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ORIGINAL ARTICLE

Socioeconomic factors influencing global paper and paperboard demand

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Abstract To clarify the socioeconomic factors influencing global paper and paperboard demand, a panel data analysis was conducted covering the period 1961–2014. This study used paper and paperboard demand as the dependent variable, and a country's economic level, Internet usage rate, plastic packaging demand, and time trend as the explanatory variables. An inverse U-shaped quadratic relationship, such as an environmental Kuznets curve, was found between economic level and paper and paperboard demand, which saturates and begins to decline as economic level increases. The economic level representing the turning point differs significantly with the use, ranging from around 37,000 US$/person for newsprint paper to around 66,000 US$/person for printing and writing paper. For both newsprint paper and printing and writing paper, demand declines owing to the spread of the Internet as the economic level rises, although this reductive effect is greater for printing and writing paper than for newsprint paper. A substitution relationship is not found between wrapping paper and corrugated cardboard on the one hand and plastic packaging on the other hand as the economic level becomes higher.

Keywords Panel data analysis · Economic level · Environmental Kuznets curve · Internet · Plastic packaging

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Introduction

The use of wood helps to mitigate climate change by storing carbon, substituting materials, and substituting energy [1]. On the other hand, over-harvesting of wood raises concerns about impacts on forest biodiversity and carbon storage [2]. This study focuses on one use of wood—for paper and paperboard. The global pulp and paper industry is one of the largest consumers of energy [3] after the petrochemical, steel, and cement industries. As such, the pulp and paper industry has an impact on climate change and resource depletion, and is related to various global environmental issues. Therefore, it is important to examine the global environmental impact of the production and consumption of paper and paperboard in the future. Such an examination requires predicting future changes in paper and paperboard demand. To predict such demand, it is essential to clarify the impact of human socioeconomic activity on the demand.

Some earlier studies [4–9] use regression models to analyze the impact of changes in economic level and price on paper and paperboard demand. These studies have demonstrated that an increase in economic level increases the demand while an increase in price decreases demand, and that economic level has a greater impact than price. However, many of these prior studies have examined only linear or log linear regression models. It is possible that some relationships are nonlinear, such as quadratic, cubic, or logarithmic. Nevertheless, such nonlinearity has not often been explored. For the relationship between economic level and resource consumption such as the one for paper and paperboard consumption, a hypothesis known as the environmental Kuznets curve (EKC), generally indicated by an inverse U-shaped quadratic curve, is applied. The

EKC holds that environmental burdens increase during initial periods of economic development, but these burdens tend to be mitigated or reduced after a certain level of economic development has been attained [10]. Resource consumption brings about various environmental burdens throughout material life cycles, including the production, transportation, and disposal of resources. For this reason, several studies [11–14] have investigated the presence of the EKC between economic level and resource consumption. Examining whether an EKC-type relationship displaying saturation and subsequent decline exists between economic level and paper and paperboard consumption provides an important insight into the future prediction of the demand. However, almost no cases of prior research provide a detailed examination of this. Although Kayo et al. [15, 16] showed the existence of an EKC relationship between economic level and paper and paperboard demand, they mainly focused on advanced countries; as such, the global situation, including that of developing countries, remains unclear.

Other strands of the literature have assessed the impact of changes in demand for substitute materials on paper and paperboard demand. In particular, prior research [17–21] exists that analyzes the impact of electronic media, such as computers and the Internet, on newsprint paper and printing and writing paper demand. Zhang and Buongiorno [17] reported that the spread of electronic media, such as computers, in the United States between 1960 and 1991 had no impact on the demand for paper. However, the impact from electronic media recently has been confirmed, with Hujala [19] reporting that globally, the spread of the Internet has caused a decline in demand for newsprint paper, while the spread of computers has driven an increase in demand for office paper. On the other hand, Latta et al. [20] reported that the spread of the Internet has caused the demand for newsprint paper to decline, while in the United States and other OECD countries, the demand for printing and writing paper has also declined. Thus, there are various conflicting claims on the impact from electronic media; the relationship has not been clarified and further research is needed. Moreover, wrapping paper and corrugated cardboard are thought to have a substitution relationship with plastic packaging. Relevant prior research includes a report [22] on the United States between 1983 and 1991, which shows there is no clear substitution relationship between them. However, the recent global situation has yet to be clarified.

