WORKING PAPER

INCOME AND PRICE ELASTICITIES OF DEMAND FOR PAPER AND BOARD: CONSIDERATIONS IN NUMERICAL ESTIMATION

Esko Uutela

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IIASA
International Institute
for Applied Systems Analysis

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FOREWORD

The objective of the Forest Sector Project at IIASA is to study long-term development alternatives for the forest sector on a global basis. The emphasis in the Project is on issues of major relevance to industrial and governmental policy makers in different regions of the world who are responsible for forestry policy, forest industrial strategy, and related trade policies.

The key elements of structural change in the forest industry are related to a variety of issues concerning demand, supply, and international trade of wood products. Such issues include the development of the global economy and population, new wood products and substitution for wood products, future supply of roundwood and alternative fiber sources, technology development for forestry and industry, pollution regulations, cost competitiveness, tariffs and non-tariff trade barriers, etc. The aim of the Project is to analyze the consequences of future expectations and assumptions concerning such substantive issues.

The research program of the Project includes an aggregated analysis of long-term development of international trade in wood products, and thereby analysis of the development of wood resources, forest industrial production and demand in different world regions. This article studies alternative approaches for forecasting demand for paper and board. Some numerical results and comparison with earlier work is given. The paper resulted from the authors participation in the Young Scientist Summer Program in 1984 at IIASA.

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Esko Uutela

1. INTRODUCTION

The Global Trade Model (GTM) developed by the Forest Sector Project (FSP) at IIASA for analyzing global production, consumption, and international trade in forest products has four basic forces driving the model (see Kirjasniemi et al. 1983, Dykstra and Kallio 1984):

(i) Demands for end products.

(ii) Competitiveness of industries (technology, production costs).

(iii) Available resources.

(iv) Differences in transportation costs.

Roughly speaking, the demands for end products in different regions determine the absolute level of global production of forest products, and elements (ii), (iii), and (iv) determine how production is distributed between the regions.

The preliminary Global Trade Model (GTM-1) includes forest products consumption as a part of the objective function. The demand module of GTM-1 is given as a price (or inverse consumption) function showing for each region i and product k the relation between price π_{ik} and consumption c_{ik} (Dykstra and Kallio 1984):

$$\pi_{ik} = P_{ik}(c_{ik}) \qquad (1)$$

Consumption $c_i = (c_{ik})$ refers to the demand for end products which are consumed outside the forest sector. The demand for intermediary products, i.e., logs, pulpwood, pulp and recycled paper, can be derived from the technical input coefficient matrix $A_i = (A_{ikm})$ and the output levels of end products, assuming that consumption of intermediary products outside the forest sector is negligible. The price function of GTM-1 for end products is:

$$\pi_{ik} = \lambda_{ik} (c_{ik})^{-\gamma_{ik}} \tag{2}$$

where $-1/\gamma_{ik}$ is the price elasticity of demand and λ_{ik} the level parameter for the demand curve. As can be seen from equations (1) and (2), GTM-1 is a static model with simplified demand functions where all important demand shifters are exogenous and their effects on consumption levels are investigated through separate analyses.

The purpose of this paper is to present some estimation results of paper and board consumption functions with special emphasis on the long-term price and income elasticities of demand. The results described here are based largely on practical forecasting work in a forest industry consulting company. Data problems related to elasticity measurement are discussed and estimation results compared with those from consumption studies by other researchers. Attention is also paid to the dynamic aspects of elasticities, i.e., changes in the numerical values of elasticities over time and income level, as well as to their variation across countries and different paper grades.

2. MODELS USED FOR ESTIMATING INCOME AND PRICE ELASTICITIES OF DEMAND

Most of the recent international long-term consumption studies made in the pulp and paper sector have been based on pooling cross-sectional and time-series data instead of using the traditional country-wise time-series analysis. As Buongiorno (1978) has stated, pooling alleviates problems posed by short time-series, small variability in the data, and high collinearity between explanatory variables measured in value terms.

Both static and dynamic models have been used for estimating consumption functions. One of the most important static functions, widely used in general demand studies, is (Houthakker 1965):

$$C_{ijt} = A_j Y_{it}^{b_j} P_{ijt}^{c_j} P'^{d_j}_{ijt} \varepsilon_{ijt} \tag{3}$$

where i, j, and t refer to a specific country, product, and year, respectively. C is consumption per capita, Y is income (or GDP) per capita, P is the price of the product in question, and P' is the price of the most direct substitute.

A dynamic version of the model (3) based on Nerlove's partial adjustment model is (see Nerlove 1958):

$$C_{ijt} = A_j C_{ij,t-1}^{\lambda_j} Y_{it}^{b_j} P_{ijt}^{c_j} P'^{d_j}_{ijt} \varepsilon_{ijt} \tag{4}$$

where the only difference to equation (3) is the introduction of a lagged dependent variable $C_{ij,t-1}$ (= consumption in the previous year) into the model. The quantity demanded in period t depends on, among other things, on the quantity demand in previous periods due to a habit formation process which is characteristic of human behavior (Houthakker and Taylor 1966). In the case of paper and board, the habitual nature of consumption is evident; this is stated, e.g., by Åberg (1968).

Nerlove's dynamic theory allows a distinction between short-term and long-term demand elasticities (Nerlove and Addison 1958). Nerlove postulates that equation (3) represents, in fact, the long-term demand if demand adjusted immediately to changes in explanatory variables:

$$\log C^{*}_{ijt} = a_j + b_j \log Y_{it} + c_j \log P_{ijt} + d_j \log P'_{ijt} + \varepsilon_{ijt} \qquad (5)$$

where C^{*}_{ijt} is the long-term equilibrium of consumption which would be observed if all explanatory variables remained at a fixed level for a sufficiently long time. Since Y_{it}, P_{ijt}, and P'_{ijt} change continuously, C^{*}_{ijt} is never observed. To measure the ratio between C_{ijt} and C^{*}_{ijt} the hypothesis used is that the ratio (C^{*}_{ijt}/C_{ijt}) will be closer to unity than the ratio $(C^{*}_{ijt}/C_{ij,t-1})$ because there will tend to be greater coincidence between short- and long-term demand in year t than between short- and long-term demand in successive years (Nerlove and Addison 1958, see also Koutsoyiannis 1973). This implies that

$$\frac{C^{*}_{ijt}}{C_{ijt}} = \left[\frac{C^{*}_{ijt}}{C^{\lambda}_{ij,t-1}}\right]^{\lambda} \quad 0 < \lambda < 1 \qquad (6)$$

where λ measures the velocity of adjustment to demand rigidities. By substituting (6) into (5)

$$C^{*}_{ijt} = \left[\frac{C_{ijt}}{C^{\lambda}_{ij,t-1}}\right]^{1/(1-\lambda)} = a_j Y_{it}^{b_j} P_{ijt}^{c_j} P'^{d_j}_{ijt} \varepsilon_{ijt} \qquad (7)$$

so that

$$C_{ijt} = a_j^{(1-\lambda)} Y_{it}^{b_j(1-\lambda)} P_{ijt}^{c_j(1-\lambda)} P'^{d_j(1-\lambda)}_{ijt} C^{\lambda}_{ij,t-1} \varepsilon_{ijt} \qquad (8)$$

or

$$C_{ijt} = A_j Y_{it}^{B_j} P_{ijt}^{C_j} P'^{D_j}_{ijt} C^{\lambda}_{ij,t-1} \varepsilon_{ijt} \qquad (9)$$

we obtain the short-term consumption function, from which it is possible to estimate both the short- and long-term elasticities by computing from the regression and of the relationships:

$$b_j = \frac{B_j}{1-\lambda}, \quad c_j = \frac{C_j}{1-\lambda}, \quad d_j = \frac{D_j}{1-\lambda}, \quad 0 < \lambda < 1 ,$$

where capital letters refer to short-term elasticities and the lower case to long-term elasticities. The closer λ is to unity the faster the velocity of adjustment, the static model being an ultimate case where the adjustment of consumption is completed in one year ($\lambda = 1$).

