RECYCLING OF SOLID WASTES - A CLASSIC PROBLEM IN SUPPLY AND DEMAND

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Recycling can recover the value of solid waste materials. Recycling reduces solid wastes, conserves virgin materials, and preserves and improves environmental quality. Ideally, it has been stated that "what we must aim for essentially is a steady-state world, one in which per capita consumption has virtually leveled off and the goods used are for the most part produced from recycled materials" [6]. Trends in recycling, however, are not encouraging, and, in fact, resource recovery is losing ground [3, 7].

Currently, recycling is largely that of relatively homogeneous waste materials. The Council on Environmental Quality has identified over 50 systems in various stages of development aimed primarily at the technology of recovering materials from mixed wastes [7]. It has been stated that the limiting factor to increased use of waste materials is economics – not technology. Economics implies a comparison of the costs of recycling with the value of recycled materials relative to the cost of disposal by other methods.

Factors affecting the supply of, and demand for, processed solid waste materials can be identified, but the exact nature of their effect has not been well established. The purpose of this paper is: (1) to identify certain factors affecting the market for solid waste materials, and (2) to show the possible effect of several policy changes on the supply of, and demand for, waste materials.

OBSTACLES IN THE MARKET SYSTEM

Waste materials have been recycled for many years, resulting in a large recycling industry with a volume in the billions of dollars [2]. Currently only about 5 percent of the waste produced in the United States is collected and then only a portion is recycled. A major obstacle with recyclable materials is market expansion [1]. Accumulated waste materials become junkyards of unsalable salvage unless there are buyers to whom one can sell the inventory at a profit.

When price fulfills its function in a totally impersonal market atmosphere, and all solid waste materials of a given type offered for sale are purchased, an equilibruim market price exists [4]. If a state of equilibrium prices exist, any change in the supply of, or demand for, a specific solid waste material can disrupt the equilibrium conditions.

The core of the problem is one of market development such that increased supplies of waste materials can enter the market channel without causing disruption. Any effort expended on market development requires knowledge of the expected response in supply and demand to various policy alternatives. An analysis of the markets for such products would be concerned with a specification of the demand and supply schedules with factors that cause shifts.

Since most solid waste materials are substitutes for virgin materials, the slope of the demand curve probably is relatively flat. With waste materials being close substitutes, sellers face a demand situation in which, for a given percentage change in price, the quantity demanded will change proportionally more in the opposite direction of the price change. Buyers of solid waste materials probably are facing a relatively flat supply curve, with small changes in price resulting in proportionally greater changes in quantity in the same direction.

Changes in Demand

For recycling to make a significant impact on the solution to the waste disposal problem, the market environment must be improved. Creating and/or improving the demand for solid waste materials tends to shift the demand curve to the right and possibly upward (D D to D' D' in Figure 1). Without shifting

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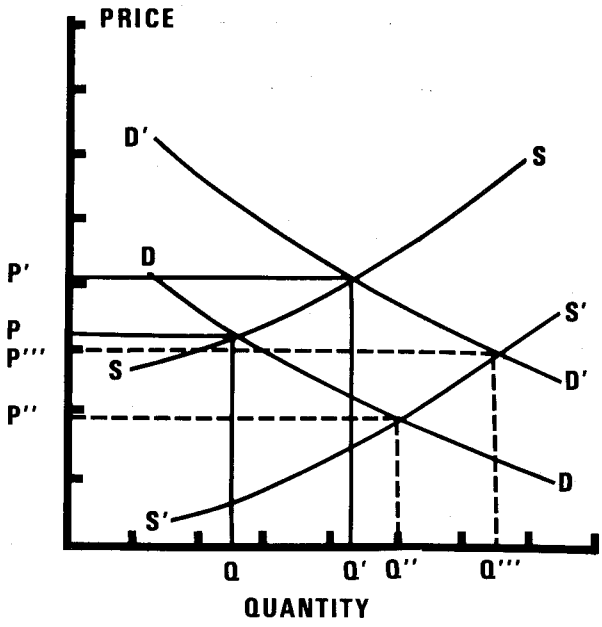