In view of the issues raised by such prior research, this study focuses on economic level and substitute materials, and aims to clarify the socioeconomic factors that influence paper and paperboard demand globally.

Materials and methods

Overview of methods

We categorized the following five uses of paper and paperboard: (1) newsprint paper, (2) printing and writing paper, (3) sanitary paper, (4) wrapping paper and corrugated cardboard, and (5) other paper and paperboard. We analyzed the impact of socioeconomic factors on each use. Specifically, we first considered the impact of economic level by positing several regression models, such as quadratic models. We performed a panel data analysis (regression analysis using panel data) for each use of paper and paperboard, taking per capita demand as the dependent variable and per capita real GDP (hereafter real GDP is called "GDP") as the explanatory variable. Next, to examine the impact of substitute material, we performed a panel data analysis adding the Internet usage rate, per capita plastic packaging demand, and time trend as explanatory variables. Stata version 13 [23] was used for the statistical analysis.

Data

For our analysis, we used the longest period for which the various data were obtainable for countries (and regions) around the world. The per capita demand (t/person) for each use of paper and paperboard in each country was calculated using production, import and export data from the Food and Agriculture Organization of the United Nations (FAO) [24] to find the apparent consumption (=production + import − export), and dividing this by the population data obtained from the World Bank [25]. In the FAO [24] data, we examined "newsprint" for newsprint paper, "printing and writing papers" for printing and writing paper, "household and sanitary papers" for sanitary paper, "wrapping and packaging paper and paperboard" for wrapping paper and corrugated cardboard, and "other paper and paperboard n.e.s" for other paper and paperboard. These statistical data rely on reports from the governments of each country, but some countries are often unable to report statistics to the FAO. In such cases, the FAO often records the previous year's data for that country as a provisional estimate. In the statistical data of such countries, production and consumption do not respond to changes in socioeconomic factors and do not reflect actual conditions [9]. Therefore, we excluded such countries' data for paper and paperboard from our analysis to avoid the influence of provisional estimate values from our analysis and to improve the reliability of the data. Specifically, where the ratio of provisional estimates in each country's data was 50% or higher, or where the same data were

recorded for 4 or more consecutive years, we assumed the reported statistics to be unreliable and excluded them. We also excluded from the analysis any data in which one or more of the production, import, or export data were missing, and data for which apparent consumption was negative. For the economic level indicator, we used per capita GDP data (constant 2005 US$/person), obtained from the World Bank [25]. As an indicator for the spread of electronic media, we used the Internet usage rate (%), and obtained the data from the International Telecommunication Union [26] for "percentage of individuals using the Internet". This item shows the ratio of Internet users within the total population of a country, and the population aged 5 years and over. Other items relating to electronic media include "percentage of households with Internet", "percentage of individuals using a computer", and "percentage of households with computer". However, we did not use these items due to their paucity of data. Per capita plastic packaging demand (t/person) was calculated by obtaining the apparent consumption from the United Nations [27] data on production and the United Nations [28] data on imports and exports, and then dividing this by the population [25]. To determine the production volume, we looked at the items "boxes, cases, crates, and similar packing articles of plastics" and "sacks and bags of plastics". Imports and exports were based on the items "boxes, cases, crates, etc. of plastic" and "sacks and bags (including cones) of polymers of ethylene". Data in which the apparent consumption was negative were excluded from the analysis. The descriptive statistics for each data set used in the analysis are shown in Table 1.

Panel data analysis

Impact of economic level on paper and paperboard demand

We conducted a panel data analysis with per capita paper and paperboard demand as the dependent variable and per capita GDP as the explanatory variable. We assumed that demand equals apparent consumption. The regression models were the linear, quadratic, cubic, and logarithmic models shown in the equations, respectively, below:

$$D_{it} = a + b_1 \mathrm{GDP}_{it} + c_i + e_{it} \quad (1)$$

$$D_{it} = a + b_1 \mathrm{GDP}_{it} + b_2 \mathrm{GDP}_{it}^2 + c_i + e_{it} \quad (2)$$

$$D_{it} = a + b_1 \mathrm{GDP}_{it} + b_2 \mathrm{GDP}_{it}^2 + b_3 \mathrm{GDP}_{it}^3 + c_i + e_{it} \quad (3)$$

$$D_{it} = a + b_4 \ln \mathrm{GDP}_{it} + c_i + e_{it} \quad (4)$$

where D represents per capita demand for paper and paperboard for each use, GDP represents per capita GDP, a represents a constant term, b_1, b_2, b_3, and b_4 represent regression coefficients, c represents the unique characteristics of each country, e represents an error term, i represents the country, and t represents time (years). The period 1961–2014 was covered for this analysis (Table 1).

