demand-supply balance can be ensured. The emphasis in Finland has so far been on the supply sector. In order to reduce the shortcomings in the determination of demand, the Forest Research Institute, Forest Economics Department, in the summer of 1967 decided to start work on studying the domestic use of the end products of the wood-working industry. In addition to end-use statistics, it was considered to be useful to acquire experience of and information on the suitability of various forecasting methods for analyzing the use of wood-based end products. The present paper is a part of this latter effort.

In the last twenty years, studies of the demand for paper have been carried out mainly by international organizations. The factors used to explain the consumption of paper have been population, income level, literacy, etc. Among the best of these studies, as regards both the theoretical basis and the findings, was the WORLD DEMAND FOR PAPER TO 1975 published by FAO (1960). The study was a cross-section analysis covering the whole world, with national income as the only independent variable. Special attention was devoted to the selection of the form of the functions and the results of the correlation analysis. This FAO study, and the time-series analysis of newsprint sales by RIIHINEN (1962a), provided the greatest incentive for the present paper.

The paper was presented as part of the *pro gradu* examination for a Master of Forestry degree. The work was carried out under the supervision of Prof. Seppo ERVASTI. Prof. Päiviö RIIHINEN perused the manuscript and gave assistance and instructions. I am indebted to them, and to Mr. SIMULA's co-worker, Mr. Olli SAASTAMOINEN, for his support during the course of the project.

Helsinki 1971.

Lauri Heikinheimo

Forest Economics Department

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TIIVISTELMÄ

Tämän tutkimuksen tarkoituksena on ekonometrisen mallin avulla kvantitatiivisesti kuvata paino- ja kirjoituspaperin myyntiin vaikuttavia tekijöitä. Tarkastelun kohteena on paino- ja kirjoituspaperin myynti Suomessa ajanjaksona 1950–1966.

Paino- ja kirjoituspaperi on graafisen ja paperinjalostusteollisuuden raaka-aine; siitä valmistetaan aikakauslehtiä, kirjoja, muita painotuotteita sekä paperinjalosteita. Näillä lopputuotteilla ei ole varsinaisia substituutteja eräitä poikkeuksia lukuunottamatta.

Paino- ja kirjoituspaperin kysyntäfunktion määrittämiseksi tutkittiin siitä valmistettujen tuotteiden kysyntää. Aikakauslehtien kysyntäkäyrä oletettiin verraten joustamattomaksi kuluttajien tulotason muutosten suhteen. Ne heijastuvat levikin määrän ja ilmoitustilan käytön muutoksina.

Kirjojen kysyntä määräytyy edellisestä yksinkertaisemmin, koska niiden osto on ainutkertainen tapahtuma ja suoritettavan kertaoston arvo on yleensä kuluttajan käytettävissä oleviin tuloihin nähden vähäinen. Muut painotuotteet ovat yleensä ilmaishyödykkeitä, joiden kysyntään kuluttaja ei suoranaisesti vaikuta. Muut paperinjalosteet ovat tyypillisiä kertakulutushyödykkeitä, joiden kysyntä voidaan luokitella samantyyppiseksi kirjojen ja aikakauslehtien kanssa.

Paino- ja kirjoituspaperin ostopäätöksiin vaikuttavia tekijöitä analysoitiin käyttäjäryhmittäin. Niiden kustannus- ja tuottorakenteesta ei kuitenkaan ollut saatavissa riittävästi tietoja, joten tarkastelun lähtökohdaksi otettiin paperia käyttävän teollisuuden asiakkaiden, so. kuluttajien talous. Menettely oli perusteltua lisäksi sen vuoksi, ettei eri käyttäjäryhmien päätöksenteon rakenteessa havaittu olennaisia eroja. Lisäksi voitiin olettaa, että kuluttajien talouden pohjalta päästään parhaisiin tuloksiin.

Päätöksenteossa vallitsevat aikaviiveet osoittautuivat moniselitteisiksi, joten kokeiluja suoritettiin sekä viivästymättömillä että viivästyneillä malleilla.

Logaritmista funktiomuotoa käytettiin kuvaamaan mallin muuttujien välisiä riippuvuussuhteita. Muuttujien valinnassa oli rajoittavana tekijänä käyttökelpoisten havaintosarjojen vähälukuisuus, joten malli jouduttiin muodostamaan vain kolmea selittävää muuttujaa, tulotasoa, paperin hintaa ja suhdannekehitystä, käyttäen.

Kokeilut eri malleilla osoittivat, ettei aikaviiveiden sisällyttäminen parantanut mallin selittävyyttä, jota arvosteltiin yhteiskorrelaatiokertoimen ja selitysvirheen hajonnan suuruudella. Myöskään muuttujien transformoiminen ei vaikuttanut mallin selvityskykyyn parantavasti. Parhaaksi todetussa mallissa selittävinä muuttujina olivat vain tulosaso ja suhdannekehitys, koska paperin hinnan sisällyttäminen heikensi selittävyyttä.

Parametriestimaatein perusteella voitiin olettaa, että paino- ja kirjoituspaperin tulojousto on 1.7–2.0 ja hintajousto ~ 0. Muihin tutkimusten tuloksiin verraten tulokset osoittautuivat varsin yhdenmukaisiksi.

Parhaimmaksi katsotuille malleille suoritettiin vielä jäännöstermianalyysi. Testauksen tuloksen perusteella voitiin olettaa, ettei ole olemassa selityskykyä parantavia muuttujia, koska jäännöstermit sisälsivät vain satunnaisvaihtelua. Analyysin perusteella tehdyt olettamukset eivät aina ole yksiselitteisiä, koska eri menetelmät voivat antaa samasta aineistosta erilaisen lopputuloksen.

Mallin taustana olevan teorian sisältämien hypoteesien oikeutuksesta ei suoritettu analyysi antanut viitteitä. Eri tekijöiden vaikutussuhteiden suunta ja suuruus voidaan helposti asettaa kyseenalaiseksi. Paino- ja kirjoituspaperia käyttävän teollisuuden päätöksentekoon vaikuttavien tekijöiden poikkeavuus esitetystä teoriasta ei kuitenkaan aiheuta tutkimusongelman käsittelyyn olennaisia muutoksia, koska malli muodostettiin kuluttajien talouteen perustuen.

0. SUMMARY

The purpose of this study was to describe quantitatively the factors influencing the sales of printing and writing paper by the means of an econometric model. The study was concerned with the sales of printing and writing paper in Finland for the period of 1950–1966.

Printing and writing paper is the raw material for the printing and coverting industries; the end products may be periodicals, books, other printing products and converted paper products. They have no real substitutes.

Determining the demand function for printing and writing paper requires an examination of the demand for commodities made thereof.

The demand curve for periodicals was assumed to be relatively inelastic with respect to changes in the consumer's income level. This is reflected in increased circulation and use of advertising space.

The demand for books is determined more simply since they involve one-time purchase decisions and the value of each purchase is often relatively small compared to the consumer's disposable income. Other printing products are usually free of charge and the consumer has no direct influence on the demand. Converted products are generally disposable commodities with demand comparable to that for books and periodicals.

Factors having an effect on purchasing decisions of printing and writing paper were analyzed by user industries. However, no information was available on their cost and yield structure so that consumers, the customers of these industries, were taken as the basis for modeling. This procedure was accepted also for the reason that the user industries were analogous as to their decision-making process. Previous studies also supported the contention that using consumers as the basis of models produces the best models.

Time lags in decision-making have many possible interpretations so that models both with and without lags were tested.

Logarithmic functioning was used for describing relationships between variables in the models. The limiting factor in selecting the variables was the small amount of applicable data; the final models formed consisted of only three explanatory variables: level of income, price of paper and economic trends.

Tests with various models showed that the inclusion of time lags did not improve the degree of determination in a model. Nor did transformation of the variables improve the models. In the best model, the explanatory variables were level of income and economic trends, since inclusion of paper price reduced the degree of determination.

Income elasticity of printing and writing paper was assumed to be 1.7–2.0 and price elasticity to be 0 on the basis of parameter estimates. The results agreed quite well with other studies in this field.

Residual-term analysis was carried out for the best models. It could be assumed from these tests that there were no other variables which would improve the degree of determination since the residual terms contained only random variation. However, assumptions based on this analysis are not clearcut because other methods can produce different results from the same material.

The analysis did not provide any indications as to the validity of the assumptions underlying the model theory. The direction and importance of relationships between factors can easily be regarded as uncertain. However, differences between the theory set forth and the actual decision-making process in industries using printing and writing paper does not require basic changes in the method of studying the problem since the model was based on consumers.

1. INTRODUCTION

The purpose of this study is to describe quantitatively, by means of an econometric model, the factors influencing the sales of printing and writing paper. The study is concerned with the sales of printing and writing paper in Finland for the period 1950–1966.