Figure 1. PRICE-QUANTITY RELATIONSHIPS FOR SOLID WASTE MATERIALS RESULTING FROM SHIFTS IN DEMAND AND/OR SUPPLY

the supply schedule, more materials would be sold at a higher price (P' Q' at D' S intersection point). Factors that may shift demand are: (1) improved technology of separating waste materials so that a homogeneous product will be available in a steady and substantial quantity to satisfy buyers' needs, (2) a change in prices of solid waste materials relative to prices for virgin materials, (3) technology and processing of solid waste into usable sources of inputs, (4) development, promotion and specified requirements for new products to be made from waste materials or a blend of waste and virgin materials, and (5) laws and regulations requiring waste materials to recycled and that restrict, through penalties,other methods of disposal.

When solid waste materials are used in competition with virgin materials to make new goods, such waste material must be fairly homogeneous. Individuals, community groups, and municipalities are separating waste into the various separable forms. However, the quantity of waste materials is highly variable and too heterogeneous. Improved machinery and equipment to separate waste materials will solve the technical aspects, but the cost of using such technology will need to be in line with current disposal system costs before municipal governments will shift to recycling.

Increased prices for virgin materials could result from higher transportation rates, depletion of virgin materials, or changes in taxation policies. This could result in a shift in demand for solid waste materials provided the price of virgin materials increases more than that of waste materials.

Many solid waste materials are blends of several raw materials and processes. Technological break throughs in processing of solid waste to make it usable may improve the demand for waste materials. Examples are: (1) the process for deinking scrap paper, and (2) the electric furnace in steel making in which a 100 percent charge of scrap can be used.

Products made from waste materials, if equal to or better in quality and price than those made from virgin materials, could result in shifts in the demand for waste materials. Requirements by some firms and governmental bodies for paper products made from waste paper may shift the demand for waste paper.

Changes in regulations and/or laws may influence the use of solid waste materials. The cost of transporting solid waste materials to processing locations tends to be higher than the cost of transporting virgin materials. Reducing transportation rates for waste materials to make such materials more competitive price-wise could shift demand. Waste paper or scrap metals may be made more competitive with virgin pulp or virgin ores by decreasing the depletion and/or capital gains allowances. This would tend to increase the cost of virgin materials relative to waste materials. However, the elimination of such allowances could reduce exploration for and development of new areas containing virgin materials.

Changes in Supply

Several of the factors shifting the demand for waste materials may shift supply also. If the supply shifts to the right (S S' in Figure 1) without an accompanying shift in demand, the quantity sold Q" would sell at a lower price P". With a shift in both the supply and demand, price equilibrium may be aP''' for the quantity Q'''.

Efficient mechanical separation at a reasonable cost, and if widely adopted, may increase the supply of some waste materials substantially, resulting in a shift in supply. Prior to 1973-1974 there was evidence that with a small increase in the amount of waste paper and some other waste materials, resulting from the emphasis on recycling many buyers had a glut of materials in their yards because of the lack of markets. Waste materials sold at a low price, and in some cases there were no buyers. This result is depicted by the area P"Q" in Figure 1.

SCRAP IRON AND STEEL - AN EXAMPLE

An analysis of the price-quantity relationship of scrap iron and steel purchased for making steel shows

demand relationships that may be expected for some solid waste materials. Iron and steel scrap make up approximately 50 percent of the inputs in steel making [8]. Scrap consists of that purchased from scrap processors and from steel mill returns. Purchased scrap, mill revert, and pig iron are substitutable and complementary inputs in steel making.

The quantity of each used is a function of the quantity of steel manufactured. However, the percent of scrap and pig iron used in furnace charges varies by the type of furnace used. The open hearth furnace charge averages about 45 percent scrap and 55 percent pig iron. The basic oxygen converter charge averages about 30 percent scrap and 70 percent pig iron, while the electric furnace charge is almost 100 percent scrap.