Table 1 Descriptive statistics for data used in the analysis

Variable	Period	*n*	*N*	Mean	Min.	Max.	Std. Dev.
Per capita newsprint paper demand (t/person)	1961 to 2014	92 (OECD: 22, BRIICS: 4, the others: 66)	2330	0.01083	0	0.09691	0.01437
Per capita printing and writing paper demand (t/person)		104 (OECD: 23, BRIICS: 5, the others: 76)	2728	0.02083	0	0.2133	0.02732
Per capita sanitary paper demand (t/person)		84 (OECD: 25, BRIICS: 5, the others: 54)	1636	0.0007023	0	0.04679	0.007622
Per capita wrapping paper and corrugated cardboard demand (t/person)		113 (OECD: 28, BRIICS: 4, the others: 81)	2379	0.03843	0	0.2567	0.04027
Per capita other paper and paperboard demand (t/person)		66 (OECD: 17, BRIICS: 4, the others: 45)	1487	0.007371	0	0.1071	0.01181
Per capita GDP (constant 2005 US$/person)		199 (OECD: 35, BRIICS: 6, the others: 158)	8278	9379	50.04	158803	15468
Internet usage ratio (%)	1990 to 2014	226 (OECD: 35, BRIICS: 6, the others: 185)	4566	20.34	0	98.32	4.660
Per capita plastic packaging demand (t/person)	1995 to 2013	25 (OECD: 16, BRIICS: 1, the others: 8)	341	0.005315	0	0.06480	0.006543

n represents the number of target countries (and regions) in the analysis, and is the number of countries after excluding some data to increase data reliability. The numbers of countries before data exclusion were 219 for newsprint paper, 231 for printing and writing paper, 201 for sanitary paper, 203 for wrapping paper and corrugated cardboard, and 205 for other paper and paperboard. OECD represents the number of OECD member countries, and BRIICS represents the number of BRIICS (Brazil, Russian Federation, India, Indonesia, China, and South Africa) countries. *N* represents the total sample size

To estimate the regression coefficients and constant term, we conducted an ordinary least squares estimation, as well as a fixed-effects estimation considering the unique characteristics of each country and a random-effects estimation. The ordinary least squares estimation method assumes that all countries in the analysis have the same slope and constant term, and the method does not depend on the unique characteristic of each country. On the other hand, the fixed-effects estimation considering the unique characteristics of each country assumes the same slope for all countries, but with different constant terms for each. The random-effects estimation assumes that the unique characteristics are probability variables rather than constant terms. As a result, in the ordinary least squares estimation, c_i in formulas (1)–(4) is not considered equal to 0, while in the fixed-effects estimation, it is considered a constant that differs for each country and in the random-effects estimation, it is assumed a probability variable and estimated by including an error term. We conducted the F test, the Breusch–Pagan test, and the Hausman test on each of these estimation methods, and determined the most appropriate estimation method. The F test tests the null hypothesis that ordinary least squares estimation is more suitable than fixed-effects estimation; if this hypothesis is rejected, then fixed-effects estimation is adopted. The Breusch–Pagan test tests the null hypothesis that ordinary least squares estimation is more suitable than random-effects estimation; if this hypothesis is rejected, then random-effects estimation is chosen. The Hausman test tests the null hypothesis that random-effects estimation is more suitable than fixed-effects estimation; if the hypothesis is rejected, then fixed-effects estimation is selected.

Having conducted the panel data analysis as described above, we selected the regression model that could best explain the data from among those whose regression coefficients were all statistically significant as those with the highest coefficients of determination with adjusted degrees of freedom (adj. R^2). Furthermore, we used Akaike's information criterion (AIC) for model selection and confirmed the lowest AIC model to be consistent with the highest adj. R^2 model.

