FORECASTS OF WASTEPAPER SUPPLY AND CONSUMPTION IN THE UNITED STATES TO 1985[1]

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ABSTRACT

Recycling of wastepaper is a partial solution to the solid waste management problem and a source of fibrous material in the production of paper and board products. Unlike virgin fiber, wastepaper is the result of past paper and board consumption. To consider these important facts and others affecting wastepaper supply and consumption, a model of the paper and board industry inclusive of wastepaper recycling was constructed. The results of application of this model showed that wastepaper supply and consumption can vary widely depending on the future recovery rates and utilization levels of wastepaper by the paper industry. By assuming the most optimistic wastepaper recovery and utilization increases by 1985, a domestic wastepaper supply shortfall is forecasted. However, the most likely future wastepaper utilization scenario indicates a surplus of wastepaper by 1985 given average recovery rates. The model can be used to consider a broad range of wastepaper recovery and utilization situations and alternative economic growth rates.

Keywords: Paper recycling, pulp and paper industry, forecasting, econometrics.

INTRODUCTION

The demand for paper and paperboard products and subsequent disposal of those products are of prime interest to the paper industry and others concerned with paper solid waste disposal and recovery. Recovery and reuse of wastepaper as fibrous input for the paper industry are important for many paperboard and construction paper and paperboard products and less so for paper products.

In this nation, recovery and use of wastepaper as input into various paper and paperboard manufacturing processes are well established. Prior to 1860, old cotton fiber paper, straw and rags were the main raw inputs for the paper industry. Today the paper industry's fibrous inputs are significantly different with roundwood and wood residues accounting for 80% of the total fibrous inputs. Wastepaper and other nonwood fibrous material contribute the balance. Despite the decline of wastepaper relative to virgin pulp in paper and board production, total tons of wastepaper consumed during 1950–1975 increased from 7.2 million tons (metric) to 10.7 million tons. In 1975 wastepaper represented approximately 8% of fibrous material used in total paper production, 25% of fibrous material used in paperboard and construction paper and board production (Colletti 1978).

Forecasts of wastepaper demand and supply are needed to assess possible future wastepaper use, fiber substitution, production costs, and environmental damage resulting from paper solid waste. The paper industry's demand for wastepaper during the next decade depends upon the growth of the general economy, relative demand for paper and paperboard products utilizing wastepaper and technical changes which result in increased consumption of wastepaper instead of virgin pulp.

This paper presents the results of a study undertaken to comprehend better the wastepaper market and its role within the pulp and paper industry. A model of the pulp and paper industry was developed describing the flow of wastepaper from consumption of paper and paperboard products through disposal, recovery, and finally back into paper and paperboard production (Colletti 1978). The model was used to simulate various wastepaper supply and demand scenarios over a ten-year period.

To be able to forecast wastepaper supply and demand, one must forecast paper and paperboard consumption. Thus, following a brief overview of the computer model, consumption of paper, paperboard, and construction paper and paperboard is discussed. This is followed by a discussion of wastepaper recovery and utilization and by forecasts of wastepaper supply and use to the year 1985. It would be difficult to provide reliable forecasts for longer periods, particularly given the currently very unstable economic conditions.

OVERVIEW OF THE MODEL

An econometric-linear programming model was used to forecast annual wastepaper demand and supply to 1985 based on data for the period 1950–1976. The structure of the entire model is summarized in Table 1, where the variables used are also defined. More details regarding the model, as well as specific parameter estimates can be found in Colletti (1978).

The demand equations (Table 1, Eq. 1) assume that long-run demand for paper and paperboard is determined by the level of economic activity. In the short-run, demand adjusts only partially to GNP changes. Demand equations were estimated by econometric methods for each of nineteen major groups of paper and paperboard products (Table 2). Although the hypothesis that demand is also affected by prices was examined, all statistical tests were negative. Further research is being done on this subject, particularly in view of recent results, based on international evidence indicating a significant negative elasticity of demand with respect to price (Buongiorno 1978).