The important aspect relative to recycling is the quantity of, and demand for, purchased scrap in steel making. Data were analyzed for the period 1935 through 1969. The quantity of scrap purchased was hypothesized to be a function of the quantity of mill revert and pig iron used and the quantity of steel manufactured. The result of the multiple regression equation was:

(1) $S = 5274 - 1.6020M - 0.5879PI + 1.2805SI$

$R^2 = .88$ (7.09) (2.03) (5.66)

where

S = thousand net tons of purchased scrap consumed annually,
M = thousand net tons of mill revert consumed annually.
PI = thousand net tons of pig iron consumed annually, and
SI = thousand net tons of steel produced annually.

The values in parentheses are t-values.

Iron and steel scrap was positively related to steel production and negatively related to mill revert and pig iron. Residual analysis was used to estimate the relationship of the residuals obtained from equation 1 to the composite price of heavy melting steel scrap. The residual S* is the difference between the observed value S and the estimated value S from equation 1. The equation for estimating the relationship was $S^* = b_4 + b_5P$ where S* was the residual value and P was the price per ton of scrap.

In the demand relationships, price was considered as a dependent variable of quantity purchased. The equations used to determine the relationship of price to quantity were:

(2) $\hat{S} = b_0 + b_1M + b_2PI + b_3SI$,

(3) $S - S = S^*$,

(4) $S^* = b_4 + b_5P$,

(5) $S = S^* + S$ OR $S = b_4 + b_5P + b_0 + b_1M + b_2PI + b_3SI$,

and in terms of P (price of scrap per ton)

(6) $P = [b_0 + b_4 + b_1M + b_2PI + b_3SI - S] \div -b_5$

Since there were three distinct levels of prices, the data were analyzed for the three periods.

The following equations estimate the relationship of the price of scrap to the quantity used:

(6.1) 1935-1946: $P = 20.59 - 0.000913M - 0.000335PI + 0.000730SI - 0.00057S$,

(6.2) 1947-1959: $P = 44.82 - 0.001218M - 0.000447PI + 0.000973SI - 0.00076S$, and

(6.3) 1960-1969: $P = 32.04 - 0.000430M - 0.000159PI + 0.000346SI - 0.00027S$.

The relationships show that the price of scrap (P) was related negatively to the quantity used (S). The relationship at the means show that, for a given percentage change in the quantity demanded, the price will change proportionately less in the opposite direction indicating an elastic demand for scrap. The differences in the intercept value b_0 for the various periods indicate that the demand for scrap shifted. The differences in the values of the coefficient for S (the quantity of scrap) indicate that the slope of the demand curve changed also. These changes are depicted in Figure 2.

The analysis of the demand for scrap iron and steel shows the substitution effect of various inputs, the effects of a shift in demand, and the generally elastic demand that may be expected for many waste materials. Even though within rather wide ranges in quantity, price changes may be rather small, but a shift in demand may result in substantial price changes.

PRIVATE VERSUS PUBLIC INVESTMENT

Many actions related to increased recycling are supply increasing. Shifts in supply without accompanying shifts in demand may be price depressing. Development of recycling methods within the private sector must be based on the profit motive. Firms engaged in recycling must earn a return on

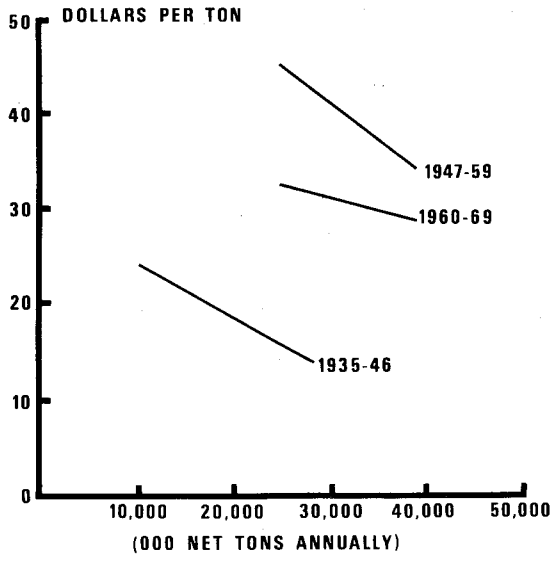

Figure 2. SHIFTS IN DEMAND FOR PURCHASED IRON AND STEEL SCRAP, UNITED STATES, 1935-1969.

their investment at least equal to returns from other types of investment. When the cost of salvaging and handling waste materials is greater than the price received, recycling will not become a successful endeavor.