Impact of substitute materials on paper and paperboard demand

We conducted a panel data analysis using the regression models shown in the following equations:

$$\mathrm{Dnp}_{it} = a + b_5\mathrm{GDP}_{it} + b_6\mathrm{INT}_{it} + b_7\mathrm{GDP}_{it} \times \mathrm{INT}_{it} + b_8T_{it} + c_i + e_{it} \quad (5)$$

$$\mathrm{Dw}_{it} = a + b_9\mathrm{GDP}_{it} + b_{10}\mathrm{PLA}_{it} + b_{11}\mathrm{GDP}_{it} \times \mathrm{PLA}_{it} + b_{12}T_{it} + c_i + e_{it} \quad (6)$$

where Dnp represents per capita newsprint paper demand or per capita printing and writing paper demand, INT represents Internet usage ratio, T represents the time trend, Dw represents per capita wrapping paper and corrugated cardboard demand, and PLA represents per capita plastic packaging demand. b_5, b_6, b_7, b_8, b_9, b_{10}, b_{11}, and b_{12} are regression coefficients. $\mathrm{GDP}_{it} \times \mathrm{INT}_{it}$, and $\mathrm{GDP}_{it} \times \mathrm{PLA}_{it}$ are interaction terms. The period 1990–2014 was covered for model (5) and 1995–2013 for model (6) (Table 1).

The interaction terms of per capita GDP and substitute materials (Internet usage ratio and per capita plastic packaging demand) were introduced to analyze whether the impact of Internet use and plastic packaging demand on paper and paperboard demand changes with economic level. In addition, to check for the existence of other factors exerting an impact on paper and paperboard demand, a time trend was incorporated as a surrogate variable. Using the variance inflation factor (VIF), we examined the possibility of multicollinearity among the explanatory variables and found it to be unlikely, because VIF was less than 5 for models (5) and (6).

We estimated the regression coefficients and constant term using ordinary least squares estimation, fixed-effects estimation, and random-effects estimation as outlined above, and determined the most suitable estimation method by the F test, Breusch–Pagan test, and Hausman test.

Results

Impact of economic level on paper and paperboard demand

Figure 1 shows actual per capita paper and paperboard demand against per capita GDP for target countries and periods. The results of the panel data analysis by models (1)–(4) are shown in Table 2. For each regression model, only the results of the estimation methods deemed most suitable from the three tests are presented. For newsprint paper, printing and writing paper, and sanitary paper, when comparing per capita demand and per capita GDP, the adj. R^2 was highest for the quadratic model displaying an inverse U-shape, confirming the statistical significance of the regression coefficient. This adj. R^2 for this quadratic model was 0.5198 for newsprint paper, 0.6081 for printing and writing paper, and 0.4670 for sanitary paper. For wrapping paper and corrugated cardboard, the adj. R^2 was highest for the cubic model at 0.6144; however, the regression coefficient was not statistically significant. Accordingly, the inverse U-shaped quadratic model, which has the next highest adj. R^2 of 0.6134, which is also statistically significant,