Paper and paperboard prices were estimated by cost-plus margin models (Table 1, Eq. 2). The price equations represent the relationship between output price and input costs of fibrous material, chemicals, machinery, labor, energy, consumer demand, past prices, and general economic indicators.

Production costs (Table 1, Eq. 3) were estimated by a product-specific weighted input cost function. The relationship was derived from industry estimates of average input costs by product (U.S. EPA 1976; Little 1976).

Pulp, paper, and board capacity formation (Table 1, Eq. 4) was modeled with annual year-end capacity as the dependent variable. An attempt was made to relate current capacity, past idle capacity, past paper and board demand, capital

TABLE 1. *Structure of econometric-linear programming model of the U.S. pulp and paper industry.*

A. Equations

1. Demand:

$$APPCON_{ij} = a_1 + a_2 * GNP_j + a_3 * APPCON_{ij-1}$$

2. Price level:

$$WPI_{ij} = f(Y_{ij}, WPI_{ij-n}, ICOST_{ijk}, GE_j)$$

3. Variable costs of production:

$$VCOS_{ij} = (P_i * (w_1 * WPIxx_{ij} + w_2 * WPICHM_j + w_3 * WPILPA_j$$
$$+ w_4 * WPIMAC_j + w_5 * WPIPOW_j) * K * S$$

4. Capacity formation:

$$CAP_{ij} = f(GNP_j, WPIxx_{ij-n}, APPCON_{ij-n}, CAP_{ij-n}, WTCC_j)$$

5. Production decisions:

$$Min\ C'X$$
$$Subject\ to\ AX \leq B$$
$$and\ X \geq 0$$

6. Wastepaper disposal profile:

$$THRU_{ij} = d_1 * APPCON_{ij} + d_2 * APPCON_{ij-3} + d_3 * APPCON_{ij-8}$$

B. Variable definitions
(in order in which they appear in equations 1 through 6)

$APPCON_{ij}$	= apparent consumption of paper product i in year j (in metric tons).
GNP_j	= per capita gross national product (1967 dollars) in year j
$a_k, k = 1, 2, 3$	= estimated coefficients.
WPI_{ij}	= estimated price of product i in year j ($/metric ton).
Y_{ij}	= consumer demand for product i in year j.
WPI_{ij-n}	= price of product i, lagged n years.
$ICOST_{ijk}$	= input costs of k factors, including raw materials, labor, power, and chemicals.
GE_j	= general economic indicators, including gross national product, disposable income, production of durable and nondurable goods.
$VCOS_{ij}$	= production cost of paper product i in year j ($/metric ton).
P_i	= estimated production cost of product i in 1967 (quoted selling prices for all nineteen paper products in 1967 were adjusted by the 1976 ratio of production costs to selling prices for each product).
$w_k, (k = 1, \ldots, 5)$	= factor input ratios where $\sum_{k=1}^{5} w_k = 1.0$
$WPIxx_{ij}$	= wholesale price indices of the following six pulp and wastepaper types (i = 1, . . . , 6):
$WPIUAT_j$	= wholesale price index of unbleached sulfate pulp (1967 = 100).
$WPIFAT_j$	= wholesale price index of bleached sulfate pulp (1967 = 100).
$WPIFIT_j$	= wholesale price index of bleached sulfite pulp (1967 = 100).

TABLE 1. *Structure of econometric-linear programming model of the U.S. pulp and paper industry.*