In several international studies either a static (3) or a dynamic (4) model, or both, has been used for estimating forest products consumption functions (with or without some modifications); for example, among others, by Buongiorno (1977, 1978, and 1979), FAO (1977a), Baudin and Lundberg (1984) and Suhonen (1984). In the FAO (1977a) study, an additional explanatory variable, literacy rate L_{it}, was introduced into the static consumption model for newsprint and printing and writing papers in the developing countries, the model thus being:

$$C_{ijt} = a_j Y_{it}^{b_j} P_{ijt}^{c_j} P'^{d_j}_{ijt} L_{it}^{e_j} \varepsilon_{ijt} \tag{10}$$

In his work, Wibe (1984) used a simplified "dynamic" function where time T represented (as a yearly index) substitution effects over time:

$$C_{ijt} = A_j e^{\alpha_j T} Y_{it}^{b_j} P_{ijt}^{c_j} \varepsilon_{ijt} \tag{11}$$

where T is time measured in years and α_j is interpreted as the yearly rate of substitution for forest products.

In several earlier paper demand studies, income (or GDP/capita) was the only explanatory variable in the cross-sectional consumption models (e.g., FAO 1960, FAO 1963b, Sundelin 1970, 1976). The relationship between paper consumption and income per capita in these models was assumed to be an S-shaped curve based on Engel's law of diminishing marginal utility with increasing income. Different mathematical functions have been used to describe the cross-sectional S-curve in year t, of which one of the most complicated is (FAO 1960):

$$C_{ij} = S_\infty \int_{-\infty}^{\ln Y_i} \frac{1}{\rho\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\ln Y_i - \mu}{\rho}\right)^2} d \ln Y \tag{12}$$

where Y is GDP per capita, S_∞ the saturation level of consumption (kg/capita) defined *a priori*, and ρ and μ parameters of the log-normal function. A simpler formulation was used by Sundelin (1976):

$$C_{ij} = A_j Y_i^{b_j} Y_i^{c_j \log Y_i} \tag{13}$$

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

All the above consumption functions are implicitly based on the consumer demand theory. However, the demand for forest products has only indirect connections to this theory. A relatively small fraction of forest products is consumed as such *directly by consumers* (e.g., sawnwood for do-it-yourself purposes, household and sanitary papers); the bulk comprises intermediate – or rather complementary – products related to the output of other commodities. Additionally, the value of forest products is normally very small compared with the total costs of the consumer or producer. According to Åberg (1968), paper and board costs in Sweden accounted for only 1–2 percent of the total consumption value in the industry and trade, as well as in private households. The only exception in the paper and board sector is in printing houses; the costs of newsprint might be up to 30% of the total costs of newspaper publishing. Therefore, it has been discussed whether traditional demand theory, using relative prices of substituting commodities as exogenous variables, is able to explain the variation in consumption levels.

Although the product characteristics of forest products are the reason for assuming their demand to be *derived demand* rather than *final consumer demand*, the estimation of demand relationships from production or cost functions is not as straightforward as for many capital goods or raw materials. Especially in the paper and board sector, the consumption is widespread among numerous branches of the economy indicating that there are also several different production or cost functions to be identified. The complexity of processes or systems, to which forest products consumption in these branches is tied, might also contribute difficulties to the interpretation of estimation results. For these reasons, and the limited availability of sectoral input—output data, there are only a few studies known to the present author which apply derived demand theory to forest products. Doran and Williams (1982) used the Diewert cost function (or a generalized Leontief production function, see Diewert 1971), based on Shephard's duality theorem (Shephard 1953) of the equivalency of the production function, and minimum cost function to analyze the demand for domestically produced sawnwood in Australia in the period 1957—1977. Own-price elasticity for sawnwood and cross-price elasticity for five substitutes/complements were estimated. Frenger (1983) used the same generalized Leontief production function approach for estimating price elasticities in six manufacturing sectors of Norway covering the period 1962—1980. Both short-term and long-term elasticities were estimated for four variable inputs: material, energy, labor, and capital.

It is evident that there are too few experiences of the use of the derived demand approach in the forest sector to make any conclusions as to its suitability for consumption analysis of forest products. The two above-mentioned national studies only provide examples of results from two specific cases, which are not to be generalized to the global level. On the other hand, there is little evidence that models based on the traditional consumer demand theory, in spite of their theoretical weaknesses, would in practice produce forecasts of a completely false magnitude. For example, the paper consumption forecast prepared by FAO (1963a) in the early nineteensixties for the whole of Latin America up to 1975 used a simple income-related model and differed by only 1.8% from the actual consumption in 1975 (1974—76 three-year average, see Uutela 1979). For these reasons, the rest of this paper deals with elasticity estimation for paper and board obtained from traditional demand models.

3. DATA PROBLEMS FACING ELASTICITY MEASUREMENT

When using international data for cross-sectional or pooled cross-sectional and time-series analysis, there arise some data problems which may have a drastic effect on the estimation results. These problems include, among others:

(i) Availability of valid and reliable price data directly comparable with similar data series from other countries

(ii) Choice of an appropriate deflation method for all value data

(iii) Exchange rate variation when converting value data from national currencies into a common currency.

Availability of suitable price data (i) is a problem because value data on domestic consumption are normally not available. The FAO yearbook statistics include only import and export values of commodities traded internationally. Recent efforts by FAO to collect domestic price series for forest products have yielded relatively short time series for a few countries, with varying product classification. Only a few developed countries systematically publish domestic price series for specific paper and board grades. For building a global model, the contribution of these price series is insufficient. Therefore, the most suitable available information on price levels for many countries is the unit value of imports or exports. FAO (1977a) and Buongiorno (1978) in their studies used average export (FOB) values for net exporting countries and average import (CIF) values for net importing countries. This approximation seems justified for countries which are either major importers or major exporters of paper and board grades. Problems arise when imported or exported quantities are small and/or there are clear quality/grade differences in comparison with domestic consumption, i.e., export or import prices do not represent the average prices of domestic consumption of a certain product group. Fortunately, this heterogeneity has serious effects only on a few countries and products; in many cases domestic prices follow closely the world market prices, with allowance for differences in transportation and other trading costs. Buongiorno (1978) made a comparison between wholesale domestic price and unit values of foreign trade of newsprint for five countries, resulting in correlation coefficients varying from 0.90 (FRG) to 0.99 (US). However, this does not hold for all countries and products. Before any statistical analysis the unit value data series should be checked and distorted price series replaced by domestic price estimates.

Deflation of value data (ii) should always be made using national deflators and national currencies. When using FAO unit value data for product prices, prices are directly expressed in current US dollars. These figures include both the US inflation and changes in exchange rates. Since consumption is rather a function of ***real income*** and ***real prices*** than a function of ***money income*** and ***nominal prices***, one has to adjust the unit value series from the US inflation. In some studies (e.g., FAO 1977a, Wibe 1984, Suhonen 1984) the prices in current US dollars have simply been divided by the US wholesale price index, which closely follows the index of export prices of manufactured goods. Then it is assumed that changes in official exchange rates sufficiently reflect differences in cost developments between the USA and other countries. Some researchers have used US nominal prices as such without deflating then at all (see e.g., Buongiorno 1978). In these cases it is evident that the numerical values of the estimated elasticities are distorted by the likely correlation between price and time (or inflation).

Exchange rate variations (iii) cause comparability problems between countries. As stated in an earlier paper by the author (Uutela 1983), the choice of base year and currency used in cross-sectional studies may affect rankings between countries with respect to GDP per capita and product prices. It has been shown that when using the same per capita income and per capita paper consumption data — but base year 1978 instead of 1970 for the US dollar exchange rate for GDP figures — the country rankings changed and the variation in the data increased, thus reducing the overall fit of the cross-sectional model remarkably (JPI 1982). Large fluctuations in the value of the US dollar since the beginning of the period of flexible exchange rates in the early 1970s make reliable comparisons of purchasing power and commodity prices over time and between different countries difficult.

The effect of different deflators and exchange rate variations on price series are illustrated in Figure 1. It can be seen that price series develop rather differently depending on the data manipulation made, and evidently there would be remarkable differences in the parameter estimates of consumption models based on these data. To see these differences, three consumption models for two products, total paper and board and newsprint, and one country, the Federal Republic of Germany, were built of using data for 1964–82 based on FAO (1977b, 1984) and IMF (1982). The models were:

$$\log C_{jt} = a_j + b_j \log Y_{jt} + c_j \log P_{jt} + \varepsilon_{jt} \tag{14}$$

$$\log C_{jt} = a_j + b_j \log Y_{jt} + c_j \log P_{jt} + d_j C_{j,t-1} + \varepsilon_{jt} \tag{15}$$

$$\log C_{jt} = \log A + a_j T + b_j \log Y_{jt} + c_j \log P_{jt} + \varepsilon_{jt} \tag{16}$$

of which (14) and (15) are the logarithmic forms of models (3) and (4), but without prices of substitutes as explanatory variables, and (16) is the logarithmic form of (11) used by Wibe (1984). The price variables (all CIF import prices) used were chosen as follows:

A) Nominal price in US dollars.