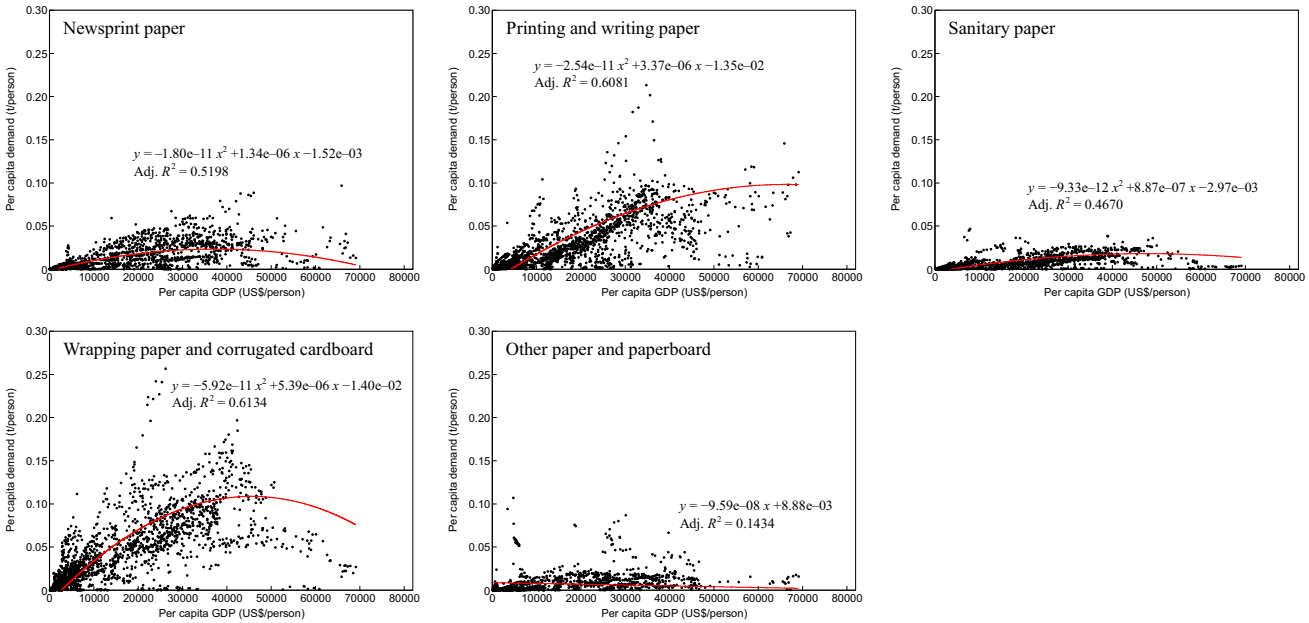

Fig. 1 Per capita paper and paperboard demand versus per capita GDP for target countries covering the period 1961–2014. *Solid lines* represent the regression models judged to have the best explanatory power (the quadratic model for newsprint paper, printing and writing paper, sanitary paper, and wrapping paper and corrugated cardboard; the linear model for other paper and paperboard). Adj. R^2 denotes the adjusted coefficient of determination

Table 2 Results from analysis of the impact of economic level on paper and paperboard demand

Use	Regression model	Estimation method	Adj. R^2	a	b_1	b_2	b_3	b_4
Newsprint paper	Linear	Fixed	0.4798	6.36e−03**	3.49e−07**	–	–	–
	Quadratic	Random	0.5198	−1.52e−03*	1.34e−06**	−1.80e−11*	–	–
	Cubic	Random	0.5195	−1.72e−03	2.28e−17**	−2.01e−11**	1.39e−06	–
	Logarithmic	Random	0.4378	−3.12e−02**	–	–	–	4.67e−03**
Printing and writing paper	Linear	Fixed	0.5858	−3.34e−03**	1.86e−06**	–	–	–
	Quadratic	Fixed	0.6081	−1.35e−02**	3.37e−06**	−2.54e−11**	–	–
	Cubic	Fixed	0.6007	−1.87e−01**	4.51e−06**	−6.67e−11**	4.19e−16**	–
	Logarithmic	Fixed	0.4625	−1.78e−01**	–	–	–	2.34e−02**
Sanitary paper	Linear	Random	0.3677	1.30e−03	2.88e−07**	–	–	–
	Quadratic	Fixed	0.4670	−2.97e−03**	8.87e−07**	−9.33e−12**	–	–
	Cubic	Random	0.4667	1.10e−03	1.22e−07	1.56e−11**	−2.37e−16**	–
	Logarithmic	Fixed	0.4020	−3.78e−01**	–	–	–	4.98e−03**
Wrapping paper and corrugated cardboard	Linear	Random	0.5055	5.76e−03**	1.78e−06**	–	–	–
	Quadratic	Fixed	0.6134	−1.40e−02**	5.39e−06**	−5.92e−11**	–	–
	Cubic	Fixed	0.6144	−1.26e−02**	5.11e−06**	−4.94e−11**	−9.84e−17	–
	Logarithmic	Fixed	0.5091	−2.91e−02**	–	–	–	3.76e−02**
Other paper and paperboard	Linear	Fixed	0.1434	8.88e−03**	−9.59e−08*	–	–	–
	Quadratic	Fixed	0.1468	8.95e−03**	−1.04e−07	1.37e−13	–	–
	Cubic	Random	0.1648	1.53e−04	1.26e−06**	−4.36e−11**	4.11e−16**	–
	Logarithmic	Fixed	0.1456	6.66e−03	–	–	–	9.44e−05

"Fixed" denotes fixed-effects estimation and "Random" denotes random-effects estimation. Adj. R^2 denotes the adjusted coefficient of determination

**,* 1 and 5% significance levels, respectively. The numbers of countries (n) and the total sample size (N) were 92 and 2112 for newsprint paper, 104 and 2607 for printing and writing paper, 84 and 1601 for sanitary paper, 113 and 2300 for wrapping paper and corrugated cardboard, and 66 and 1451 for other paper and paperboard, respectively

was judged to have the best explanatory power. The turning points for economic level at which the per capita demand begins to decline were, from lowest to highest, 37,222 US$/person for newsprint paper, 45,523 US$/person for wrapping paper and corrugated cardboard, 47,534 US$/person for sanitary paper, and 66,339 US$/person for printing and writing paper. For other paper and paperboard, only the linear model showed statistical significance for every regression coefficient, and a linear declining trend was confirmed. However, for this linear model, the adj. R^2 was only 0.1434.