The phases of the econometric analysis used here are developing the underlying theory of the model, forming the model, estimating the parameters, testing the model, and generalizing from the results (cf. NIITAMO 1966, p. 61). By using econometric analysis, the simultaneous influence of several factors on the dependent variable can be studied. At the same time, the systematic and random components of the phenomenon under examination can be established.

The selection of variables is preceded by a description of the basic features of printing- and writing-paper markets, an indispensable step in the development of the underlying theory of the model and in the selection of hypotheses. The heterogeneous products made from printing and writing paper necessitate a delineation of subdivisions when analyzing the factors influencing purchasing decisions and the associated time lags in the paper market.

After selecting the form of the function, various combinations of variables are tested with hypotheses of time lags between the variables. Regression analysis is used to explain the extent and nature of relationships between the variables. The method of least squares is used to calculate the parameter estimates, which, for the function adopted, minimize the sum of the squares of deviations of the observations from the values calculated from the model. The validity of the models is established from their degree of determination measured by a multiple correlation coefficient and the standard error. The best models are subjected to a residual-term analysis, which is used to determine whether there are any independent variables whose influence is not included in the model. The final phase is generalizing the results.

The sales of printing and writing paper in Finland contain five sub-groups:

1. Sales by the Finnish Paper Mills' Association (Finpap)
2. Sales by paper mills direct to customers
3. Local sales by paper mills (mainly to employees)
4. Domestic sales by Tervakoski Oy
5. Imports

The bulk of the study material consisted of Finpap's statistics on domestic paper sales. The material comprised annual total sales for 1950–1966 and was based on invoices for individual deliveries.

Figures for direct sales had to be collected by inquiries from the paper mills. The mills were asked for data on the quantities of printing and writing paper invoiced directly to the customers annually. No reliable data could be obtained for the local sales, which therefore were excluded from the study. From interviews with the mills' sales managers, local sales may be considered to have been so small (less than 0.1 % of domestic sales) that their exclusion does not lessen the reliability of the results. Tervakoski Oy is not a member of the Finnish Paper Mills' Association; therefore its domestic sales had to be studied separately. The fifth sales component, imports, was determined from the foreign trade statistics for the years in question.

2. SALES OF PRINTING AND WRITING PAPER

21. Supply of and demand for printing and writing paper

It is a characteristic of the Finnish paper industry that there are relatively few production plants. The reason is that paper-making is most profitable in large, vertically integrated plants, which can make the best use of recent technical discoveries and employ a sufficient number of technically trained personel (HOLOPAINEN 1957, p. 33). The small number of mills would lead to oligopolistic market features if the products were not mainly marketed by a single sales organization, the Finnish Paper Mills' Association, which is similar in working form to a cartel. Some of the paper on the market, however, is sold by the mills themselves. The Finpap co-operation agreement is only concerned with the prices and quality standards of printing and writing papers. Hence, the mills are relatively free to use quality, branded products, advertising, ect., as means of competition.

The price of newsprint is decided annually by negotiations between the Newspaper Association and Finpap; buyers of printing and writing paper have no corresponding co-operation. Since Finpap usually confirms the prices for a year at a time, the short-term supply curve is horizontal. It indicates the price at which the seller is prepared to meet domestic demand. However, if the association raises the price too much it will be more favourable for the buyers to obtain their raw material from abroad. So far, however, this has not happened and imports have amounted to less than one half of one per cent of total domestic consumption.

Printing and writing paper is the raw material for the printing and converting industries; the end products may be periodicals, books, other printing products, and converted paper products. These products have no real substitutes since the press, radio and television cannot be assumed to replace them directly.

The complementary production items to printing and writing paper are printing ink, labour, etc. An analysis of their effects, however, is not possible since information is unavailable concerning the cost structure in the printing and paper-converting industry.

Determining the demand function for printing and writing paper requires an examination of the demand for commodities made thereof. Both books and periodicials satisfy intellectual and spiritual needs. But as consumer goods, their purchase rests on initiative by the reader, which is linked individually and actively to the price. The price holds demand to a level that the available production factors can, or are calculated to be able to, satisfy.

Periodicals are a relatively heterogeneous group in terms of size, frequency of publication, and purposes. A considerable number are distributed free of charge, while others have a limited circulation (e.g. professional and organizational magazines). Subscriptions to periodicals constitute such a small share of the consumers' total expenses that a price increase cannot easily stop him from subscribing to or buying a copy of his particular periodical. A sufficiently high price rise would probably only limit the number of periodicals subscribed to or bought. It may be assumed, therefore, that the demand curve for periodicals is relatively inelastic and shifts with changes in the consumer's income level. This is reflected in increased circulation and use of advertising space. Changes in the prices of printing and writing papers may affect periodical prices; the publishers, however, can transfer some of the increased costs to the price of advertising space.

The demand for books is determined more simply since they involve one-time purchase decisions and the value of each purchase is often relatively small compared to the consumer's disposable income. Other printing products are usually free of charge, and the consumer has no direct influence on the demand. Converted products are generally disposable commodities with demand comparable to that for books and periodicals.

In 1964, the consumption of printing and writing paper was distributed among the different products groups as follows (SAASTAMOINEN 1968, p. 15):

Books	9.3 %
Periodicals	29.1 %
Other printing products	40.4 %
Converted paper products	21.2 %
Total	100.0 %

22. The decision-making process in purchasing printing and writing paper

Decision-making is a choice between alternatives; in this case the alternatives are the quantities of printing and writing paper to be bought. Each end-product group is examined separately since different factors influence decisions about buying paper for different purposes.

Fig. 1 shows most of the factors affecting the purchasing decisions of printing and writing paper used to print periodicals. Printing houses and publishers have not been separated since they are often combined or co-operate closely. The cost of printing includes the actual printing cost, administrative and editorial expenses, interest, and depreciation on capital. Text is the number of pages in the periodical excluding advertisements. The standard of the contents is implicit in the circulation. The arrows of the diagram illustrate the assumed directions of factor effects. The significance of the listed factors in the decision-making process varies, with not all factors being important. On the other hand, several factors which are difficult to measure, or are completely unmeasurable, have been excluded or are only included implicitly.

The factors affecting the purchasing decisions of paper for printing books are, with due modifications, the same as in Fig. 1. An essential difference in book printing is the absence of factors arising from advertising;

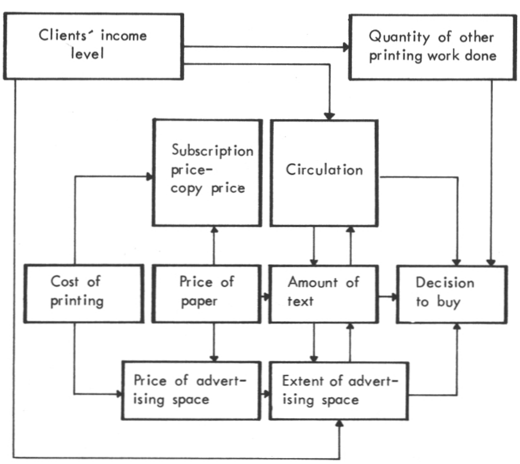

Fig. 1. Factors affecting the purchasing decisions of printing and writing paper for periodicals.

otherwise the diagram has an analogous structure.

The factors affecting the purchasing decisions of the graphic industry producing "other printing products", are also analogous to those shown in Fig. 1. Other printing products includes handbills, brochures, annual reports, calenders, preprinted forms, etc.

Converted paper manufacturing also requires printing and writing paper as raw material. The end products are writing pads, envelopes, copy books, various note pads, etc.

The relevance of the decision-making model can be easily criticized since it is based almost exclusively on theoretical assumptions. The choice of factors (and their names) can also be debated.

It is also possible to dispute whether construction of a decision-making model for a whole branch of manufacturing is at all relevant. Being a continuous activity, the decision-making process in enterprises converts the available information into decisions which guide the processes. The decision maker (enterprise) recognizes the factors on which his decision rests. However, cognizance of the role of each information source is not necessarily presupposed, and the structure of the decision-making process remains unrecognized. In spite of this, the decisions made are very similar since the content of the information is the same. Decision-making contains a great deal of random variation but also always a certain amount of permanence and logic. This is how representing a particular decision situation by a decision-making model for all enterprises of a branch can be justified.

The model in Fig. 1 disregarded the relative importance of the different factors and the time lags associated with them. If profit maximization is assumed to be the primary target of the printing and other-paper-products industry, the factors of greatest importance in regulating the total costs and returns are those that most affect the decisions on buying printing and writing paper. The model for analyzing time lags in the decision-making process is simplified when assuming that the quantity of paper used in industry depends in the main only on the returns obtained for each period and the associated expectations.