B) Constant price in 1975 US dollars, deflated by the US wholesale price index.

C) Constant price in 1975 US dollars, deflated by the German industrial products price index.

D) Constant price in 1975 US dollars, deflated by the US wholesale price index and adjusted for exchange rate fluctuations by using the average rate between the US dollar and German mark for the period 1964–82.

E) Constant price in 1975 US dollars, deflated by the German industrial products price index and adjusted for exchange rate fluctuations by using the average exchange rate for the period 1964–82.

GNP was measured in all cases at constant 1975 prices, deflated by the German GNP deflator, and converted into US dollars by using the average exchange rate of 1964–1982. The results of a total of 30

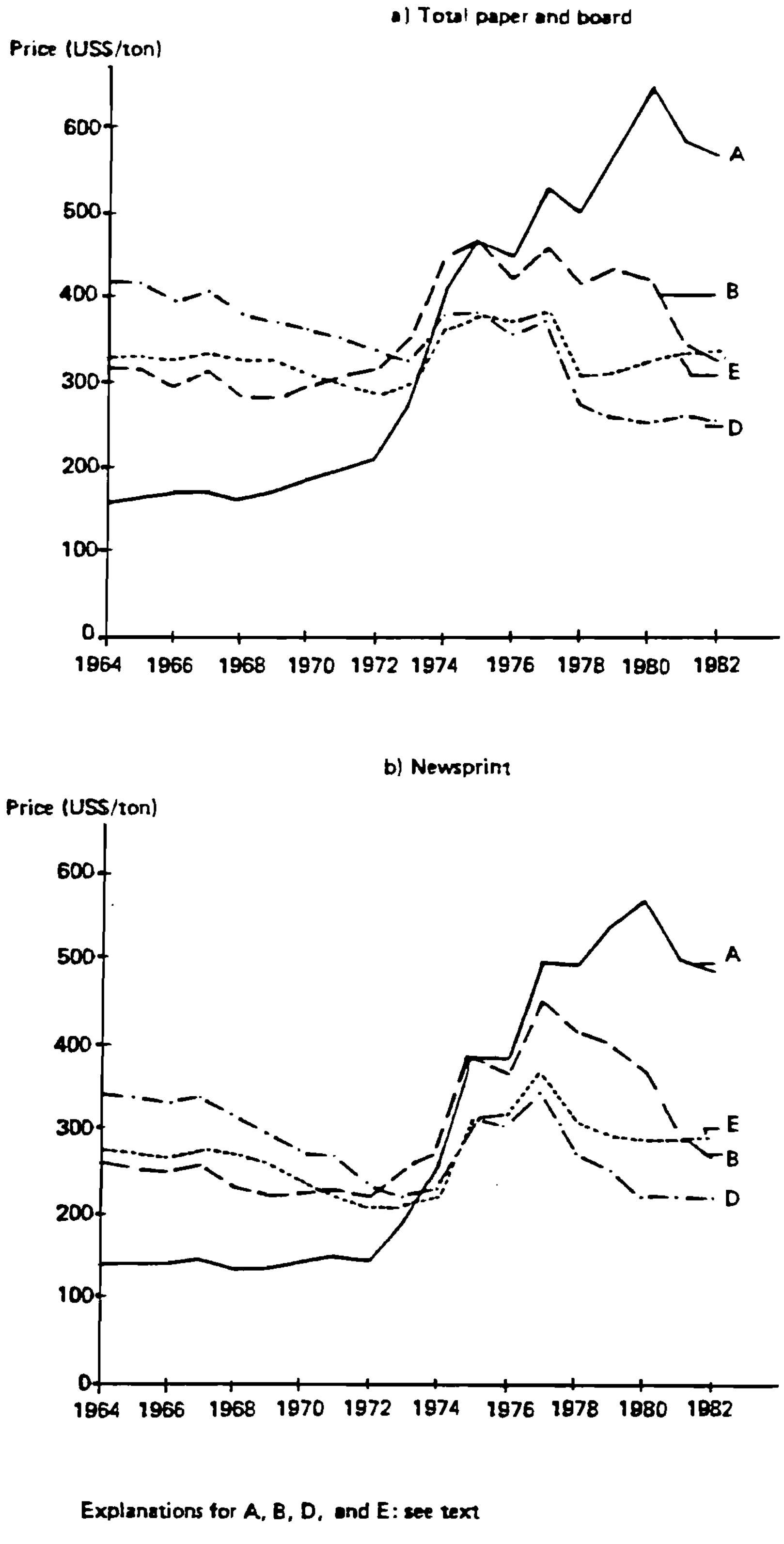

FIGURE 1. An example of the effects of different deflators and varying exchange rates on the price series of paper products in the Federal Republic of Germany 1964–82. (Explanations for A,B,D, and E given in the text).

regression equations are presented in Appendixes 1 and 2. Table 1 summarizes the results of all the static and four dynamic models.

The measured price elasticities varied from −0.15 to −0.40 for total paper and board, and from −0.14 to −0.29 for newsprint, depending on the price series used. Surprisingly, variation in income elasticities, measured from different models, was even more important; from 0.81 to 1.78 for total paper and board, and from 0.97 to 2.00 for newsprint. The static models were statistically better than dynamic models including time or lagged consumption. Parameter estimates in the dynamic models had negative signs in 19 of 20 dynamic regressions, thus violating the assumptions of Nerlove's partial adjustment theory on which the model was based. Only in four equations with time (years) as the explanatory variable is the parameter estimate statisticaly different from zero at the 0.99 confidence level.

High multicollinearity (0.94–0.98) between GNP and time/lagged consumption was the main reason for the failure with dynamic models. When introducing a time variable in consumption models, the standard error of income elasticity at least doubled and $\bar{R}^2$ did not increase remarkably; in the case of C_{t-1} it even decreased. Nominal prices also correlated relatively closely with time (0.77–0.95) as well as with GNP (0.82–0.92); in static models, however, standard errors of parameters were small. The rejection of dynamic models because of the observed multicollinearity and thus indeterminate parameter estimates narrows the variation of the measured elasticities, but the range in static models is still confusing:

	Income elasticity	Price elasticity
Total paper and board	0.81 to 1.37	−0.15 to −0.40
Newsprint	1.02 to 1.64	−0.16 to −0.27

As a result of this exercise, it seems that more attention should be paid to data preparation work before elasticity estimation. Further conclusions from the results are prevented by the limited data material used, but *a priori*, the following comments can be made:

1) Domestic deflators should be preferred to common deflators because change in exchange rates may not strictly follow different cost developments between countries

2) Exchange rate variations should be excluded from the price series if most of consumption is domestically produced and domestic pricing is not affected by foreign currencies. If the bulk is imported, it would be logical to include exchange rate changes, which affect world market prices, in the price series to be used.

TABLE 1. Estimation results of different paper consumption models for the Federal Republic of Germany 1964–82.

EQ. no.	Model type	Estimation results				
		Time	GNP	Price	$\bar{R}^2$	D-W
a)	*Total paper and board*					
1.	Static model, nominal price	-	1.369 (0.119)***	−0.152 (0.039)***	0.958	1.909
2.	Static model, constant price, US deflator	-	1.102 (0.071)***	−0.225 (0.069)***	0.951	1.908
3.	Static model, constant price, German deflator	-	1.291 (0.099)***	−0.227 (0.057)***	0.959	2.040
4.	Static model, constant price, US deflator adjusted for exchange rates	-	0.813 (0.110)***	−0.176 (0.122)	0.927	1.608
5.	Static model, constant price, German deflator adjusted for exchange rates	-	0.977 (0.051)***	−0.399 (0.114)***	0.953	2.364
7.	Dynamic model, constant price, US deflator	−0.022 (0.006)***	1.779 (0.196)***	−0.235 (0.052)***	0.972	2.161
8.	Dynamic model, constant price, US deflator adjusted for exchange rates	−0.029 (0.008)***	1.599 (0.229)***	−0.229 (0.097)*	0.959	2.083
b)	*Newsprint*					
9.	Static model, nominal price	-	1.643 (0.092)***	−0.159 (0.028)***	0.976	2.284
10.	Static model, constant price, US deflator	-	1.369 (0.067)***	−0.220 (0.052)***	0.967	1.889
11.	Static model, constant price, German deflator	-	1.515 (0.082)***	−0.198 (0.040)***	0.972	2.184
12.	Static model, constant price, US deflator adjusted for exchange rates	-	1.016 (0.090)***	−0.275 (0.099)**	0.953	1.450
13.	Static model, constant price, German deflator adjusted for exchange rates	-	1.242 (0.056)***	−0.274 (0.069)***	0.965	1.915
15.	Dynamic model, constant price, US deflator	−0.022 (0.007)***	2.000 (0.211)***	−0.179 (0.044)***	0.979	2.486
16.	Dynamic model, constant price, US deflator adjusted for exchange rates	−0.025 (0.009)**	1.815 (0.284)***	−0.209 (0.085)**	0.968	1.805

Notes: The figures in the parenthesis are standard errors of the coefficients. *** **, and * indicate coefficients significantly differ from zero at the 0.99, 0.95, and 0.90 confidence levels, respectively. $\bar{R}^2$ is the adjusted coefficient of determination and D-W the computed Durbin-Watson statistic.