$WPIGD_j$	= wholesale price index of groundwood pulp (1967 = 100).
$WPIOCC_j$	= wholesale price index of old corrugated containers (1967 = 100).
$WPIWST_j$	= wholesale price index of all wastepaper (1967 = 100).
$WPICHM_j$	= wholesale price index of industrial chemicals (1967 = 100).
$WPILPA_j$	= wholesale price index of labor in paper and allied products (1967 = 100).
$WPIMAC_j$	= wholesale price index of materials for nondurable manufacturing (1967 = 100).
$WPIPOW_j$	= wholesale price index of fuel and power (1967 = 100).
K	= constant used to obtain production costs in dollars.
S	= coefficient of cost savings used to insure production costs below selling prices. This is a necessary condition, at least in the long-run.
CAP_{ij}	= total capacity of pulp, paper or board product i in year j (metric tons).
$WPIxx_{ij\text{-}n}$	= wholesale price indices of various pulp, paper or board types, lagged n years (1967 = 100).
$APPCON_{ij\text{-}n}$	= apparent consumption of paper product i, lagged n years.
$CAP_{ij\text{-}n}$	= total capacity of pulp, paper or board product i, lagged n years.
$WTCC_j$	= computed weighted cost of capital.
C'	= a 1 × N (row) vector of production costs associated with the various paper and paperboard production activities.
X	= N × 1 vector of production and import variables.
A	= an M × N matrix of technical coefficients.
B	= an M × 1 vector of right-hand side constraints (demand, fiber availability, import limits, capacity).
$THRU_{ij}$	= amount (tons) of paper product i entering the solid waste stream in year j.
$d_k, k = 1, 2, 3$	= estimated disposal coefficients, in general $\sum\limits_{k=1}^{3}$ $d_k < 1$.

costs, and national economic indicators. Results were mixed, with equations explaining 92 to 99% of the variance of capacity during the period of observation, except for unbleached sulfite pulp (R^2 = 0.65) and soda, screenings, etc. (R^2 = 0.35).

A linear programming production function was used to determine annual domestic production plus balancing imports (Table 1, Eq. 5). The model assumed that the industry minimizes total variable production cost of meeting annual demand subject to fiber availability, production capacity, and pulp and paper import constraints. Input-output coefficients were adapted from Zabel (1975).

TABLE 2. *Paper and board products considered in the study.*

Paper Type

Newsprint
Uncoated groundwood paper
Coated paper
Uncoated book paper
Fine paper
Unbleached Kraft packaging and industrial converting
Other packaging and industrial converting
Tissue

Paperboard Type

*Recycled linerboard
Virgin linerboard
*Recycled corrugating medium
Semi-chemical corrugating medium
*Recycled container-chipboard
*Recycled folding boxboard
Solid bleached folding boxboard
*Set-up boxboard
*All other board

Construction Paper and Paperboard Type

*Construction paper and board
Wet machine board

* Major users of recycled paper.

Paper produced this year may flow through various stages of disposal, recovery, and reuse in subsequent years. This is called a disposal profile. A typical disposal model has the form of Eq. 6 in Table 1. The disposal coefficients used in the disposal profiles are based on estimates by Darnay and Franklin (1971, 1972).

Product-specific disposal profiles were used to determine the annual amount of wastepaper that could enter the solid waste stream given current paper and board consumption. This potentially available wastepaper was disaggregated into five major wastepaper grades: mixed, newsprint, old corrugated containers, de-inking stock, and high grade (pulp substitutes). Average recovery rates for the period 1950–1972 were applied to all five wastepaper grades mentioned above to yield recovered wastepaper by grade. The annual flow of recovered wastepaper was further reduced to account for fiber degradation and losses in processing (Darnay and Franklin 1969, 1971, 1972; Franklin et al. 1973). The difference between wastepaper theoretically available for use and actual recovered wastepaper (also called paperstock in the paper industry) gave the estimate of paper solid waste.

This model was used to compute paper consumption, variable cost of production, net revenue, product prices, fiber availability, and recovered wastepaper by type for each year from 1950 through the projection period. For brevity, only the forecasting results of paper consumption, fiber availability, and recovered wastepaper will be reported.