Since, with due modifications, the structure of decision-making concerning the paper purchases for newspapers and periodicals can be assumed to be analoguous, the analysis by

RIIHINEN (1962, pp. 22–24) is used here as a basis. Being aware of the price of paper, the publisher can directly influence the price of advertising space and the copy price of his products. But the subscription price must be determined in the preceding year; hence, any change in paper price cannot be compensated for in subscription prices until the following year. Advertising volume is determined by purchasing power at any given moment, and therefore the advertising space bought is affected by the income level at that point in time. The indices illustrating the use of advertising space are generally considered to be the most sensitive indicators of economic fluctuations. Changes in income level can affect circulation either directly (sales of single copies) or with a year lag (subscriptions). Subscriptions are usually made on the basis of the income level of the past year with certain expectations concerning the coming year; an annual subscription is payable either at the end of one year or beginning of the next. These factors are illustrated in Fig. 2. The broken arrow indicates an effect that cannot be verbally described. The time lag between annual advertising income and paper purchases can easily be criticized. The information supplied in the figure has, however, been limited by excluding the variable with no time lag (either R_{A_t}, A_t or π_t) from between these variables.

The study of time lags associated with purchasing decisions for printing and writing paper in the production of books, other printing products and converted paper products is facilitated by Fig. 3.

Book sales cannot be distinctly related to the income level with a year time lag since the purchase of a book is a unique, passing event which usually does not require advance planning. However, the income of one year can be assumed to affect the consumption plans of the year following. Nor is a one-year time lag between paper and book prices self-evident, although it appears natural when considering the duration of the manufacturing process and the production planning of printers. Being aware of the price of paper, the publisher can, under normal circumstances, adjust the prices

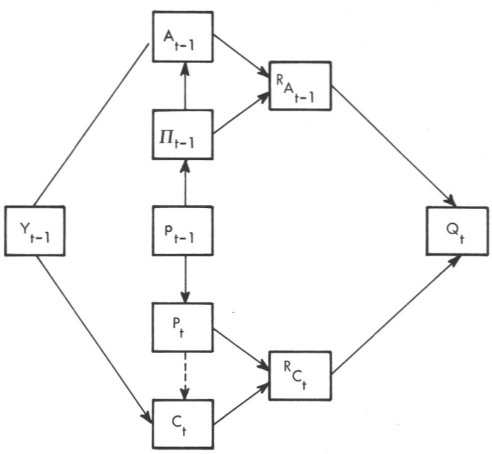

Fig. 2. Time lags between elements of the purchasing decisions for printing and writing paper in the publishing of periodicals (cf. RIIHINEN 1962, p. 73).

Y_{t-1} = income level of subscribers, advertizers and other lients in year t-1

A_{t-1} = use of advertizing space in year t-1

π_{t-1} = mean unit price of advertizing space in year t-1

P_{t-1} = price of paper in year t-1

p_t = mean subscription rate in year t

C_t = circulation in year t

$R_{A_{t-1}}$ = advertizing revenue in year t-1

R_{C_t} = revenue from subscription and sales in year t

Q_t = quantity of printing and writing paper sold in year t

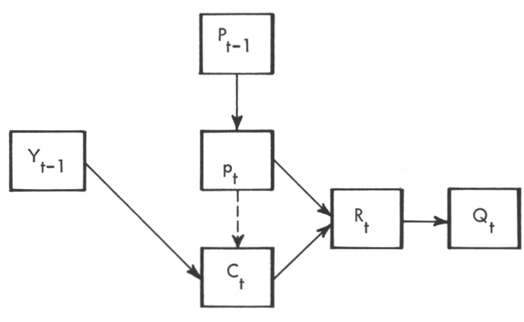

Fig. 3. Time lags between elements of the purchasing decisions for printing and writing paper in the production of books and other printing products.

R_t = revenue from the sale of products in year t

p_t = mean unit price of the product in year t

C_t = quantity sold in year t

of the books he sells and therefore the time lag may be assumed not to exist.

For the sale of other printing products, time lags may be assumed not to exist in any of the variables. The production process is short and the price is separately determined for almost every order. A parital time lag may exist between income level and the price of the final products since those ordering printing products may take into account the income level of the preceding year when they make the purchase decision.

The time lags in the sale of other converted printing- and writing-paper products are also unclear. Consumption plans may cause a partial one-year time lag between income level and quantity. On the other hand, the production process is too short to produce a time lag between the prices of paper and the converted products.

The most appropriate method of producing an econometric model for the sale of printing and writing paper would be to review each end-product group separately. Their combination would then lead to an estimate of total sales. This model, in principle, would serve to forecast the sales quantity in the short run, but there are two restrictions which make the procedure impossible. First, the proportions of the various end-product groups in total sales cannot be reliably determined. Second, the data obtainable on the variables explaining use by the different groups is insufficient.

A basis comparable to the total-sales models is the economic standing of the customers (advertisers, subscribers and buyers). A model based on this can be justified by recalling that the subject represents typically derived demand and that the majority of the end products made from printing and writing paper are commodities of the same type (Chapter 1). Earlier studies have also shown that models based on customers' economic standing are the best indicators of the sales of cultural papers (RIIHINEN 1962, pp. 45—54).

Owing to the ambiguity of the models it will be necessary to review separately the models with and without time lags.

3. FORMATION OF THE MODEL

31. Mathematical form

The last phase of model formation is the specification of the assumptions concerning the quantitative relationships between variables by means of functions and the characterization of these relationships by parameters.

The use of a first-degree linear function presupposes that the mutual relationships of the model are additive:

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_n x_n + u$$

In economic phenomena, however, additiveness is unusual, and it is therefore necessary in most cases to have recourse to a logarithmic linear function:

$$y = \alpha_0 \cdot x_1^{\alpha 1} \cdot x_2^{\alpha 2} \cdots x_n^{\alpha n} \cdot u \quad \text{or}$$

$$\log y = \log \alpha_0 + \alpha_1 \log x_1 + \alpha_2 \log x_2 + \cdots + \alpha_n \log x_n + \log u$$

The relationships between the variables in the model are then assumed to be multiplicative.

Application of an exponential function to the analysis of the sales of printing and writing paper is justified because of the fact that when the income level becomes sufficiently high consumption reaches the saturation point. But sales are not reduced since the consumers, for the time being at least, have no commodity available to substitute for printing and writing paper.

32. Variables

Series of empirical observations concerning the variables of the model are required for statistical analysis. An economic study must often accept substitute variables in the analytical phase if adequate information on the actual variables is not available. However, the most important thing is not always how the content of the substitute variable agrees with that of the thing to be described, but how well the substitute is able to explain the dependent variable. The observation values of the variables in this study are index figures since they are commensurate. Another advantage is that index figures illustrate the relative changes taking place.

Components of the sales of printing and writing paper were described in Chapter 1. The variable Q indicates the quantity, in kilogrammes, of printing and writing paper sold per capita, with only persons having reached 15 years of age being included. This allows for changes in population numbers; no separate variable to describe them need be included in the model.

Net national product in 1954 prices has been used as Y, the variable for income level calculated per capita in the same way as Q.

The variable P, indicating the price of printing and writing paper, refers to the weighted mean price per kilogramme for the whole product group.

The explanatory capacity of the model was improved by excluding the nominal value of the varaibles in terms of money, income level and paper price; these were deflated. In this way it was not necessary to include a separate variable to indicate progressive inflation. Nor was there any need to assume that the change in purchasing power had remained constant during the period. The deflator used was the price index of the net national product, obtained by dividing the annual net national product at production-cost prices by the net national product of the base year. Even at their best, however, these figures, which are designed to indicate changes in real income and real prices, provide only a very superficial idea of the time variations in the possibilities the population has of satisfying its needs. But no better means are available for achieving this (cf. TAMMINEN 1967, p. 157).

The third independent variable, the trend variable B, was by selected using the overall index of export volume as the series of observations. The observation values were obtained by the trend-ratio method, dividing the index values by the trend values of the corresponding years calculated from the equation:

$$y = 8.512\,x + 131.706$$

It would have been justifiable to include in the model certain other exogenous variables, e.g. those measuring literacy and other education. Literacy has, however, remained at much the same level during the period and would therefore have increased the degree of determination of the model very little. No comparable observations were available concerning the development of other education and so this had to be excluded from the study. It may be assumed, however, that variables for income level and other education contain a quite similar variation.

Accordingly, the variables representing this series of observations can be classified as follows. The data for these variables is shown in the appended tables I—IV. The period of measurement used has been one year.