4. SOME EXPERIENCES FROM WORK DONE AT A CONSULTING COMPANY

4.1 Background

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

- Real prices did not change much from the early 1950s up to 1973.
- Differently from many other industrial products, paper and board do not have suitable or acceptable substitutes at a cheap price (FAO 1977a).
- Paper and board are complementary products whose share of the total price of products to which they are related is very small and, therefore, even large price increases would not much affect their consumption (USDA 1973).
- Price variables include short-term variation which can reduce even the coefficient of determination in long-term consumption models (FAO 1960).
- The consumption of paper and board is habitual and thus the effects of price movements are weak (Åberg 1968).
- The use of price as an exogenous variable in a practical forecasting situation would require that reliable price forecasts are available; forecasting price developments may be even more difficult than forecasting future demand levels.

Rapid increases in real prices of paper and board in 1973–1977 caused a growing interest in studying their effects on consumption, which led to studies (FAO 1977a, Buongiorno 1978) in which price parameters had values that significantly differed from zero. However, in the late 1970s real prices began to decline again, more or less returning to the same development path where they were before the oil crisis (see Figure 1). Therefore, it was decided by Jaakko Pöyry Companies to suggest a study (Suhonen 1984) of the importance of price variables in consumption models by using data material that also included the latest price developments.

4.2 Data and Models Used

The models used were of type (3) and (4). By using a stepwise regression procedure, it was possible to study the effects of the introduction of a lagged endogenous variable on the statistical properties of the consumption model. Separate models were constructed for newsprint, printing and writing papers, wrapping and packaging papers, as well as for sack paper. Substitute prices used were printing and writing paper prices for newsprint and vice versa, and low density polyethylene (LDPE) prices for wrapping and packaging papers and sack paper.

The data material included 40 countries and the years 1965–80 for newsprint and printing and writing papers, and 14 countries and the years 1970–80 for wrapping and packaging paper and sack paper. In the latter case the number of countries was limited by the availability of relevant price series for LDPE. Twenty-three of the 40 countries were developed countries and 17 newly industrialized or developing countries. Data were collected mostly from Jaakko Pöyry's Forest Products Market and Price Data Banks, FAO Yearbooks, and LDPE series from several professional publications, national statistics, and earlier studies (e.g., UNIDO 1981, SRI 1981). GDP figures were deflated by national GDP deflators and converted into US dollars by using the 1970 exchange rate. Prices were deflated by the US wholesale price index. No adjustments for fluctuating exchange rates were made.

All models were estimated from pooled cross-sectional time-series data to broaden the variation range of observations. A dummy variable was set for each country to absorb the specific variation between countries not explained by differences in income, prices, and prices of substitutes in past consumption. Therefore, the estimated model was:

$$\log C_{it} = a + b \log C_{i,t-1} + c \log Y_{it} + d \log P_{it}$$

$$+ e \log P'_{it} + z_i \sum_{k=1}^{k-1} D_{ik} + \varepsilon' \qquad (17)$$

where k refers to the number of countries, for every product j in question. The numerical values of dummy variables tell how much a country deviates from the average level of estimates calculated from the pooled data.

Additionally, the data material was grouped, according to the level of GDP per capita in 1980 and the period of observation, into clusters to analyze whether elasticities varied systematically between different income classes and over time. A separate consumption model was built for the EEC region, which is composed of countries with a relatively similar economic and cultural background.

4.3 Statistical Tests Used

In addition to the traditional calculation of adjusted coefficients of parameters and Student's t-statistic, some other statistical tests were also made. Autocorrelation of residuals were tested using the Durbin-Watson statistic calculated both from the original country-wise data and data sorted into a rising order according to the GDP per capita. Homoscedasticity was tested with the help of the Goldfeld-Quandt test based on splitting one regression residual into two subsamples, one with low and the other with high values of explanatory variable, and then calculating an F-ratio of the two variances (see Goldfeld and Quandt 1965). Since the consumption models included a lagged endogenous variable, special attention was paid to detecting the consequences of possible multicollinearity in them. The approach adapted here was Frisch's Confluence Analysis (Frisch 1934, see also Koutsoyiannis 1973) based on the value $r_{x_i x_j}$:s, $\bar{R}^2$ and a stepwise procedure to study the effects of new variables on the values of the estimates of parameters and standard errors introduced first in the consumption models. The importance of differences between different data clusters were tested by using analysis of variance.

4.4 Estimation Results

4.4.1 Newsprint

The results of the regression analyses and statistical tests for newsprint are presented in Appendix 3. It should be noted that the coefficients Y_t, P_t, and P'_t refer to the short-term elasticities. Based on Nerlove's partial adjustment theory (Nerlove 1958) it was possible to calculate the long-term elasticities presented in Table 2. The coefficient of adjustment (λ) measures the velocity of adjustment. Although it is impossible to calculate the number of periods required for a complete adjustment (the function used is asymptotic with regard to time), it is possible to choose some arbitrary percentage of adjustment and calculate the number of periods required to reach it, or to calculate the percentage of adjustment after a certain number of periods. According to Nerlove and Addison (1958), the number of periods (N) required for adjustment to within, e.g., 5% of the long-term equilibrium level may be determined by the formula

$$(1 - \lambda)^N = 0.05 \ , \tag{18}$$

where λ is the coefficient of adjustment (or 1 minus the coefficient of the C_{t-1} variable) and N the number of periods required. This method was later been used by, among others, Yadav (1975) for calculating elasticities for the following periods.

TABLE 2. Estimated long-term elasticities for newsprint.

Data group	Long-term elasticities			Coefficient of adjustment (λ)	Percentage of adjustment after 3 years - % -
	Income	Own-price	Cross-price		
All data 1965–80	+0.84	−0.30	+0.06	0.64	95
Years 1965–72	+1.13	−0.18	+0.03	0.77	99
Years 1973–80	+1.04	−0.17	+0.11	0.84	100
GDP per capita* < USD 1000	+1.02	−0.28	+0.09	0.58	92
GDP per capita USD 1001–3000	+1.19	−0.73	+0.02	0.36	74
GDP per capita > USD 3000	+0.59	−0.04	+0.01	0.71	98
EEC region	+0.75	−0.45	+0.36	0.57	92

* GDP per capita in year 1980, measured in US dollars at 1970 prices.

The estimated parameters for C_{t-1} and Y_t differed in all cases significantly from zero even at the 0.99 confidence level. Own price-variable was important at the 0.90 confidence level in all other cases except for the income group GDP per capita > USD 3000, whereas cross-price elasticity was important only for the years 1973–80 and the EEC region (see Appendix 3).

In general, income elasticity tended to decrease over time and with increasing GDP per capita, although the highest income elasticity was measured in the group GDP per capita USD 1001–3000. Own-price elasticities varied between −0.04 (richest countries) and −0.73 (medium-income countries). The latter figure depends heavily on the low coefficient of adjustment (short-term elasticity only −0.26), which indicates a strong dependency on past consumption (or the habitual nature of consumption) rather than a high price sensitivity. The EEC region, which predominantly imports newsprint, seems to be more price-sensitive than the average of countries.

The choice of the period for estimation affected the numerical values of estimates. Over the entire period 1965–80 the price variable appears to have varied more than in 1965–72 or 1973–80. Correspondingly, the value of income elasticity for the complete data set was lower.

4.4.2 Printing and writing papers

The results for printing and writing papers are presented in Appendix 4, and the corresponding long-term elasticities in Table 3. The price variable used to represent prices of substitutes for printing and writing papers was the price of newsprint.