Impact of substitute materials on paper and paperboard demand

Figure 2 shows actual per capita paper demand against Internet usage ratio for target countries and periods. The results of the panel data analysis by model (5) are presented in Table 3. Only the results of the estimation methods deemed most suitable from the three tests are presented. For both newsprint paper and printing and writing paper, the Internet usage regression coefficients (b_6) were positive, while the regression coefficients (b_7) for the interaction terms of per capita GDP and Internet usage ratio were negative. In other words, as per capita GDP increased, the increase in the Internet usage ratio depressed per capita demand more strongly. In newsprint paper, the regression coefficient for the Internet usage ratio was 5.17e−05 and the regression coefficient of the interaction term was −2.44e−09. In printing and writing paper, the regression coefficient for the Internet usage ratio was 7.29e−05 and the regression coefficient of the interaction term was −5.14e−09. This shows that the reductive effect (b_6 + b_7 × GDP) on per capita demand from an increase in the Internet usage ratio was greater for printing and writing paper (7.29e−05 − 5.14e−09 × GDP) than for newsprint paper (5.17e−05 − 2.44e−09 × GDP). For newsprint paper, the regression coefficient (b_5) for per capita GDP was negative although the statistical significance of the regression coefficient was not confirmed. Conversely, for printing and writing paper, the per capita GDP regression coefficient was a positive value, confirming the statistical significance. Furthermore, the regression coefficient (b_8) for the time trend in newsprint paper was negative, confirming its statistical significance, while the regression coefficient of the time trend in printing and writing paper was not statistically significant.

Figure 3 shows actual per capita wrapping paper and corrugated cardboard demand against per capita plastic packaging demand for target countries and periods. The results of the panel data analysis by model (6) is shown in Table 4, which presents only the result from the most suitable estimation method as determined by the three tests. The regression coefficient (b_{10}) for per capita plastic packaging demand was positive (4.00e−01), and the regression coefficient (b_{11}) for the interaction term of per capita GDP and per capita plastic packaging demand was negative (−2.18e−05), but the statistical significance was not confirmed. The regression coefficient (b_{12}) for the time trend was positive and its statistical significance was confirmed.

Discussion

Impact of economic level on paper and paperboard demand

The results (Table 2) of the panel data analysis by models (1)–(4) show that globally, demand for newsprint paper, printing and writing paper, sanitary paper, and

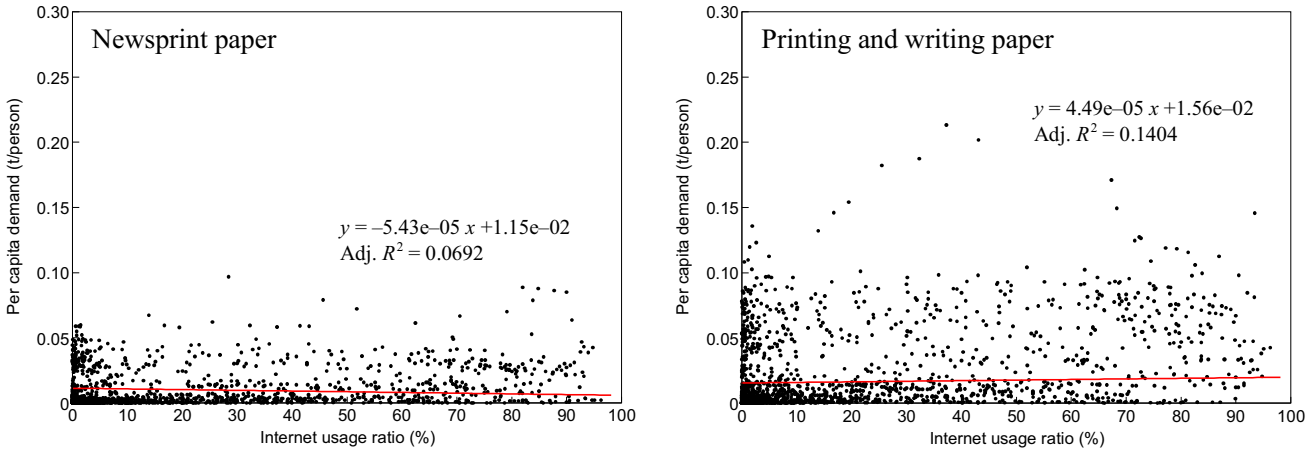

Fig. 2 Per capita paper demand versus Internet usage ratio for target countries covering the period 1990–2014. *Solid lines* represent the linear regression models. Adj. R^2 denotes the adjusted coefficient of determination