Variable	Interpretation	Position in model
Q	– quantity of printing and writing paper sold per capita	– dependent endogenous without time lag
Y	– income per capita in 1954 prices	– independent exogenous with/without time lag
P	– mean price per kg of printing and writing paper	– dependent endogenous with/without time lag
B	– economic development	– independent exogenous without time lag

4. ESTIMATION OF PARAMETERS, INTERPRETATION AND VALIDITY OF THE MODEL

41. Method of estimating

The alternatives for estimating the parameters of the model in this case are the least-squares method, the maximum-likelihood method and variance analysis. Under certain conditions, the first two are equally applicable, but general theoretical considerations make the maximum-likelihood method the best alternative. The present study, however, used the least-squares regression analysis, which is simpler to calculate. According to STONE (1951, p. 67), its application to time-series data presupposes that it meets conditions such as the following:

1. The residual term (u) must have a normal distribution with mean values $\bar{u} \sim 0$, and s^2 must be constant when the autocorrelation coefficient is ~ 0; otherwise the normal significance tests are not valid.
2. The independent variables must contain no observation error; if they do, the residual term can be interpreted as measuring the error of the independent variable or as being the effect of excluded variables.

The problems connected with the use of the least-squares method have been divided by WOLD (1952, pp. 28–52) into the following main groups:

1. Selection of the mathematical form of the model (discussed here in Section 31)
2. Selection of the variables (Section 32)
3. Bias produced by observation errors (Section 32)
4. Significance tests (Section 43)
5. Multicollinearity (Section 42)
6. Problems arising from simultaneous relationships. The least-squares method is unbiased if applied to one relationship. When there are several relationships, the potential bias increases.

According to KLEIN (1962, p. 181) it can be concluded that, with narrowly defined markets, short time intervals and well-specified variables, the method of least squares usually has the best possibility of yielding unbiased results in a single-equation model.

42. Multicollinearity

In studying the characteristics of parameter estimates, it is necessary to make sure that the coefficient values are correct and describe the true relationships in the population. One way of approaching this problem is to examine the multicollinearity between variables; that is to say, the mutual linear correlation of independent variables. Multicollinearity is obvious if the paired correlation coefficients between variables, the measures of the extent of correlation, are strong. In such a case, parameter values are arbitrary and the role of the various variables in the determination cannot be specified. But if there is not strong correlation, the coefficient values can be assumed to be correct in terms of significance.

The method used for studying multicollinearity is the correlation matrix, which shows the paired correlation coefficients between all the variables of the model.

A frequently used method which attempts to reduce multicollinearity is transformation of the original observations. In the present study, the transformed variables used were the ratios between successive observation values:

$$\Delta \log x_t = \log \frac{x_t}{x_{t-1}}$$

43. Testing the reliability of parameters

The reliability of the estimated parameter values was tested by the t-test, which tells whether a parameter value differs significantly from zero. The test variable t is obtained from the formula (MENGES 1961, p. 201):

$$t = \frac{A_i - \bar{A}_i}{a_i}$$

A_i = estimate of the parameter to be tested
$\bar{A}_i$ = hypothetical value of the parameter (= 0)
a_i = standard error of the parameter estimate

$$a_i = \frac{s_y^2}{(x_i - \bar{x}_i)^2}$$

s_y^2 = variance of the dependent variable
x_i = the variable with parameter-value a_i
$\bar{x}_i$ = mean value of x_i

The test variable t has been tabulated for various degrees of freedom and various confidence levels. The degrees of freedom of the t-test refer to the differences between the number of observations and the number of parameters in the equation studies.

44. Validity of the model

The validity of the model is in the main decided by its intended use, the original goals for which the model was formed. It is then possible to determine the empirical validity by the following methods (NIITAMO 1966, p. 9):

- how well the model explains events,
- how effective the model is for forecasting events,
- in what way the model helps to affect events.

However, it is difficult to distinguish between these approaches since they are closely interconnected. If the purpose of the model is to describe the conditions related to the time and place of the study, its validity can be measured by means of one or more of the following statistical parameters (cf. FERBER—VERDOORN 1962, p. 100):

1. The correlation coefficient measures the extent of correlation between the model and the observations. It is an abstract measure, unrelated to the units used. Regressions can be compared by means of the correlation coefficient.

2. The standard deviation measures the deviations between the observations and the regression model. A low deviation indicates a high degree of determination for the observation material.

3. The ratios of parameter estimates to standard errors indicate the significance of the influence of each independent variable in the model. The beta coefficients also measure the relative importance of the variables.

4. The partial correlation coefficients measure not only the net effects of the independent variables but also their multicollinearity.

5. In the case of time-series studies, the presence of serial correlation indicates that certain regularities remain in the unexplained variable (cf. autocorrelation). There are, therefore, variables which would improve the degree of determination of the model. On the other hand, absence of serial correlation in the residuals does not necessarily indicate that variables of this type do not exist.

The correlation coefficient in the present study has been calculated, with the aid of the residual variance (s_j^2) and the original variance (s_i^2) of the dependent variable, from the formula (EZEKIEL 1950, p. 136):

$$R = \sqrt{1 - \frac{s_j^2}{s_i^2}}$$

When the value of R is high, the degree of determination of the model is great. The F-test is used to measure the significance of this degree of determination. The F-values are obtained by dividing the variance of the regression equation by the residual variance. The theoretical F-values have been tabulated according to the degrees of freedom of the variances at the different confidence levels.

If the primary purpose of the model is forecasting, the above criteria can still be successfully used. However, the validity of the model is ultimately decided by the error in extrapolation. It may be said that the multicollinearity between independent variables need not be taken into account, since the intention therewith is not to explain the structure of the phenomenon studied, i.e. the part played by the various factors.

This thinking, however, cannot be accepted straightfowardly since the periods for observation and forecasting can be selected arbitrarily. If the model in a given period produces a good result, this does not mean that it will do so at other times as well, especially if the conditions have changed.

Given these difficulties with the validity criteria, created by the overlapping targets of the model, the *a priori* non-statistical hypotheses underlying a function assume dominant importance. From a statistical point of view, the significance of partial correlations and of regression coefficients as the basis of judgement becomes more important than the actual magnitude. It should be borne in mind that correlation measures only association and not causation. Lack of correlation does not necessarily indicate lack of causation; an underlying relationship between two variables may be camouflaged by the interactions of the pertinent variables. If correlation is indicated, proof of causation must depend on *a priori* considerations and not on the correlation itself (FERBER & VERDOORN 1952. pp. 100—101).

51. Models without time lag

To specify relationships between variables, the function form selected was:

$$y = \alpha_0 \cdot x_1^{\alpha 1} \cdot x_2^{\alpha 2} \dots$$

with the logarithmic function being

$$\log y = \log \alpha_0 + \alpha_1 \log x_1 + \alpha_2 \log x_2 + \cdots$$

Owing to the numerous potential interpretations of time lags, models of two types were studied. In the first, all variables were without time lag; in the second the variable describing income level had a one-year time lag (models both with and without time lag).

When the parameters of the model were estimated by the least-squares method, the following values were obtained: [1]

$\log Q_t =$
$.059 + 2.029 \log Y_t + .058 \log P_t - .441 \log B_t$

standard error			
.037	.187	.218	.201
t-value			
1.596	10.843	.265	–2.195

Q_t = quantity of printing and writing paper produced in Finland and sold in year t per capita (at least 15 years old)

Y_t = real national product in year t per capita (at least 15 years old)

P_t = mean price per kg of printing and writing paper in year t

B_t = trend variable: the general index of export volume divided by the corresponding trend value

The standard errors (s), correlation coefficients (R) and degrees of freedom (ø) of the regression equation were:

s = .056 R = .986 ø = 13

When the confidence limits of the parameters were tested with the t-test, the parameter estimate of the income level was found to differ significantly from zero with a probability of P = .01 and that of the trend variable with a probability of P = .10. The parameter estimate for paper price acquired no significant value at all.

1. The base of the logarithmic system used was Neper's e.

Table 1. Correlation matrix for the variables in Model I.

Variable	$\log Q_t$	$\log Y_t$	$\log P_t$	$\log B_t$
$\log Q_t$	1.000	.981	–.820	–.140
$\log Y_t$		1.000	–.858	–.034
$\log P_t$			1.000	–.106
$\log B_t$				1.000

Table 1 presents the correlation matrix of the model variables. As can be seen from this table, the income level and paper price contain significant and similar variation.

Furthermore, it can be determined from the correlation matrix that the trend variable and paper price contain a higher degree of similar variation than the trend variable and income level. The reason is, apparently, that the domestic sales price of paper is partly determined by export prices, which directly affect the export volume and hence the trend developments.

The high value (.986) of the correlation coefficient testing the degree of determination of the model is accounted for by the trend, typical of time-series analysis, contained in Q, Y and P. The correlation coefficient, on testing, proved to differ significantly from zero.