TABLE 3. Estimated long-term elasticities for printing and writing papers.

Data group	Long-term elasticities			Coefficient of adjustment (λ)	Percentage of adjustment after 3 years - % -
	Income	Own-price	Cross-price		
All data 1965–80	+1.52	−0.00	−0.14	0.61	94
Years 1965–72	+1.25	−0.24	+0.53	0.62	95
Years 1973–80	+1.31	+0.16	−0.27	0.79	99
GDP per capita < USD 1000	+1.47	+0.08	−0.15	0.62	95
GDP per capita USD 1001–3000	+1.42	−0.21	+0.08	0.52	89
GDP per capita > USD 3000	+1.43	−0.01	−0.18	0.87	100
EEC region	+1.56	+0.02	−0.11	0.75	98

Again, the estimated parameters for lagged consumption and income were important in all the models. In contrast with this, own price and substitute price received unexpected signs in several equations, and when they had the expected signs, the coefficients differed significantly from zero in only one case (years 1965–72, see Appendix 4). One reason for this inelasticity may be found in the price series used. The breakthrough of coated printing paper grades which have higher prices made the internal grade structure of printing and writing papers in the 1970s more heterogeneous. The average price, and also the relative price, of printing and writing papers increased; meanwhile the consumption grew strongly due to advantageous developments in end uses and production technology (JP 1984). Additionally, the use of newsprint price as substitute for printing and writing paper was a somewhat arbitrary choice made in the lack of better variables. Actually, newsprint and other printing papers compete strongly only in a few end uses.

The income elasticities measured were notably higher than for newsprint (between 1.25 and 1.56 compared with 0.59 to 1.19 for newsprint). There was no clear tendency in respect of GDP per capita or time; income elasticities were in most cases between 1.3 and 1.5, the highest numerical value being for the EEC region.

Since the values of own-price and cross-price elasticities were largely meaningless, the effects of multicollinearity were cautiously tested. With the help of Frisch's Confluence Analysis and a stepwise regression procedure it was noticed that multicollinearity did not affect the regressions; price elasticities did not change much regardless of the set of variables used in the regressions.

4.4.3 Wrapping and packaging papers and boards

The data material for wrapping and packaging papers and sack paper was more concise than for newsprint and printing and writing paper, consisting of 14 developed countries and 11 years. The estimation results are presented in Appendix 5 and the long-term elasticities in Table 4.

Lagged consumption and income were important variables in explaining consumption except for the highest income group, whereas own-price and substitute-price variables were not important at all, having either wrong signs or too large a standard error (see Appendix 5).

The almost complete inelasticity of consumption to price changes may be a consequence of the low value of packaging materials in relation to the total value of the final products to be packed, or the total costs of the whole distribution system. No single variable could be found which unambiguously explained the complete substitution mechanism; prices of packaging materials may be of minor importance compared with, e.g., traditional packaging and/or the distribution system replaced by a new alternative system.

The use of the price of LDPE as substitute price also has some disadvantages. First, the substitution effects of LDPE are limited to a number of products (mainly wrapping papers) only. In the case of cartonboards, LDPE can even be considered as a complementary product, because boards used for packaging liquids are normally coated with LDPE.

TABLE 4. Estimated long-term elasticities for wrapping and packaging papers and boards.

Data group	Long-term elasticities			Coefficient of adjustment (λ)	Percentage of adjustment after 3 years - % -
	Income	Own-price	Cross-price		
All data 1970–80	+0.62	–0.10	–0.03	0.71	98
Years 1970–75	+0.93	–0.03	–0.16	0.53	90
Years 1976–80	+0.82	+0.19	–0.09	0.65	96
GDP per capita < USD 3000	+1.27	–0.11	–0.32	0.57	92
GDP per capita > USD 3000	+0.28	–0.02	+0.05	0.81	99
EEC region	+0.62	–0.07	–0.18	0.71	98

Second, the technological development in the manufacture of shrink foils and other films from LDPE was not taken into account when constructing price series. Today it is possible to produce many times more plastic film from the same quantity of LDPE than in the early 1970s (Volpert 1982).

Income elasticity for wrapping and packaging papers and boards behaved as expected; it decreased with increasing GDP per capita and also over time. Compared with cultural papers, the income elasticities were even somewhat lower than those measured for newsprint.

4.4.4 Sack paper

The results of regressions for sack paper are shown in Appendix 6 and the corresponding long-term elasticities in Table 5. It can be seen that in this case short-term and long-term elasticities were quite similar due to the high values of the coefficient of adjustment.

In most cases the estimates of parameters for lagged consumption were significantly different from zero at the 0.90 confidence level. The price of LDPE had a positive sign in all equations, but the standard errors were too large to make it an important explanatory variable. Income elasticities for the highest income group and the EEC region were negative, indicating that sack paper has already passed the saturation phase of its life cycle and is thus an inferior commodity on high income levels.

Price elasticities varied between –0.26 and –0.56, which means that sack paper was the most price-sensitive of the four paper grades investigated here. It was also the bulkiest product of those studied here. Similarly to newsprint, the EEC region is a major importer of sack paper, and it accounted for the most negative value.

TABLE 5. Estimated long-term elasticities for sack paper.

Data group	Long-term elasticities			Coefficient of adjustment (λ)	Percentage of adjustment after 3 years - % -
	Income	Own-price	Cross-price		
All data 1970–80	+0.12	−0.46	+0.21	0.61	94
Years 1970–75	+0.60	−0.36	+0.15	0.80	99
Years 1976–80	+0.18	−0.26	+0.15	0.67	96
GDP per capita < USD 3000	+0.69	−0.53	+0.02	0.64	95
GDP per capita > USD 3000	−0.07	−0.26	+0.15	0.78	99
EEC region	−0.37	−0.56	+0.13	0.96	100

5. COMPARISON OF RESULTS WITH OTHER STUDIES

5.1 Background

There are not very many international studies dealing with elasticity measurement from paper consumption models. The studies referred to here include FAO (1960), FAO (1977a), Buongiorno (1978), and Wibe (1984), whose results are compared with the results of Suhonen (1984) discussed earlier in this paper. It should be remembered that strict comparisons between different studies may sometimes be confusing because of different composition of countries, different deflation methods and exchange rate manipulations, different time periods for observations, as well as different explanatory variables used in the consumption models. From the Global Trade Model's point of view it is, however, important to compile the existing results from earlier works to be used as references when establishing relationships between consumption, prices, substitute prices, income, and other possible demand shifters for the final GTM.

5.2 Income Elasticities

Income elasticities had been measured already in an early work by FAO (1960), where a clear tendency of decreasing income elasticities with increasing GDP/GNP per capita was found. Elasticities were measured by using time-series data of both individual countries and cross-sectional comparisons between countries from a model, where income per capita was the only explanatory variable. In a later study by FAO (1977a) it was noted that for cultural papers the highest income elasticities were to be found in high and medium income countries, whereas for industrial paper grades they were found in the low and very low income countries. When price effects and literacy level were taken into account in the model, the income elasticities measured for developing countries drastically decreased.

A summary of income elasticities measured in different studies is presented in Table 6. For comparison, all GNP/GDP per capita figures were converted into constant US$ 1975 prices. It should be noted that the results from Buongiorno (1978) and Suhonen (1984) refer to long-term elasticities, whereas the income elasticities of other studies are to be interpreted as short-term elasticities.

TABLE 6. Comparison of income elasticities measured in different paper consumption studies.

Study/Income Group	Explanatory variables included in the model	Time period	Income elasticity: Newsprint	Income elasticity: Printing and writing papers	Income elasticity: Other paper and board/packaging paper and board
FAO (1960)	Y_t	before 1960			
GNP per capita*					
> US$ 3000			0.4–0.8	0.5–0.8	0.5–1.3
US$ 1500–3000			0.8–1.1	0.9–1.2	0.8–1.6
US$ 750–1500			1.1–1.5	1.2–1.6	1.1–2.0
< US$ 750			1.5–2.9	1.6–2.8	1.5–3.0
FAO (1977a)	Y_t, P_t	1963–73			
GDP per capita					
> US$ 3000			0.7	1.4	1.0
US$ 1500–3000			0.5	1.5	1.4
US$ 700–1500			0.8	1.6	1.7
< US$ 700			0.7	0.7	1.7
Buongiorno (1978)	$Y_t, C_{t-1},$	1963–73			
GDP per capita	P_t, P'_t				
Average	(for cultural		1.0	1.3	1.6
> US$ 2600	papers only)		0.8	1.6	1.4
< US$ 2600			1.1	1.2	1.7
JP/Suhonen (1984)	$Y_t, C_{t-1},$	1965–80			
GDP per capita	P_t, P'_t	(cultural			
Average		papers)	0.8	1.5	0.6
> US$ 4750		1970–80	0.6	1.4	0.3
US$ 1600–4750		(other	1.2	1.4	1.3
< US$ 1600		grades)	1.0	1.5	..
Wibe (1984)	$Y_t, P_t,$	1970–79	•		
GDP per capita	Time				
Average			1.2	1.2	1.2
> US$ 2500			0.9	1.3	1.1
US$ 600–2500			1.4	1.5	1.4
< US$ 600			1.4	1.4	1.1

* at US$ 1975 prices.