Table 3 Results from analysis of the impact of Internet use on demand for newsprint paper and printing and writing paper

Use	Estimation method	Adj. R^2	a	b_5	b_6	b_7	b_8
Newsprint paper	Fixed	0.3713	1.67e−02**	−1.25e−07	5.17e−05*	−2.44e−09**	−1.00e−04*
Printing and writing paper	Fixed	0.5767	4.52e−03	1.11e−06**	7.29e−05*	−5.14e−09**	7.07e−05

"Fixed" denotes fixed-effects estimation. Adj. R^2 denotes the adjusted coefficient of determination

**, * 1 and 5% significance levels, respectively. The numbers of countries (n) and the total sample size (N) were 92 and 1450 for newsprint paper, and 104 and 1810 for printing and writing paper, respectively

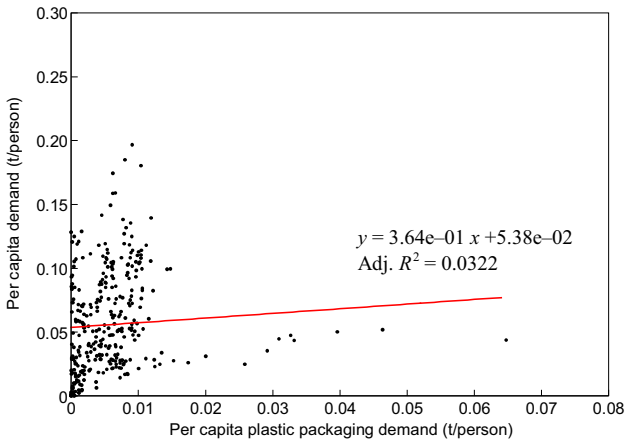

Fig. 3 Per capita wrapping paper and corrugated cardboard demand versus per capita plastic packaging demand for target countries covering the period 1995–2013. *Solid line* represents the linear regression model. Adj. R^2 denotes the adjusted coefficient of determination

wrapping paper and corrugated cardboard tends to saturate and decline as the economic level rises. Prior research [15, 16] has already confirmed this trend in advanced countries, but it is now clear that the same phenomenon is occurring globally, including in developing countries. However, the economic level at which demand begins to decline differs by use, ranging from a minimum of 37,222 US$/person for newsprint paper to a maximum of 66,339 US$/person for printing and writing paper. Moreover, these values were more than double the average economic level in the analysis target countries for 2014 (11,381–13,204 US$/person). This indicates that the economic level must rise considerably before demand begins to decline, and that it is necessary to consider the significant differences in the demand turning points between different paper and paperboard uses. Moreover, the adj. R^2 was more than 0.6 for printing and writing paper and wrapping paper and corrugated cardboard, and around 0.5 for newsprint paper and sanitary paper. This indicates that while the economic level is an important factor influencing demand for these four paper uses, there is also an effect from other socioeconomic factors, such as the price of each use of paper and paperboard, education level, urbanization, industrial structure, lifestyle, and culture for paper usage. On the other hand, the adj. R^2 for other paper and paperboard was only around 0.1, suggesting that economic level alone is not sufficient to explain demand.

Impact of substitute materials on paper and paperboard demand

The results (Table 3) of the panel data analysis by model (5) show that newsprint paper and printing and writing paper have a substitution relationship with the Internet as the economic level rises. However, the reductive effect of Internet use on printing and writing paper begins to manifest at a relatively low economic level while the effect on newsprint paper is not observed until the economic level has risen substantially. Specifically, the economic levels are 14,183 US$/person or more [(7.29e−05 − 5.14e−09 × 14,182) > 0 > (7.29e−05 − 5.14e−09 × 14,183)] and 21,189 US$/person or more [(5.17e−05 − 2.44e−09 × 21,188) > 0 > (5.17e−05 − 2.44e−09 × 21,189)], respectively. Conversely, Hujala [19] reported that the spread of the Internet has reduced demand for newsprint paper, but has had a negligible impact on the demand for printing and writing paper. Latta et al. [20] showed that the spread of the Internet has driven the decline in demand for newsprint paper, while only in the United States and other OECD countries has the demand for printing and writing