Since the parameter estimate of paper price did not significantly differ from zero, another model was formed with the income level and trend variable as the only independent variables:

Model II

$\log Q_t = .065 + 1.986 \log Y_t - .455 \log B_t$

standard error			
	.027	.090	.187
t-value	2.452	22.037	– 2.430

s = 0.54 R = .986 ø = 14

Testing showed that the parameter estimates differed significantly from zero. The deviation of the regression equation was 0.02 units smaller in Model II than in Model I. The correlation between independent variables is only –.034; there is no multicollinearity. Moreover, since the correlation coefficients are equal and the degrees of freedom are one more, it may be concluded that Model II has a higher degree of determination than Model I.

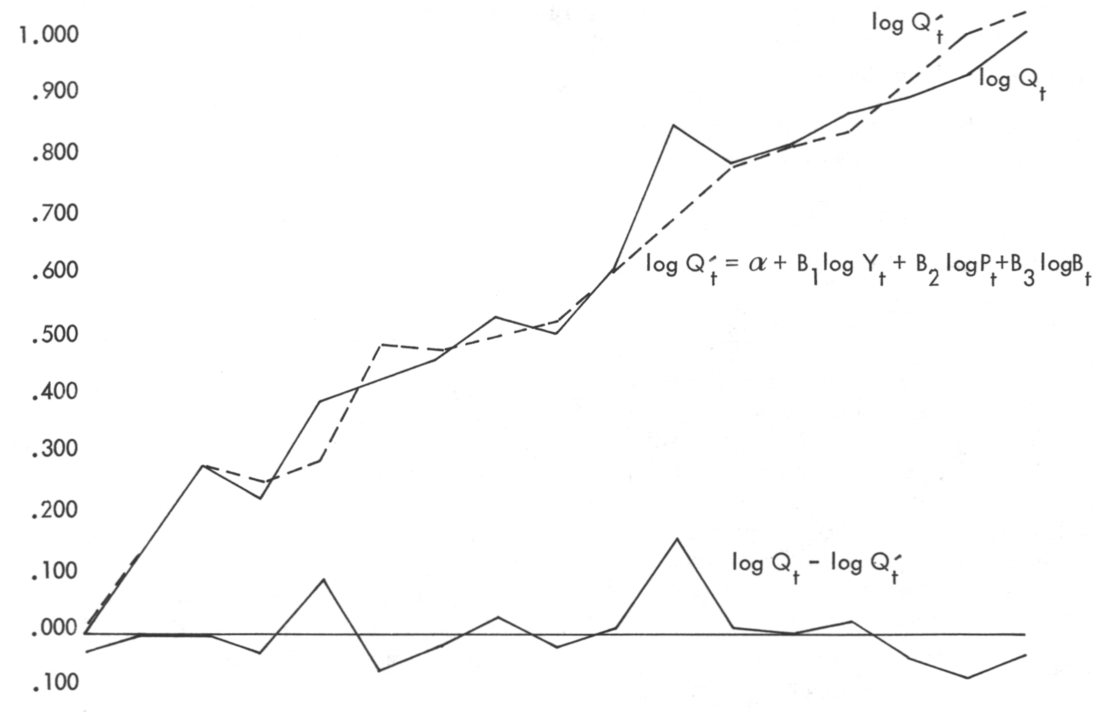

Fig. 4. Model I.

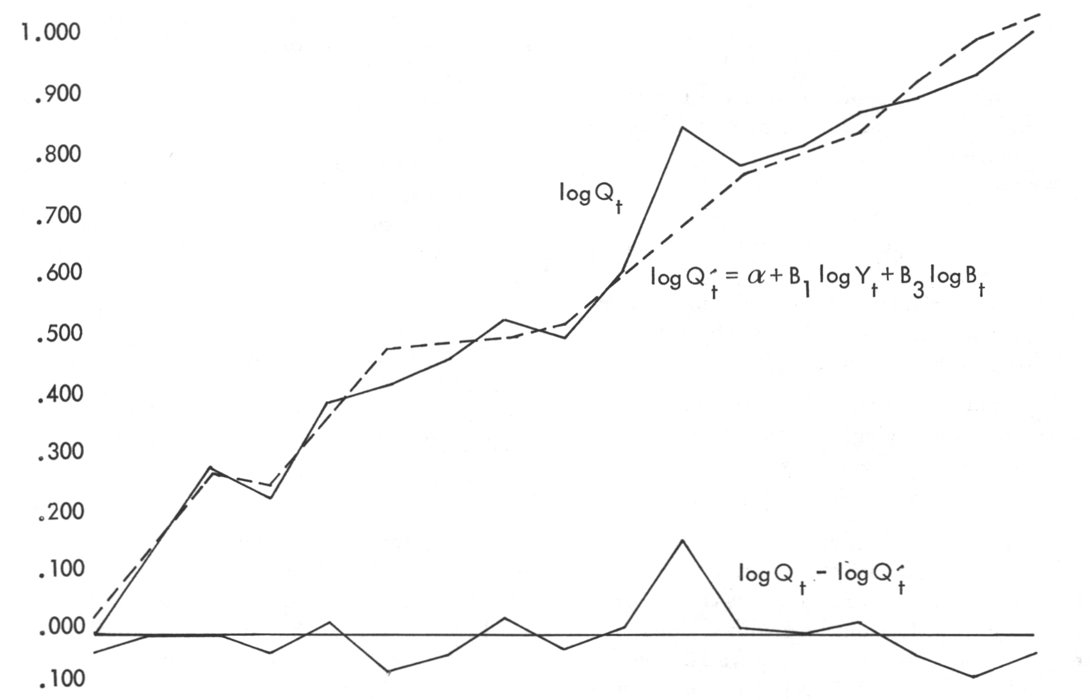

Fig. 5. Model II.

Figs. 4 and 5 show the logarithmic empirical ($\log Q_t$) and theoretical ($\log Q'_t$) values, calculated with the aid of Models I and II, of the sale of printing and writing paper, and the residual term ($\log Q_t - \log Q'_t$).

Another model, with the logarithmic consecutive differences of the original variables as new variables, was tested in order to eliminate the multicollinearity between the independent variables observed in Model I. The transformed variable $\log x_t$ was obtained from the formula:

$$\Delta \log x_t = \log \left(\frac{x_t}{x_{t-1}} \right)$$

The calculation was carried out as above, and the model acquired the following form:

Model III

$$\Delta \log Q_t = .188 + 1.561 \, \Delta \log Y_t + .278 \, \Delta \log P_t - .052 \, \Delta \log B_t$$

standard error			
.038	.923	.366	.382
t-value			
4.841	1.692	.758	− .136

s = .072 R = .613 ø = 12

The correlation between Y and P, the most strongly correlated independent variables, has almost disappeared, as can be seen from Table 2.

Because the influence of the trend disappeared, the value of the correlation coefficient diminished considerably and the degree of determination of the model expressed by its

Table 2. Correlation matrix of the variables in Model III

Variable	$\log Q_t$	$\log Y_t$	$\log P_t$	$\log B_t$
$\Delta \log Q_t$	1.000	.561	.240	.255
$\Delta \log Y_t$		1.000	−.009	.684
$\Delta \log P_t$			1.000	−.460
$\Delta \log B_t$				1.000

means remained under 40 % (R_2 = .375). Testing of the correlation coefficient showed that it did not differ significantly from zero. A similar result was obtained when testing the parameter estimates of all the variables of the model. Furthermore, since the deviation of the regression equation was bigger than in Models I and II it can be concluded that the transformation of the variables did not improve the degree of determination of the model. The empirical observation values and those corresponding to Modell III are presented in Fig. 6.

52. Models with time lag

The models with time lag were formed so that the values of the variable indicating the income level were lagged by one year compared with the other variables. In calculation, the parameter estimates of the original observation values acquired the following values and characteristics:

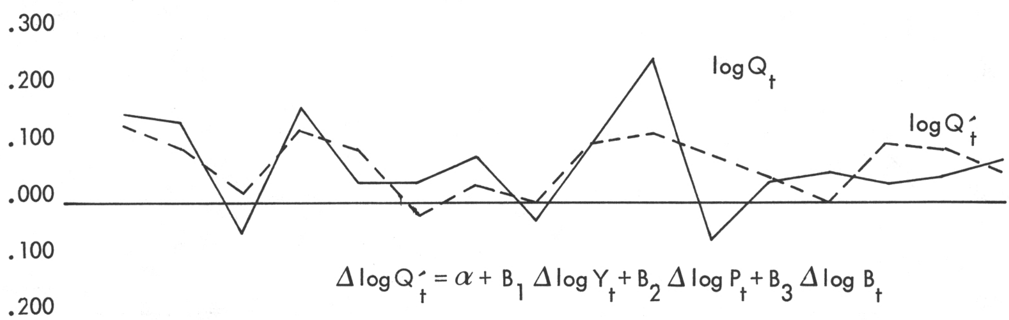

Fig. 6. Model III.