For newsprint and industrial grades, there seems to be a falling trend in income elasticity with rising income, whereas in the case of printing and writing papers the highest elasticities seem to be in medium and high income countries. It is also important to include price and/or other variables in the models for developing countries, otherwise the income variable absorbs variation which in reality does not belong to it. These variables include the literacy rate used by FAO (1977a), and a supply availability index, which was found to be an important explanatory variable first by Gregory (1966) and then in a later study by Uutela (1979).

There have also been discussions as to whether the developing countries will follow the same per capita consumption patterns as industrialized countries with increasing income. In another study Wibe (1983) argues that the developing countries do not follow the path set by the already industrialized nations, but have a lower consumption of paper products because of the availability of "new" technologies (e.g., radio, television, plastics, etc.). This was also the *a priori* expectation of a study by Uutela (1979). However, the results were not as expected, but showed instead that the countries reaching a certain GDP per capita level in the 1970s consumed more paper and board per capita than those countries that had reached the same GDP level in the 1950s or 1960s. The interpretation of this surprising result may be that although there are nowadays more substitutes for paper and board than, e.g., in the 1950s, there are, on the other hand, also many more end-use applications (and industries) for paper and board (e.g., computer print-outs, consumer packages).

A conclusion of the different elasticities presented in Table 6 and other experiences gained from practical work is given in Table 7. The assessment is partly subjective and applies only to countries with average economic, cultural, social, etc. conditions. In extreme cases the values of elasticities may considerably differ from those in Table 7. However, they may give the reader some indication of the magnitude of income elasticities in different product groups and income classes.

5.3 Own-Price Elasticities

Price elasticities tend to vary quite a lot depending on the product, country group, time period for measurement and, as was shown in Section 3, the way the price variable is valued. Therefore, the price elasticity estimates compiled in Table 8 must be interpreted very carefully. FAO (1977a) and Buongiorno (1978) concluded that in low-income countries, which normally also import most of their paper products, the consumption is seriously affected by price increases. Suhonen (1984) found only very small correlations with income levels; the price variable was not significant at all for printing and writing papers and wrapping and packaging papers, and only slightly significant for newsprint and sack paper.

Any conclusions as to the numerical level of price elasticities of Table 8 are difficult to make. However, newsprint seems to be the most price-sensitive and printing and writing paper may be the less price-

TABLE 7. Conclusion of the numerical values of income elasticities based on earlier studies and practical experiences from forecasting work.

Income group	Newsprint	Printing and writing papers	Other Paper and board/packaging paper and board
High income (GDP per capita > US$ 3000)	0.4–0.8	1.0–1.5	0.3–1.2
Medium income (GDP per capita US$ 1500–3000)	0.6–1.2	1.2–1.8	1.0–1.6
Low income (GDP per capita < US$ 1500)	0.7–1.5	0.7–1.5	1.4–2.0

TABLE 8. Comparison of own-price elasticities measured in different paper consumption studies.

Study/Income Group	Explanatory variables included in the model	Time period	Own-price elasticity: News-print	Own-price elasticity: Printing and writing papers	Own-price elasticity: Other paper and board/packaging paper and board
FAO (1977a)	Y_t, P_t	1963–73			
GNP per capita					
> US$ 3000			−0.2	−0.3	-0.1
US$ 1500–3000			−0.3	+0.1	−0.1
US$ 750–1500			−0.5	−0.3	−0.3
< US$ 750			−0.8	−1.2	−0.7
Buongiorno (1978)	$Y_t, C_{t-1},$	1963–73			
GDP per capita	P_t, P'_t				
Average	(for cultural		−0.7	−0.5	−0.7
> US$ 2600	papers only)		−0.6	−0.2	−0.3
< US$ 2600			−0.8	−0.7	−0.8
JP/Suhonen (1984)	$Y_t, C_{t-1},$	1965–80			
GDP per capita	P_t, P'_t	(cultural			
Average		papers)	−0.3	−0.0	−0.1
> US$ 4750		1970–80	−0.3	+0.1	−0.1
US$ 1600–4750		(other	−0.7	−0.2	−0.0
< US$ 1600		grades)	−0.0	−0.0	..
Wibe (1984)	Y_t, P_t	1970–79			
GDP per capita	Time				
Average			−1.1	−0.8	−0.9
> US$ 2500			−2.6	−0.4	−1.3
US$ 600–2500			−0.7	−0.5	−0.3
< US$ 600			−0.6	−1.1	−1.4

sensitive product. The studies by FAO (1977a) and Suhonen (1984), where the same deflation method but different time periods were used, produced results of largely the same magnitude. Wibe's (1984) study prices resulted in the most negative price elasticities.

5.4 Cross-Price Elasticities

The results from the few paper consumption studies which include substitute prices as an explanatory variable are not very encouraging. In FAO's (1977a) study even the sign of the cross-price elasticity was, against the *a priori* expectation, negative in most equations. Newsprint accounts for the best results; for industrial grades, there is only one international study known to the author that deals with substitute prices. The results from three studies are presented in Table 9. The prices of substitutes used in all three studies were printing and writing paper price for newsprint and vice versa, and LDPE price for packaging paper and board in the study by Suhonen (1984).

The poor results are partly explained by the choice of substitute variables. As discussed earlier in this paper, prices of different materials as such may not be decisive factors for buying or consumption decisions for paper and board; there are many intervening variables such as labor intensity and costs, flexibility of use, or product performance, which together determine the ranks between different alternatives. It is a question of *system substitution* rather than *product or price substitution*. For this reason, the traditional price theory may not be able to explain paper and board consumption.

The effects of real substitutes for paper and board, such as new electronic information media or plastic-based packaging systems, are extremely difficult to quantify and include as explanatory variables in consumption models. There are hardly any statistics which could measure these relationships. Even the national input–output statistics normally have too rough a classification of products and industries for paper and board substitution analysis. The best applicable method might be a market research approach; it would require product by product a thorough analysis of the most important end-use sectors to understand their decision-making patterns and buying practices. This would not be possible without extensive field work based on interviews and deep discussions with people in the relevant branches.

TABLE 9. Comparison of cross-price elasticities measured in different paper consumption studies.

Study/Income Group	Explanatory variables included in the model	Time period	Cross-price elasticity: Newsprint	Cross-price elasticity: Printing and writing papers	Cross-price elasticity: Other paper and board/packaging paper and board
FAO (1977a)	Y_t, P_t	1963–73			
GNP per capita	P'_t,				
> US$ 3000	literacy rate		+0.1	−0.6	..
US$ 1500–3000			−0.0	−0.3	..
US$ 750–1500			+0.3	−0.6	..
< US$ 750			+0.1	−0.0	..
Buongiorno (1978)	Y_t, C_{t-1},	1963–73			
GDP per capita	P_t, P'_t				
Average			+0.1	+0.3	..
> US$ 2600			+0.0	+0.2	..
< US$ 2600			+0.4	+0.3	..
JP/Suhonen (1984)	Y_t, C_{t-1},	1965–80			
GDP per capita	P_t, P'_t	(cultural			
Average		papers)	+0.1	−0.1	+0.0
> US$ 4750		1970–80	+0.0	−0.2	+0.1
US$ 1600–4750		(other	+0.0	+0.1	−0.3
< US$ 1600		grades)	+0.1	−0.2	..