TABLE 3. *Observed and forecasted consumption of paper, board, construction paper and board, and all paper and board (millions of metric tons).*

Year	Paper		Paperboard		Construction paper and board (plus wet machine board)		All paper and board	
	O[a]	F[b]	O	F	O	F	O	F
1950	13.6	13.5	9.8	9.7	2.6	2.4	26.0	25.6
1955	15.7	16.7	12.9	13.3	3.3	2.9	31.6	32.9
1960	18.0	17.8	14.5	14.4	3.3	3.0	35.6	35.2
1965	22.9	22.3	18.7	18.1	4.0	3.8	45.4	44.2
1970	27.3	26.1	21.6	20.7	4.2	4.3	53.0	51.1
1975	25.8	29.0	20.4	22.7	4.5	4.8	50.6	56.5
Forecast								
1985		42.3		33.1		7.2		82.6

[a] Observed.
[b] Forecasted.

PAPER CONSUMPTION FORECASTS

Forecasts of paper consumption are independent of the wastepaper recycling scenarios presented in subsequent sections. The predicted total paper and board consumption was 82.638 million tons by 1985 (Table 3). This assumed that per capita gross national product would grow at 3.1% annually from 1977 to 1985. This is slightly lower than Franklin et al.'s (1973) estimate of 83.752 million tons and significantly lower than previous (prerecession) U.S. Forest Service forecasts of 92.061 million tons (Hair 1967), or Slatin's (1972) forecast of 95.303 million tons. Most consumption equations used in the model are tied directly or indirectly to economic activity[2]; thus any perturbation in the economy would cause a change in the consumption of paper.

Wastepaper use is dominant in paperboard manufacture. Specifically, six paperboard products determine the demand for most of the wastepaper consumed in the paper industry. Consumption forecasts indicate limited growth for recycled corrugated medium, recycling folding boxboard, set-up boxboard, and all other paperboard. Decreased consumption is forecasted for recycled linerboard and container-chipboard. Increased consumption of wastepaper must come from alterations in the fiber mixes of paper and board products currently made from virgin pulps or from a reversal of the downward trends of demand for the six paperboard products mentioned above. Such products as newsprint, tissue, printing and writing paper, and construction paper and board are potential candidates for increased wastepaper utilization due to favorable technical and economic factors (Franklin et al. 1973).

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[2] Thirteen of the estimated consumption equations have per capita gross national product (GNP) as an explanatory variable. The remaining equations were found to be independent of economic activity. The models explained 94 to 99% of the variance of apparent consumption over the period of observation, for all products except virgin linerboard ($R^2 = 0.50$), and semi-chemical corrugating medium ($R^2 = 0.62$).

TABLE 4. *Recovery[a] rates—average and increased and percent change by wastepaper category.*

Wastepaper categories	Average (1950–1973)	Increased (1980–1985)	Percent change
Mixed paper	0.09	0.40	344%
Newsprint	0.22	0.45	105%
Old corrugating containers	0.32	0.50	56%
De-inking	0.08	0.13	53%
High-grades-pulp substitute	1.00	1.00	0%

[a] Recovery is defined as the ratio of wastepaper recovered as paperstock to wastepaper generated given specified disposal profiles.

WASTEPAPER RECOVERY AND UTILIZATION

Recovered wastepaper was forecasted under two different assumptions regarding recovery rates. The first one assumed the continuation of past average recovery rates while the second assumed increased recovery rates. The recovery rates assumed in the two cases appear in Table 4. Franklin et al. (1973) provided the recovery rate data by wastepaper category for the period 1950–1973 and estimates of the maximum average recovery rates during the 1980–1985 forecast period. Their increased recovery rates were based on technical feasibility assuming sufficient wastepaper demand.

Wastepaper demand is forecasted assuming two alternative wastepaper utilization patterns—that is, different wastepaper input coefficients, defined as the number of pounds of wastepaper utilized on average to produce a ton of product, are assumed for each paper and board product during the forecast period. The first pattern assumes that the utilization of wastepaper that was observed during the period 1970 to 1975 would continue until 1985.

The second wastepaper utilization pattern assumes that wastepaper is used as much as possible in making all types of paper and paperboard. The result is a large increase in wastepaper utilization. This radical departure from the dominant use of virgin fiber in all paper production may not be economically feasible given present prices, but it is technically feasible (Glassey and Gupta 1974).