Model IV

$\log Q_t =$

$.178 + 1.735 \log Y_{t-1} - .177 \log P_t + .110 \log B_t$

standard error			
.061	.345	.373	.338
t-value			
2.927	5.026	−.474	.327

$s = .085 \quad R = .961 \quad \varnothing = 12$

The content of Model IV differs remarkably from that of Model I. Confidence testing of the parameter estimates revealed that only the income-level coefficient differed significantly from zero. The standard error of the regression equation in the different phases of calculation showed that including variables P_t and B_t did not improve the degree of determination. The relatively small growth of the correlation coefficient also supports this assertion. Unlike Model IV, Model I showed a distinct diminution of the standard error, and a more pronounced growth of the correlation coefficient, after paper price and the trend variable had been included in the model. The diminution of the absolute value of the coefficients of variable P_t noted in Model I, following the addition of variable B_t, is still noticeable though not quite so pronounced. The multicollinearity between the variables (Table 3) is parallel in both models despite the time lag.

Table 3. Correlation matrix of the variables in Model IV

Variable	$\log Q_t$	$\log Y_{t-1}$	$\log P_t$	$\log B_t$
$\log Q_t$	1.000	.959	−.862	−.010
$\log Y_{t-1}$		1.000	−.871	−.058
$\log P_t$			1.000	−.157
$\log B_t$				1.000

On the whole, Model IV may be considered to have a lower degree of determination than Model I. The observations calculated by means of Model IV and the empirical observations, as well as the residual term between them, are shown in Fig. 7.

Since the parameter estimate of the trend

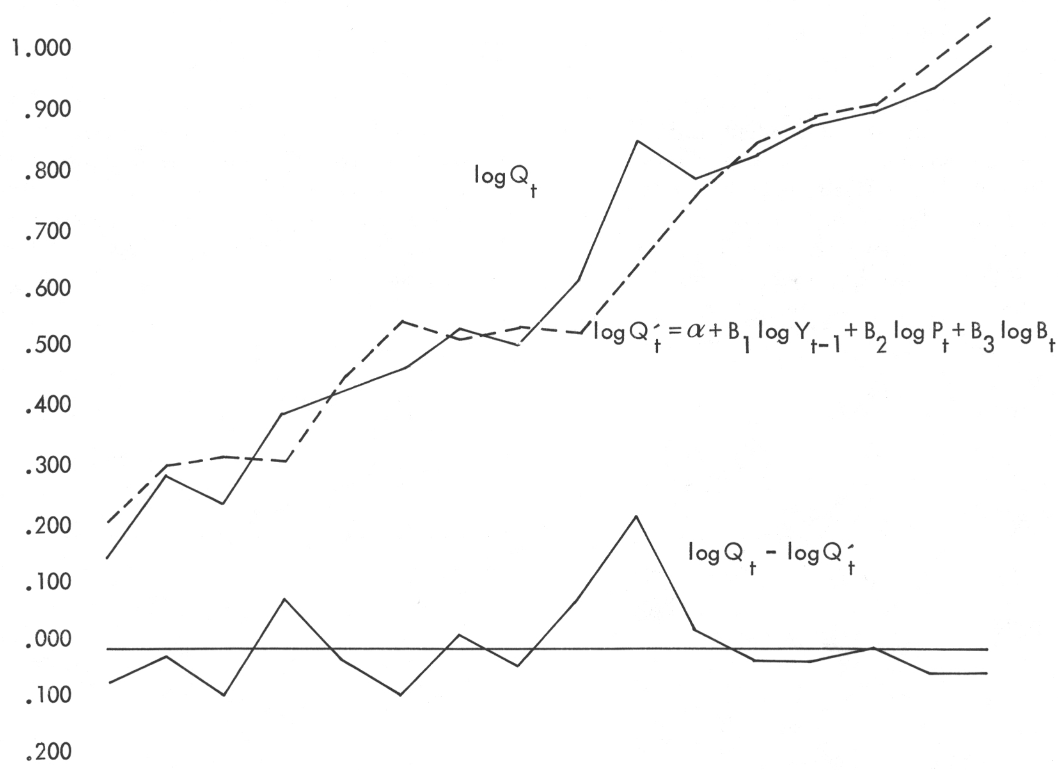

Fig. 7. Model IV.

variable did not significantly differ from zero, it was considered necessary to form a time-lag model corresponding to Model II. For comparison, however, the calculation was carried out with the transformed values of the Model IV variables:

Model V

$\Delta \log Q_t =$

$.061 + .261\, \Delta \log Y_{t-1} + .570\, \Delta \log P_t + .413\, \Delta \log B_t$

standard error	.032	.754	.363	.318
t-value	1.921	.346	1.568	1.297

s = .081   R = .467   ø = 11

A comparison of Model V with the corresponding model without time lag, Model III, reveals pronounced changes in the parameter coefficients. The significance of paper price and the trend variable has increased decisively whereas the role of income level is secondary. Confidence testing of the parameter estimates revealed, however, no significant difference from zero. It is therefore difficult to draw conclusions, and those drawn may lead to spurious results. On the basis of the standard error, Model III may be considered preferable to Model V even though neither has a degree of determination reaching the level calculated with the original values. The empirical observation values and the theoretical values corresponding to Model V are presented in Fig. 8.

Table 4. Correlation matrix of the variables in Model V

Variable	$\Delta \log Q_t$	$\Delta \log Y_{t-1}$	$\Delta \log P_t$	$\Delta \log B_t$
$\Delta \log Q_t$	1.000	.024	.309	.172
$\Delta \log Y_{t-1}$		1.000	.246	–.462
$\Delta \log P_t$			1.000	–.429
$\Delta \log B_t$				1.000

53. Discussion of the models

Owing to the strong influence of the income level, the degrees of determination of the models do not differ very much. Transformation of the variables did not generally improve the degree of determination (Table 5). The hypothesis concerning a time lag for the income level must be rejected on the basis of the results obtained, since the degree of determination of the models without time lag proved to be better.

Table 5. Standard errors and multiple correlation coefficients of the models.

Model	Standard error s	Multiple correlation coefficient R
Original variables:		
I	.056	.986
II	.054	.986
IV	.085	.961
Transformed variables:		
III	.072	.613
V	.081	.467

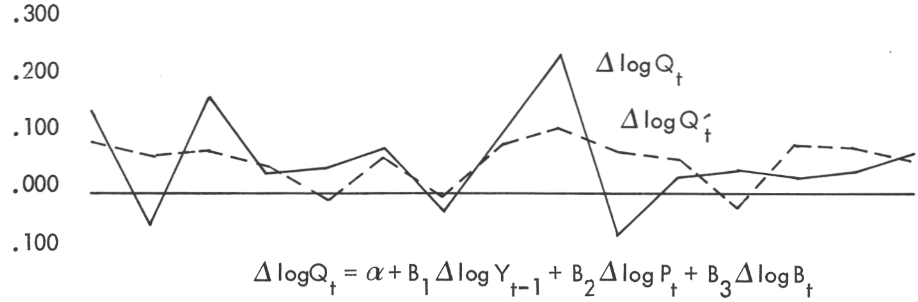

Fig. 8. Model V.

On the basis of the standard deviation of the regression equation and correlation coefficients, Models II and I can be considered the best for indicating sales of printing and writing paper.

The similar degree of determination is also expressed in the graphs of the residual terms (Figs. 9 and 10). The only remarkable and consistent deviation occurs in 1960. It is difficult to trace the cause of this remarkable difference, since no substantial changes which might have produced a major increase in the demand for printing and writing paper took place at that time in the Finnish economy. The development of paper prices was also relatively constant and therefore the finding can hardly be attributed to exceptional changes in stocks held for speculative purposes.

A study of the level of the parameter estimates of the models (Table 6) reveals the uniformity already pointed out. The following assumptions can be made on the basis of the coefficients:

- the income elasticity of printing paper is 1.7–2.0;
- the price elasticity of printing and writing paper is ~ 0.

The conclusions, however, must be made with reservation since the elasticity has been assumed to be constant throughout the period under review.

The FAO study presented a somewhat greater income elasticity for areas with income levels corresponding to Finland (FAO 1963, pp. 26–49). In RIIHINEN's (1962, p. 81) paper concerning the sales of newsprint, the estimated income-level parameter was slightly lower

Table 6. Parameter estimates of the model variables.

Model	Independent variable Y	P	B
Original variables:			
I	2.029	.058	–.441
II	1.986		–.445
IV	1.735	–.177	.110
Transformed variables:			
III	1.561	.278	–.052
V	.261	.570	.413

(1.322–1.715) than the value in this study. Also, in the FAO report the income elasticity of newsprint remained somewhat lower than that of printing and writing paper.