6. CONCLUSIONS

The basic aim of this paper was to compile some practical results from income and price elasticity measurement. The following conclusions can be drawn:

- The numerical values of income and price elasticities are sensitive to the explanatory variables included, deflation methods and exchange rate treatment used for converting income and price variables into constant prices and a common currency, as well as the time period for observations in international models. So far, too little attention has been paid to these data manipulations before undertaking the numerical estimation.
- Short-term and long-term elasticities should be distinguised; the consumption of many paper and board grades is habitual and does not react to changes in income and/or prices immediately, i.e., within one year. Thus the use of dynamic models (e.g., the partial adjustment model) for measuring elasticities would be preferable.
- The velocity of adjustment to changes in income and prices is faster in high income countries than in low income countries. The adjustment processes seem also to accelerate with time, which may be an indication of growing flexibility because of increasing supply of commodities and tightening competition in a society.
- The use of country-specific dummy variables in pooled cross-sectional and time-series models is essential; otherwise the measured price and income elasticities may absorb some of the variations caused by other variables omitted from the regression, which results in serial correlation of the regression residuals; i.e., the numerical values of elasticities will be meaningless. In some earlier studies, the statistical properties of consumption models are not discussed in detail, leaving the reader dubious as to the validity of the results.
- Elasticities tend to change with income levels and over time. The use of constant elasticities for a period longer than 10 years may lead to unrealistic forecasts.
- Income (GDP per capita) is the most important explanatory variable for all paper grades, except grades that have already passed their saturation level (e.g., sack paper in industrialized countries). The numerical values of income elasticities vary on both sides of unity; when using the three-grade classification the lowest values are for newsprint and the highest for printing and writing papers (industrialized countries) or for industrial paper and board (developing countries).
- With increasing income, there is a tendency for the income elasticities of newsprint and industrial grades to fall. In the case of printing and writing papers, the highest income elasticities seem to be in the medium income class; the elasticities for the high income group also exceed unity in most countries.

- Own-price elasticities measured vary a lot depending on the time period, model type, and price variable used for observations. Of the different paper grades studied here, sack paper and newsprint were the most price-sensitive and printing and writing papers the least price-sensitive products. This is an indication of decreasing importance of price when the unit value of products grows; the bulkier the product, the more price-sensitive it seems to be. It is also evident that price becomes all the more important a variable as the level of disaggregation of products grows. Net importing countries seem also to be more price-sensitive than self-sufficient countries.
- Price elasticities seem to decrease over time and with increasing income. The inelasticity of consumption of some grades is likely to be the result of the lack of cheap substitutes for paper products. The high price elasticities measured for developing countries may, at least partly, be caused by insufficient supply restricting consumption rather than the price level as such.
- The results of the use of substitute prices for paper products are not very encouraging. It is extremely difficult to find appropriate substitutes for paper products which could be measured in quantitative terms. It is also questionable as to whether the conventional consumer price theory can be used to explain system substitution where many other non-price factors may be more decisive than material prices alone for consumption choices.
- Substitution of forest products for other commodities will be the Achilles' heel in the demand analysis for GTM of FSP. The future of mature industries, as the forest industries are, may depend more on the ability to compete successfully with other commodities than changes in external economic conditions. Therefore, the emphasis of the demand forecasting for GTM should be in substitution analysis, because the current knowledge substitution mechanisms for forest products is too limited. Any attempt using different approaches to substitution would be welcome.

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APPENDIX 1. Estimation results of models for total paper and board consumption in the Federal Republic of Germany in 1964–1982.

EQ. no.	Model type	Estimation results Constant	Time	GNP	Price	$\overline{R}^2$	D-W	SE
1.	Static model, nominal price	1.891 (0.493)***	-	1.369 (0.119)***	–0.152 (0.039)***	0.958	1.909	0.037
2.	Static model, constant price, US deflator	3.887 (0.322)***	-	1.102 (0.071)***	–0.225 (0.069)***	0.951	1.908	0.040
3.	Static model, constant price, German deflator	2.797 (0.321)***	-	1.291 (0.099)***	–0.227 (0.057)***	0.959	2.040	0.037
4.	Static model, constant price, US deflator adjusted for exchange rates	5.266 (1.282)***	-	0.813 (0.110)***	–0.176 (0.122)	0.927	1.608	0.049
5.	Static model, constant price, German deflator adjusted for exchange rates	5.599 (0.671)***	-	0.977 (0.051)***	–0.399 (0.114)***	0.953	2.364	0.039
6.	Dynamic model (t), nominal price	1.712 (1.450)	–0.001 (0.011)	1.396 (0.249)***	–0.147 (0.055)***	0.955	1.874	0.038
7.	Dynamic model (t), constant price, US deflator	0.248 (1.043)	–0.022 (0.006)***	1.779 (0.196)***	–0.235 (0.052)***	0.972	2.161	0.030
8.	Dynamic model (t), constant price, US deflator adjusted for exchange rates	1.721 (1.359)	–0.029 (0.008)***	1.599 (0.229)***	–0.299 (0.097)*	0.959	2.083	0.036
17.	Dynamic model (t), constant price, German deflator	1.087 (1.258)	–0.011 (0.008)	1.573 (0.223)***	-0.195 (0.060)***	0.961	1.863	0.036
18.	Dynamic model (t), constant price, German deflator adjusted for exchange rates	3.391 (1.786)*	–0.011 (0.009)	1.312 (0.257)***	–0.332 (0.122)**	0.955	2.159	0.038
19.	Dynamic model (C_{t-1}), nominal price	2.067 (0.729)**	–0.129 (0.157)	1.549 (0.225)***	–0.166 (0.044)***	0.946	1.722	0.038
20.	Dynamic model (C_{t-1}), constant price, US deflator	4.442 (0.677)***	–0.157 (0.172)	1.261 (0.200)***	–0.237 (0.074)**	0.937	1.744	0.042
21.	Dynamic model (C_{t-1}), constant price, US deflator adjusted for exchange rates	5.862 (1.584)***	–0.057 (0.205)	0.823 (0.232)***	–0.200 (0.129)	0.907	1.598	0.050
22.	Dynamic model (C_{t-1}), constant price, German deflator	3.242 (0.581)***	–0.181 (0.155)	1.515 (0.210)***	–0.250 (0.062)***	0.950	1.916	0.037
23.	Dynamic model (C_{t-1}), constant price, German deflator adjusted for exchange rates	6.046 (0.932)***	–0.106 (0.166)	1.069 (0.176)***	–0.404 (0.120)***	0.940	2.288	0.041

Notes: The figures in the parenthesis are standard errors of the coefficients. ***, **, and * indicate coefficients that significantly differ from zero at the 0.99, 0.95, and 0.90 confidence levels, respectively. $\overline{R}^2$ is the adjusted coefficient of determination, D-W the computed Durbin-Watson statistic and SE the standard error of the regression.

APPENDIX 2. Estimation results of models for newsprint consumption in the Federal Republic of Germany in 1964–1982.

EQ. no.	Model type	Estimation results						
		Constant	Time	GNP	Price	$\bar{R}^2$	D-W	SE
9.	Static model, nominal price	−1.681 (0.404)***	-	1.643 (0.092)***	−0.159 (0.028)***	0.976	2.284	0.035
10.	Static model, constant price, US deflator	0.280 (0.311)	-	1.369 (0.067)***	−0.220 (0.052)***	0.967	1.889	0.041
11.	Static model, constant price, German deflator	−0.697 (0.321)**	-	1.515 (0.082)***	−0.198 (0.040)***	0.972	2.184	0.038
12.	Static model, constant price, US deflator adjusted for exchange rates	2.622 (0.999)***		1.106 (0.090)***	−0.275 (0.099)**	0.953	1.450	0.049
13.	Static model, constant price, German deflator adjusted for exchange rates	1.295 (0.445)***	-	1.242 (0.056)***	−0.274 (0.069)***	0.965	1.915	0.043
14.	Dynamic model (t), nominal price	−2.355 (1.443)	−0.005 (0.010)	1.755 (0.248)***	−0.144 (0.041)***	0.975	2.205	0.036
15.	Dynamic model (t), constant price, US deflator	−3.387 (1.208)***	−0.022 (0.007)***	2.000 (0.211)***	−0.179 (0.044)***	0.979	2.486	0.033
16.	Dynamic model (t), constant price, US deflator adjusted for exchange rates	−2.124 (1.823)	−0.025 (0.009)**	1.815 (0.284)***	−0.209 (0.085)**	0.968	1.805	0.041
24.	Dynamic model (t), constant price, German deflator	−2.387 (1.387)*	−0.014 (0.009)	1.878 (0.238)***	−0.157 (0.046)***	0.975	2.177	0.036
25.	Dynamic model (t), constant price, German deflator adjusted for exchange rates	−1.368 (2.183)	−0.014 (0.011)	1.655 (0.336)***	−0.199 (0.090)**	0.966	1.772	0.042
26.	Dynamic model (C_{t-1}), nominal price	−1.999 (0.559)***	−0.105 (0.147)	1.838 (0.263)***	−1.176 (0.036)***	0.969	2.331	0.036
27.	Dynamic model (C_{t-1}), constant price, US deflator	0.281 (0.363)	−0.107 (0.183)	1.515 (0.275)***	−0.239 (0.067)***	0.956	1.889	0.043
28.	Dynamic model (C_{t-1}), constant price, US deflator adjusted for exchange rates	2.746 (.1.147)**	0.017 (0.207)	0.969 (0.245)***	−0.269 (0.118)**	0.939	1.556	0.051
29.	Dynamic model (C_{t-1}), constant price, German deflator	−0.939 (0.435)**	−0.171 (0.168)	1.793 (0.283)***	−0.231 (0.053)***	0.964	2.316	0.039
30.	Dynamic model (C_{t-1}), constant price, German deflator adjusted for exchange rates	1.412 (0.497)**	−0.101 (0.189)	1.362 (0.259)***	−0.294 (0.088)***	0.953	1.937	0.045