Table 4 Results from analysis of the impact of plastic packaging demand on demand for wrapping paper and corrugated cardboard

Use	Estimation method	Adj. R^2	a	b_9	b_{10}	b_{11}	b_{12}
Wrapping paper and corrugated cardboard	Random	0.6034	6.21e−03	2.00e−06**	4.00e−01	−2.18e−05	8.20e−04**

"Random" denotes random-effects estimation. Adj. R^2 denotes the adjusted coefficient of determination

**, * 1 and 5% significance levels, respectively. The numbers of countries (n) and the total sample size (N) were 24 and 323, respectively

paper also decreased. For our analysis, we covered more countries and more recent years (104 countries for the period 1990–2014) than previous studies have (50 countries for the period 1990–2007 [19]; 6 major world regions for the period 1970–2011 [20]). As a result, we surmise that globally in recent years, a substitution relationship with Internet use is observed both for newsprint paper and for printing and writing paper. However, because the models used for the regression analysis differ from those of previous studies, more detailed comparison between them is difficult. In newsprint paper, there is a possibility that as per capita GDP increased, the per capita demand decreased for the period 1990–2014 from the results (Table 3) by model (5). When we conducted the regression analysis using only per capita GDP as the explanatory variable for that period for model (5), the regression coefficient for per capita GDP was negative, confirming the statistical significance. This indicates that the demand for newsprint decreased as economic level rose in recent years after 1990. Looking at the time trend, in newsprint paper, the regression coefficient for the time trend was negative and was confirmed to be statistically significant. This demonstrates the presence of other factors with a reductive effect on demand, such as advances in technology for reducing the weight of newsprint paper, the reorientation towards digital media in the advertising industry, and improvement of Internet line speed. Meanwhile, in printing and writing paper, the time trend was not statistically significant, indicating that the impact on demand from other factors with a time trend is insignificant.

With regard to wrapping paper and corrugated cardboard and plastic packaging from the results (Table 4) by model (6), we do not observe a clear substitution relationship emerging as the economic level increases. Prior research [22] reported that there was no clear replacement relationship in the United States between 1983 and 1991. The global situation including in recent years supports that in the present study. With regard to the time trend, the regression coefficient is positive and statistically significant, demonstrating the presence of other factors increasing wrapping paper and corrugated cardboard demand, such as merchandise distribution.

Conclusion

This study clarified the impact of socioeconomic factors on paper and paperboard demand over the entire world from 1961 to 2014 to facilitate future projections of paper and paperboard demand. The main findings of the study are as follows.

1. For newsprint paper, printing and writing paper, sanitary paper, and wrapping paper and corrugated cardboard, an inverse U-shaped quadratic model had the best explanatory power for the per capita demand against per capita GDP. In other words, as the global economic level rises, the paper and paperboard demand tends to saturate, and begins to decline at a certain point. However, the turning point varies widely by paper use from about 37,000 US$/person for newsprint paper to about 66,000 US$/person for printing and writing paper. The economic level must increase considerably before the demand begins to decline.
2. Both newsprint paper and printing and writing paper have a substitution relationship with Internet use as the economic level rises. However, the reductive effect of Internet usage is greater on the demand for printing and writing paper than newsprint paper; their demand begins to decline at an economic level of about 14,000 US$/person and 21,000 US$/person, respectively, due to Internet usage.
3. There is no clear substitution relationship between wrapping paper and corrugated cardboard and plastic packaging as the economic level changes.
4. Future projections for paper and paperboard demand could be more accurate by considering the economic level (the EKC relationship) as well as GDP, Internet usage, and time trend as socioeconomic factors explaining demand.

A limitation of this study is that the regression model employed is restricted to reflecting a symmetrical relationship, such as a quadratic relationship, between economic level and paper and paperboard demand. In other words, the model cannot express an asymmetrical relationship, such as a sharp increase in demand followed by a gradual decline, thus meriting further investigation. Furthermore, the level of adj. R^2 and the statistical significance of the regression coefficient for time trend demonstrate the presence of unidentified influencing factors. Therefore, an analysis considering a larger number of socioeconomic factors is likely to be important going forward.

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