The question of public versus private investment for financing recycling systems has not been solved. Each community or municipality is faced with a cost-benefit analysis, whereas private industry analyzes business endeavors on the basis of costs and returns. Private values (returns) tend to equal private costs and become measurable in terms of prices. Public values include not only a monetary return, but also a benefit return. Since it is difficult to attach a monetary value to a benefit, but there is a measurable monetary cost attached to gain the benefit, the cost of public investments will exceed public values placed on them. However, the public tends to measure only the monetary portion of the public value.

Few people are willing to incur any part of the possible added cost or inconvenience that proposed solutions for recycling require, at least under the concept of the private market. Certain policies may bring about increased recycling, such as a consumer disincentive. If solid waste collection fees were set in accordance with the volume of waste accumulated, the household, through the disincentive of the higher cost, may be motivated to separate out certain waste materials, i.e., paper, glass, and metals, and haul them to a recycle collection point. The household would be forced to make a decision based on fees saved by reducing the waste to be collected compared to the cost of time and effort in separating and hauling. Receiving a monetary return for the materials separated may be an additional motivating force.

Placing a packaging tax on paper and/or cans has been proposed as a method of financing the waste recycling channel. This would spread the added cost of recycling to those using the materials and require the individual to share in disposal costs. These proposals would tend to shift the supply of waste materials to the right, and without a shift in demand, may decrease prices for such materials.

The most promising solution to increased recycling appears on the demand side of the market. Development of useful new materials made from waste materials and market development for such materials could shift demand. Scarcity of virgin materials will shift to increased use of waste materials.

Prices for waste materials increased substantially in the two-year period 1971-1973. Data show a doubling of price for newspaper; scrap data processing cards increased 400 percent in price, and tin and aluminum prices increased about 75 percent (Table 1). Scarcity and accompanying price increases for virgin materials have been major factors in price

Table 1. PRICES PER TON FOR WASTE MATERIALS DELIVERED TO PRIME USERS, 1971 AND 1973*

Item	Price per ton	
	December 1971	December 1973
	dollars	
Newspapers (not baled)	14	30
Data processing cards	45	225
Tin	20	35
Aluminum	160	280
Tin cans	10	35
Glass	20	20

*Source: [5]

increases for scrap materials.

CONCLUSIONS

One major problem in the market system for waste materials is the lack of knowledge of the expected response to supply-demand price changes. Quantitative measures identifying the response to various changes would be of considerable benefit to policy makers. The nature in which certain factors affect the supply-demand relationships for solid waste materials is not well established.

Recycling of waste materials connotes that a market system encouraging profitable handling of such materials must exist. Data from an established waste recycling industry, scrap iron and steel, were analyzed to show factors affecting the demand for such scrap materials. Existing data for analysis of the demand for other waste materials were difficult to find.

If recycling is to become a major waste disposal method, the householder (as a producer) will need to be shown that he is at least as well or better off using the system. Waste material separation will be necessary,either at the household or at a central accumulation point. Costs of recycling as a waste disposal method probably will be higher than for current disposal methods.

Taxes, subsidies, or other allocating devices may be needed to encourage recycling of solid wastes. Some allocation of costs within the market system may be necessary to encourage more efficient and desirable systems of solid waste disposal. The pricing mechanism, under the present market environment, probably will not encourage recycling as fast as socially desirable.

The response to various allocative devices can be merely "guesstimated" with the present level of knowledge and data availability. More research is needed to determine the various levels of prices, or taxes, or subsidies that may make recycling of waste materials a major method of solid waste disposal.

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