On the basis of the theory outlined in Section 22, the models with time lag should also have been treated in the following combinations:

$$\log Q_t = \log \alpha_0 + \alpha_1 \log Y_t + \alpha_2 \log P_{t-1} + \alpha_3 \log B_t$$

$$\log Q_t = \log \alpha_0 + \alpha_1 \log Y_{t-1} + \alpha_2 \log P_{t-1} + \alpha_3 \log B_t$$

It may be concluded, however, that these models would not have given any better results since the parameter estimate of the variable describing paper price did not obtain a significant value in any of the models tried. The correlation between variables Y_t and P_t also supports this assumption.

54. Residual-term analysis

Residual-term analyses are intended to show whether the residual terms are estimates of random errors. Mathematically they are the differences between observed and dependent values. The model is said to contain autocorrelation if the residual term does not result exclusively from random factors. Autocorrelation occurs most often in time series in which the value of the dependent quantity at a given date affects systematically its value at a later date. Autocorrelation may arise from erroneous function form, the influence of variables excluded from the model, measuring errors, and the like.

The autocorrelation of residual terms can be studied either by tests developed for the purpose or by graphs. Several testing methods are available. The best known among them are the von Neumann mean-square-successive difference and the Durbin-Watson tests. Another method that may be used is the t-test, which reveals the significance of the autocorrelation coefficient. Despite the advantages of the graphic method, testing was found more objective and therefore this alternative was selected.

The formula used to calculate the autocorrelation coefficient was (MATTILA 1966, p. 129):

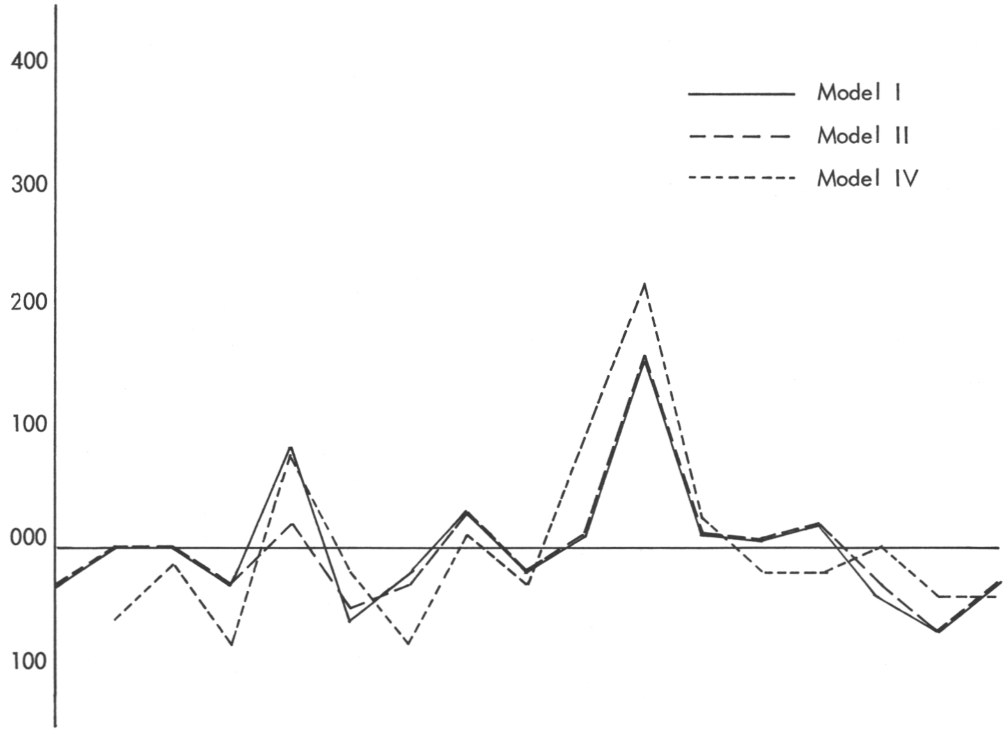

Fig. 9. Residual terms calculated with the original variables.

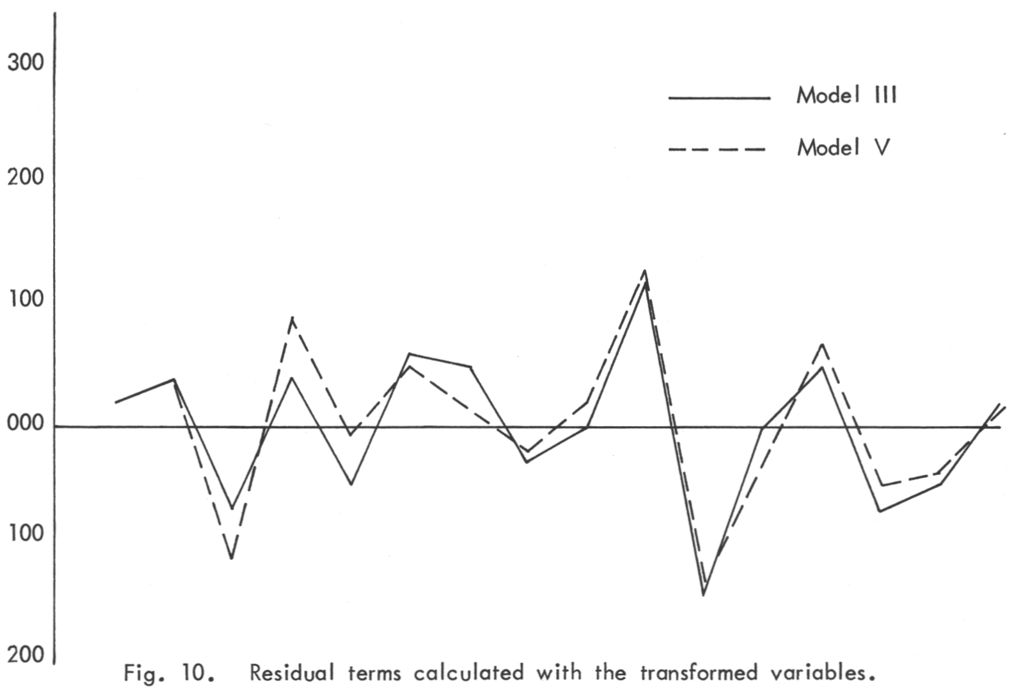

Fig. 10. Residual terms calculated with the transformed variables.

$$r_k = \frac{\sum_{t=1}^{n-k} x_t x_{t+k} - \frac{1}{n-k}\left(\sum_{t=1}^{n-k} x_t\right)\left(\sum_{t=1}^{n-k} x_{t+k}\right)}{\sum_{t=1}^{n} x_t^{\;2} - \frac{1}{n}\left(\sum_{t=1}^{n} x_t\right)^2}$$

n = number of observations
k = duration of the lag
x_t = value of residual in year t

The test quantity is obtained from the formula (MATTILA 1966, p. 132):

$$t = \frac{r_k}{s_{r_k}}$$

in which s_{r_k} is the standard error of the autocorrelation coefficient r_k:

$$s_{r_k} = \sqrt{\frac{1-r^2}{n-k-1}}$$

The calculation was carried out for Models I and II, which had proved to be the best, with one- and two-year time lags (k = 1, 2).

Model I

r_1 = –.002 S_{r_1} = .267 t-value = –.007
r_2 = –.248 s_{r_2} = .258 t-value = –.963

Model II

r_1 = .124 s_{r_1} = .258 t-value = .512
r_2 = .063 s_{r_2} = .258 t-value = .244

When the autocorrelation coefficients were tested it was found that in neither model did they differ significantly from zero. Coefficients can naturally be calculated with a time lag longer than two years, but on the basis of the tests made it could be assumed that the residual terms are not correlated. The test result therefore supports the assumption that the residual terms contain only random variation. Ocular examination of the graphs and empirical observations of Models I and II also favours this assumption.

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APPENDIX

A list of the paper grades studied. (Item numbers according to the paper-grade nomenclature of the Finnish Paper Mills' Association.)

		Item
1.	SC newsprint	0500 - 0549
2.	Mechanical paper qualities	
	21. Grade 1	1100 - 1735
	22. Grade 2	2100 - 2735
	23. Grade 3	3100 - 2735
	24. Grade 4	4100 - 4735
	25. Grade 5	5100 - 5735
	26. Special grades	
	261. Duplicating paper	5820 - 5821
	262. Calculating-machine, cash-receipt and cash-control paper	5830 - 5831
3.	Fine papers	
	31. Wood-free papers	6100 - 6735
	32. Special papers	6800 - 6843
	(Ledger, post, bank, duplicating, manifold, cash-control, bible, embossed, twisting, blotting and filter, teleprint, cheque, register-card, nautical-chart, map, and diagram paper)	

Table I. The basic values of variables Q_t, Y_t and P_t in Table IV.