Notes: see Appendix 1.

APPENDIX 3: Consmption models for newsprint

	Estimates of parameters									
	Constant	C_{t-1}	Y_t	P_t	P'_t	$\bar{R}^2$	D-W	G-Q	n	ANOVA (F^{*})
Complete data set,	−1.468	+0.364	+0.536	−0.190	+0.041	0.987	2.52	0.18	640	
years 1965–1980		(0.035)***	(0.058)***	(0.048)***	(0.046)			(1.38)		
Years 1965–1972	−3.894	+0.228	+0.868	−0.138	+0.020	0.990	2.67	0.19	320	
		(0.052)***	(0.061)***	(0.106)*	(0.060)			(1.76)		
Years 1973–1980	−4.165	+0.163	+0.875	−0.139	+0.092	0.987	2.70	0.42	320	1.16
	*	(0.055)**	(0.060)***	(0.061)**	(0.053)**			(1.76)		
GDP per capita	−2.480	+0.425	+0.592	−0.163	+0.053	0.964	2.35	0.52	272	
< US$ 1000		(0.052)***	(0.062)***	(0.077)**	(0.065)			(1.63)		
GDP per capita	−0.862	+0.638	+0.429	−0.261	+0.008	0.965	2.07	1.10	176	635.7***
US$ 1001–3000		(0.049)***	(0.070)***	(0.054)***	(0.051)			(1.86)		
GDP per capita	−0.955	+0.289	+0.422	−0.027	+0.009	0.880	1.89	1.66	192	
> US$ 3001		(0.070)***	(0.066)***	(0.072)	(0.061)			(1.81)		
EEC countries	−1.311	+0.426	+0.427	−0.258	+0.203	0.976	2.38	1.68	128	
		(0.072)***	(0.090)***	(0.066)***	(0.076)***			(2.12)		

Notes: The figures in the parenthesis under the coefficients are standard errors. ***, **, and * indicate coefficients that significantly differ from zero at the 0.99, 0.95, and 0.90 confidence levels, respectively.

$\bar{R}^2$ = adjusted coefficient of determination

D-W = Durbin-Watson statistic

G-Q = Goldfeld-Quandt statistic (figures in the parenthesis refer to the relevant percentage points of the F-distribution)

n = number of observations

ANOVA =computed F-statistic.

APPENDIX 4: Consumption models for printing and writing papers.

	Estimates of parameters									
	Constant	C_{t-1}	Y_t	P_t	P'_t	$\overline{R}^2$	D-W	G-Q	n	ANOVA (F^{α})
Complete data set,	−4.916	+0.389	+0.928	−0.003	−0.085	0.986	2.01	0.19	640	
years 1965–1980		(0.035)***	(0.055)***	(0.041)	(0.043)**			(1.36)		
Years 1965–1972	−4.830	+0.376	+0.773	−0.151	+0.330	0.993	1.87	0.16	320	
		(0.050)***	(0.063)***	(0.059)***	(0.101)***			(1.76)		
Years 1973–1980	−5.213	+0.213	+1.038	+0.123	−0.212	0.985	2.07	0.17	320	9.22***
		(0.052)***	(0.070)***	(0.060)**	(0.070)***			(1.76)		
GDP per capita	−4.839	+0.384	+0.914	0.052	−0.092	0.941	2.04	0.44	272	
< US$ 1000		(0.055)***	(0.093)***	(0.069)	(0.086)			(1.63)		
GDP per capita	−3.745	+0.477	+0.739	−0.108	+0.039	0.950	1.99	0.58	176	
US$ 1001–3000		(0.064)***	(0.115)***	(0.078)*	(0.075)			(1.86)		1040.8***
GDP per capita	−6.176	+0.126	+1.246	−0.005	−0.159	0.908	1.79	0.37	192	
> US$ 3001		(0.071)**	(0.114)***	(0.069)	(0.065)***			(1.81)		
EEC countries	−6.262	+0.252	+1.169	+0.014	−0.082	0.956	1.76	0.40	128	
		(0.081)***	(0.139)***	(0.076)	(0.075)			(2.12)		

Notes: see Appendix 3.

APPENDIX 5: Consumption models for wrapping and packaging papers and boards.

	Estimates of parameters									
	Constant	C_{t-1}	Y_t	P_t	P'_t	$\bar{R}^2$	D-W	G-Q	n	ANOVA (F^{α})
Complete data set,	+0.162	+0.294	+0.443	−0.074	−0.023	0.935	2.25	1.16	154	
years 1970–1980		(0.082)***	(0.149)***	(0.069)	(0.063)			(2.09)		
Years 1970–1975	−1.138	+0.474	+0.491	−0.017	−0.086	0.914	1.88	0.83	84	
		(0.117)***	(0.123)***	(0.081)	(0.086)			(9.28)		4.51***
Years 1976–1980	−1.896	+0.350	+0.533	+0.126	−0.061	0.943	1.97	2.15	70	
		(0.094)***	(0.087)***	(0.077)*	(0.067)			(9.28)		
GDP per capita	−2.000	+0.431	+0.725	−0.062	−0.182	0.938	1.97	0.43	55	
< US$ 3000		(0.129)***	(0.231)***	(0.087)	(0.095)**			(5.05)		116.6***
GDP per capita	+1.557	+0.190	+0.224	−0.016	+0.041	0.861	1.76	0.80	99	
> US$ 3001		(0.108)**	(0.188)	(0.093)	(0.079)			(2.69)		
EEC region	+0.219	+0.295	+0.441	−0.051	−0.128	0.660	2.19	1.62	77	
		(0.113)**	(0.191)**	(0.102)	(0.078)*			(3.79)		

Notes: see Appendix 3.

APPENDIX 6: Consumption models for sack paper.

	Estimates of parameters									
	Constant	C_{t-1}	Y_t	P_t	P'_t	$\overline{R}^2$	D-W	G-Q	n	ANOVA (F*)
Complete data set,	+0.959	+0.392	+0.073	−0.280	+0.126	0.741	2.08	1.73	154	
years 1970–1980		(0.077)***	(0.039)**	(0.125)**	(0.088)*			(2.09)		
Years 1970–1975	−1.953	+0.205	+0.477	−0.287	+0.112	0.825	2.07	5.14	84	
		(0.135)*	(0.127)***	(0.157)**	(0.135)			(9.28)		
Years 1976–1980	+0.407	+0.329	+0.122	−0.171	+0.100	0.582	1.90	3.15	70	13.54***
		(0.103)***	(0.068)**	(0.248)	(0.149)			(9.28)		
GDP per capita	−0.501	+0.364	+0.442	−0.340	+0.010	0.734	2.29	1.25	55	
< US$ 3000		(0.131)***	(0.178)***	(0.196)**	(0.149)			(5.05)		
GDP per capita	+1.865	+0.218	−0.053	−0.202	+0.119	0.733	1.96	4.20	99	9.91***
> US$ 3001		(0.105)*	(0.298)	(0.184)	(0.131)			(2.69)		
EEC region	+6.443	+0.037	−0.356	−0.533	+0.124	0.769	2.12	0.84	77	
		(0.121)	(0.091)***	(0.144)***	(0.084)*			(3.79)		

Notes: see Appendix 3.