Three scenarios combining different wastepaper recovery and utilization alternatives were evaluated for the period 1980 to 1985. In the first scenario, maximum wastepaper recovery of wastepaper from consumed paper and increased wastepaper utilization in paper manufacturing were assumed. Thus, it was an attempt to see what would happen within the paper industry assuming intensive wastepaper recycling.

In Scenario 2, maximum wastepaper recovery was also assumed. However, wastepaper utilization in paper manufacturing was assumed to remain at the average 1970–1975 level. This scenario represents expanded federal and state emphasis on resource recovery (along the lines of the Resource Recovery Act of 1970) and rising popular interest and action in local resources recovery. The paper industry's utilization of wastepaper in paper manufacture would, however, remain the same and there would be no government action to increase it.

Finally, in Scenario 3 it was assumed that wastepaper recovery would proceed at the same rate as during the period 1950–1973, and wastepaper utilization would be similar to that during the period 1970–1975.

In order of occurrence, Scenario 1 is least likely to occur, Scenario 2 is more

TABLE 5. *Observed and forecasted recoverable wastepaper, paper solid waste, domestic wastepaper recovery, wastepaper consumption, imports and surplus wastepaper (million metric tons).*

Year	Wastepaper theoretically available for recovery 1	Total paper solid waste 2	Domestic wastepaper recovery 3	Wastepaper consumption 4	Imports 5	Surplus wastepaper 6
1950	22.3	15.4	7.2	8.4	1.2	—
1955	28.2	20.2	7.6	10.1	2.5	—
1960	30.1	21.9	8.2	10.2	1.9	—
1965	37.0	27.3	9.2	10.5	1.3	—
1970	42.5	31.7	10.9	9.8	—	1.1
1975	46.6	34.9	11.9	10.1	—	1.8
1985 Forecasts						
Scenario 1[a]	66.7	36.7	29.2	46.5[c]	17.4	—
Scenario 2[a]	66.7	36.7	29.2	11.8[d]	—	17.4
Scenario 3[b]	66.7	50.8	15.5	11.8[d]	—	3.7

[a,b] Assume increased and average recovery rates, respectively.
[c,d] Assume increased and average utilization, respectively.

likely to occur, and Scenario 3 is most likely to occur. Thus, the three scenarios represent a range for possible wastepaper recovery and utilization in the future.

FORECASTS OF WASTEPAPER SUPPLY AND UTILIZATION

The amounts of paper theoretically available for recovery, wasted, and recycled, as observed between 1950 and 1975 and predicted by the model, are presented in Table 5. Wastepaper theoretically available for recovery was forecasted to increase from 46.6 million tons in 1975 to 66.7 million tons in 1985. Assuming that past levels in recovery and utilization would continue (Scenario 3), total recovered wastepaper would increase from 11.9 million tons in 1975 to 15.5 million tons in 1985. Assuming increased recovery rates (Scenarios 1 and 2), starting in 1980 total recovered wastepaper would increase to 29.2 million tons by 1985.

Likewise, forecasts of paper solid waste vary according to the assumed recovery rates. It must be noted that despite the drastic increase in recovery assumed by Scenarios 1 and 2, paper solid waste would still increase slightly from 34.9 million tons in 1975 to 36.7 million tons in 1985 due to increased paper consumption. Therefore, some 44% of total paper and board consumption in 1985 would have to be buried, burned, or diverted to alternative uses. If the average recovery rates were to continue, paper solid waste could be as high was 50.8 million tons in 1985, i.e., 61% of the apparent consumption of paper in 1985 would end up as solid waste.

Wastepaper consumption is forecasted to be 11.8 million tons in 1985 (Table 5) if average wastepaper utilization levels (Scenarios 2 and 3) continue. A shift to minimum virgin fiber utilization (Scenario 1) yields a forecast of 46.5 million tons in 1985.