Year	Population (minimum age 15 yrs)	Sales of printing & writing paper		Net national product		Index deflator	NNP at 1954 prices per capita
		Total	per capita	at current prices	at 1954 prices	NNP at current prices / NNP at 1954 prices	
	1000 persons	1000 kg	kg	million mk	million mk		mk
	1.	2.	3.	4.	5.	6.	7.
1950	2 821.0	23 755	8.42	4 476.3	6 041.2	74.10	2 141.51
1951	2 834.6	27 672	9.76	6 568.9	6 630.0	99.08	2 338.95
1952	2 861.9	32 082	11.21	6 692.0	6 767.3	98.89	2 364.62
1953	2 891.3	30 559	10.57	6 531.5	6 727.5	97.09	2 326.81
1954	2 924.5	36 353	12.43	7 347.4	7 347.4	100.0	2 512.36
1955	2 945.8	37 989	12.90	8 295.0	7.797.2	106.38	2 646.89
1956	2 989.2	39 903	13.35	9 066.1	7 837.2	115.68	2 621.84
1957	3 002.7	43 177	14.38	9 516.8	7 917.6	120.20	2 636.83
1958	3 029.0	42 407	14.00	10 180.2	7 928.4	128.40	2 617.50
1959	3 059.5	47 723	15.60	11 153.1	8 423.3	132.41	2 753.07
1960	3 106.0	61 613	19.84	12 464.4	9 171.4	135.90	2 952.80
1961	3 167.2	58 984	18.62	13 873.5	9 754.0	142.23	3 079.69
1962	3 225.5	61 880	19.18	14 867.9	10 153.1	146.44	3 147.76
1963	3 285.2	66 038	20,10	16 475.8	10 425,7	158.03	3 173.54
1964	3 339.9	69 170	20,71	18 872,1	11 099,8	170.02	3 323.39
1965	3 387.3	73 125	21.59	20 691.3	11 649.5	177.62	3 439.17
1966	3 405.8	78 812	23.14	22 036.7	12 002.9	183.59	2 524.25
1967	3 471.7	80 294	23.06	23 926.9	12 120.0	196.92	3 498.00

Sources: Column 1. Central Statistical Office, Demographic Department.
Column 2. Paper mills and the Finnish Paper Mills' Assoc.
Columns 4&5. Central Statistical Office, National Income Department.

Table II. The basic values of variable P_t in Table IV.

Year	Prices of printing & writing paper[1]			Mean price[2]	Mean price deflated by NNP price index
	Wood-free printing paper	Mechanical printing paper	SC newsprint		
	mk/kg			mk	
	1.	2.	3.	4.	5.
1950	0.4250	0.3050	-	0.3661	0.4941
1951	0.5300	0.3800	-	0.4587	0.4630
1952	0.6350	0.4550	-	0.5542	0.5604
1953	0.6350	0.4550	-	0.5383	0.5544
1954	0.6350	0.4550	-	0.5496	0.5496
1955	0.6350	0.4550	-	0.5465	0.5137
1956	0.6350	0.4550	0.2850	0.5547	0.4795
1957	0.6800	0.4900	0.2975	0.5698	0.4740
1958	0.6800	0.4900	0.3325	0.5771	0.4495
1959	0.7200	0.5200	0.3450	0.5972	0.4510
1960	0.7200	0.5200	0.3525	0.6076	0.4471
1961	0.7500	0.5200	0.3600	0.6184	0.4348
1962	0.7500	0.5400	0.3675	0.6226	0.4252
1963	0.7500	0.5400	0.3675	0.5907	0.3738
1964	0.7800	0.5600	0.3800	0.6584	0.3872
1965	0.8300	0.5700	0.3900	0.6959	0.3918
1966	0.8300	0.5700	0.4000	0.6950	0.3786
1967	0.8300	0.5700	0.4100	0.6954	0.3560

Source: The Finnish Paper Mills' Assoc.

1. Basic prices for reels.
2. Calculated as a weighted mean value of columns 1, 2 and 3. The weights used were the sales quantities of each grade.

Table III. The basic values of variable B_t in Table IV.

Year	General export-volume index 1954 = 100	Trend-value[1]	Volume index times 100 / Trend-values
	1.	2.	3.
1950	69	63.61	108.47
1951	87	72.12	120.63
1952	77	80.63	95.49
1953	86	89.15	96.47
1954	100	97.66	102.40
1955	109	106.17	102.67
1956	107	114.68	93.30
1957	117	123.19	94.97
1958	115	131.71	87.32
1959	131	140.22	93.43
1960	152	148.73	102.20
1961	160	157.24	101.75
1962	170	165.75	102.56
1963	173	174.27	99.27
1964	185	182.78	101.22
1965	194	191.29	101.42
1966	207	199.80	103.60
1967	219	208.31	105.20

Source: Bulletin of Statistics.

1. The trend values were calculated from the equation:
$y = 8.512X + 131.706$

Table IV. Observation values of the variables as index figures, 1950-1966.

Year	Q_t	Y_t	P_t	B_t
1950	1.00	1.00	1.00	1.08
1951	1.16	1.09	.94	1.21
1952	1.33	1.10	1.13	.95
1953	1.26	1.09	1.12	.96
1954	1.48	1.17	1.11	1.02
1955	1.53	1.24	1.04	1.03
1956	1.59	1.22	.97	.93
1957	1.71	1.23	.96	.95
1958	1.66	1.22	.91	.87
1959	1.85	1.29	.91	.93
1960	2.36	1.38	.90	1.02
1961	2.21	1.44	.88	1.02
1962	2.28	1.47	.86	1.03
1963	2.39	1.48	.76	.99
1964	2.46	1.55	.78	1.01
1965	2.56	1.61	.79	1.01
1966	2.75	1.65	.77	1.04
1967	2.79	1.63	.72	1.05

Source: Tables I-III

Symbols:

Q_t = Domestic sales of printing and writing paper produced in Finland in year t, per capita (minimum 15 years old)

Y_t = Real national product per capita (minimum 15 years old), in year t

P_t = Price of printing and writing paper per kg, in mk in year t, deflated by the price index of net national product

B_t = Trend variable

Table V. The logarithms of the variables in Table IV[1].

Year	log Q_t	log Y_t	log P_t	log B_t
1950	.000	.000	.000	.077
1951	.148	.086	-.062	.191
1952	.285	.095	.122	-.051
1953	.231	.086	.113	-.041
1954	.392	.157	.104	.020
1955	.425	.215	.039	.030
1956	.464	.199	-.030	-.073
1957	.536	.207	-.041	-.051
1958	.507	.199	-.094	-.139
1959	.615	.255	-.094	-.073
1960	.859	.322	-.105	.020
1961	.793	.365	-.128	.020
1962	.824	.385	-.151	.030
1963	.871	.392	-.274	-.010
1964	.900	.438	-.248	.010
1965	.940	.476	-.236	.010
1966	1.012	.500	-.261	.039
1967	1.026	.493	-.329	.049

1. The logarithm system uses Neper's base, e = 2.718 28...

Table VI. Logarithms of the transformed variables ($\Delta X_t = X_t/X_{t-1}$).

$\Delta \log Q_t$	$\Delta \log Y_t$	$\Delta \log P_t$	$\Delta \log B_t$
.148	.086	-.062	.114
.137	.009	.184	-.242
-.054	-.009	-.009	.010
.161	.071	-.009	.061
.033	.058	-.065	.010
.038	-.016	-.070	-.102
.073	.008	-.010	.021
-.030	-.008	-.053	-.088
.108	.056	.000	.067
.243	.067	-.011	.092
-.066	.043	-.022	.000
.031	.021	-.023	.010
.047	.007	-.124	-.040
.029	.046	.026	.020
.040	.038	.013	.000
.072	.025	-.026	.029

Table VII. Parameter estimates of the models and their standard errrors.

Independent variable	Model I	Model II	Model IV
	Dependent variable log Q_t		
Constant	.059 ± .037	.065 ± .027	.178 ± .061
log Y_t	2.029 ± .187	1.986 ± .090	.
log Y_{t-1}	.	.	1.735 ± .345
log P_t	.058 ± .218	.	-.177 ± .373
log B_t	-.441 ± .201	-.455 ± .187	.110 ± .338

Independent variable	Model III	Model V
	Dependent variable Δlog Q_t	
Constant	.188 ± .038	.061 ± .032
Δ log Y_t	1.561 ± .923	.
Δ log Y_{t-1}	.	.261 ± .754
Δ log P_t	.278 ± .366	.570 ± .363
Δ log B_t	-.052 ± .382	.413 ± .318

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