In the model, imports vary as needed to balance domestic wastepaper recovery (supply) and wastepaper consumption.[3] Scenario 2 (high wastepaper recovery, but low utilization) results in a large surplus of wastepaper of as much as 17.4 million tons in 1985. Scenario 1 (high wastepaper recovery, maximum utilization) results in the requirement of excessive wastepaper imports because of limited domestic supply of wastepaper. Specifically, 17.4 million tons in 1985 are needed to meet demand.

If, however, future wastepaper recovery rates and utilization in paper production follow past averages (Scenario 3), wastepaper supply may exceed wastepaper consumption by 3.7 million tons in 1985. Surplus wastepaper could be used for alternative nonpaper uses such as compost, fuel resource, and cattle feed-supplement. In fact, capital investments in large postconsumer recovery system may be justified only by the values associated with these alternative nonpaper uses.

SUMMARY AND CONCLUSIONS

In summary, if the paper industry were to shift to maximum recovery and utilization of wastepaper, as much as 17 million tons of foreign wastepaper would be required for wastepaper supply to balance consumption. Clearly, such a scenario is unlikely to occur since 17 million tons of wastepaper would hardly be available for import from other countries. If wastepaper recovery is encouraged to the maximum possible extent, while papermaking technology remains the same, there could be about 17 million tons of recovered wastepaper available for nonpaper uses by 1985. This is in addition to the 12 million tons required by the industry for paper manufacturing. Finally, from the third Scenario it is suggested that a continuation of average wastepaper recovery rates and utilization levels could result in a surplus of about 4 million tons of wastepaper. In this case the paper industry should have adequate quantities for paper manufacturing.

It is likely that past average recovery rates and average utilization levels of wastepaper will continue until 1985 since there is no large scale effort by the paper industry, the government, or the public to finance a shift toward maximum wastepaper utilization in heretofore virgin fiber products. Additionally, there is no visible pressure to expand production of the six paperboard products that utilize most of wastepaper consumed in the paper industry.

Continued pressure on the environment to assimilate solid wastes, rising disposal costs, and possible use of wastepaper as an energy source may induce increased wastepaper recovery as depicted by Scenarios 1 and 2. If a severe and prolonged oil and natural gas shortage occurs, then increased utilization of paper solid waste as an energy source for power plants is likely. Most of the additional wastepaper generated by commercial and postconsumer sources in large urban areas could be separated and burned by energy-generating plants rather than be used to produce paper products. This complicates any analysis of future wastepaper available for utilization in the paper industry with or without an increase in wastepaper demand.

Despite major problems of forces limiting recovery and utilization of waste-

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[3] Exports of wastepaper are assumed small, constant, and part of domestic wastepaper recovery. Thus, wastepaper consumption = domestic recovery plus imports.

paper, the outlook can have promise, especially if new wastepaper utilizing paper and board manufacturing mills are built. New recycled paper and board mills typically would be smaller in size and require less capital investment per ton of output relative to the typical integrated and forest-based virgin pulp, paper, and board operation. Such mills could be located close to large population centers and linked to a resource recovery facility, thus helping to minimize solid waste and produce needed paper products. Further, there may be cost savings from reduced transportation distances between the manufacturing plants and consumers.

Paper recycling is purported to help conserve forest resources. The possibility of forest resource conservation due to recycling may warrant further study if additional federal forest lands and thus the fibrous raw material for paper production are withdrawn from commercial timber production. Additionally, the potential impact of wood as a prime energy resource on virgin fiber availability and wastepaper utilization in paper production should be investigated.

For the paper industry to increase wastepaper utilization, further research and development on technologically advanced paper processes based on wastepaper are needed. Government and public support in the form of tax incentives, demonstration plants, low-cost government loans, and consumer acceptance of new paper products made from wastepaper would be needed to yield the desired results. Increases in recovered wastepaper would require similar efforts and probably could be obtained in a relatively short time, unlike the time period needed to increase wastepaper utilization through new technology.

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