Demand and Dematerialization Impacts of Second-Hand Markets

Reuse or More Use?

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Keywords

consumption
product durability
product lifetime
transaction costs
used goods
waste

Summary

The potential for second-hand markets to reduce demand for new goods is investigated. Using a variant of an economic model originally developed by Anderson and Ginsburgh, the physical implications for material use are explored. The second-hand market grows if transaction costs decrease or if product lifetime increases. In this model, growth of the second-hand market reduces demand for new goods if there are waste used goods that can be brought into the market. But if there is not a ready supply of waste used goods, growth of the second-hand market can increase demand for new goods, thereby increasing material consumption. Moreover, even when second-hand sales reduce demand for new goods, it is typically not on a one-for-one basis. The extent to which the purchase of used goods replaces the purchase of new goods is shown to be an explicit function of the relative value provided by used versus new goods.

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Introduction

Contrasts in the Environmental and Economic Assessments of Second-Hand Markets

Since the 1970s, a growing body of research by environmental scientists has suggested that greater material efficiency, use of better materials, reuse and recycling, and the growth of the service economy are contributing to the "dematerialization" of the economy (Larson et al. 1986; Williams et al. 1987). In this context, it is often suggested that the recycling and reuse of products, materials, and wastes have significant potential for increasing material efficiency and reducing environmental impacts. Taking this idea to its limit, Graedel and Allenby (1996) have suggested that the ultimate goal of environmental management could be the evolution of the economy into a system in which all materials are reused and recycled. But despite the interest in dematerialization and reuse of materials, there is as yet no theoretical framework for understanding the future evolution of material use in industrialized societies (Thomas et al. 2003).

Lacking such a framework, there is a tendency to rely on assumptions. The slogan "reduce, reuse, recycle" is intended to encapsulate the environmental benefits of reducing material and energy use, reusing products, and recycling. With respect to the reuse of products, the U.S. EPA (2002) stated that "Reusing items or making them with less material decreases waste dramatically. Ultimately, less materials will need to be recycled or sent to landfills or waste combustion facilities." The ReUse Development Organization, a U.S. nongovernmental organization devoted to promoting reuse, said, "Reuse conserves valuable natural resources, [and] reduces the amount of water and air pollution and green house gases. . . . Reusing an item . . . replaces new items that would utilize more water, energy, timber, petroleum, and other limited natural resources in their manufacture" (ReDo 2003). In the environmental assessment literature it is typically assumed that the reuse of an item reduces demand for new products on a one-to-one basis (Graedel and Allenby 1996; U.S. Congress 1992; Curran 1996; Stahel 1994).

The environmental assessment literature does take into account the possibility that some new goods may have less environmental impact than older models. This situation can arise for energy-consuming products, if most of the environmental impact is from use of the product rather than from manufacturing or disposal and if there have been significant improvements in energy efficiency. A key example is the refrigerator, because chlorofluorocarbon refrigerants have been banned and average energy consumption has been reduced by about two-thirds over the past 25 years (U.S. NRC 2001). For many products, however, typical life-cycle assessments indicate that the environmental impact of continuing to use an old product is small compared to the net environmental impact of disposal of the old product and manufacture and use of a new model of the same product.

There has, however, been little theoretical or empirical analysis of the general relationship between the reuse of products and the demand for new products. As shown in figure 1, environmental life-cycle assessment takes into account the energy and wastes associated with a product's entire life cycle (Curran 1996). The drawing and the accompanying framework implicitly assume consideration of a single item, which could either be generated from raw materials or from recycled materials and could be purchased either newly manufactured or reused.

In contrast, a number of economists have concluded that second-hand market activity can increase demand for new goods. Fox (1957) argued that second-hand markets support and promote primary markets by making consumer products into "liquid assets" that consumers can easily sell. Kursten (1991) argued that the overall effect is to increase consumers' wealth and increase overall demand. Scitovsky (1994, 37) argued that second-hand markets for consumer durables "stimulate the economy partly by enabling the well-to-do the sooner to replace their worn out or obsolescing durable goods with new ones and thereby increasing the total demand for them". This implies that second-hand markets may actually increase material consumption, rather than decrease it.

The economics literature has also addressed planned obsolescence and the incentives of pro-

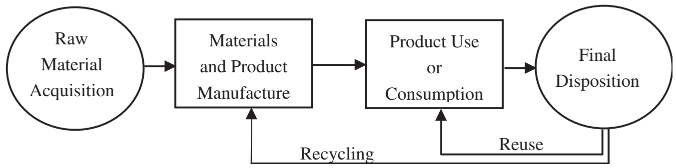

Figure 1 General materials flow diagram for a product life cycle. *Source:* Adapted from Curran (1996). Reproduced with permission of the McGraw-Hill Companies.

ducers to alter the durability of their products (Scitovsky 1994; Swan 1970; Mussa and Rosen 1978; Rust 1985; Hendel and Lizzeri 1999a). The idea that producers might want to decrease the durability of their goods in order to induce consumers to replace their goods more frequently is consistent with the idea that reuse of products reduces demand for new products. Hendel and Lizzeri (1999a) discussed the incentive of monopolist producers to control rental markets and to prevent maintenance, in order to support purchase of new goods.

In addition, the economics literature has addressed the circumstances that promote or inhibit second-hand markets. Akerlof (1970) hypothesized that lack of information about the quality of used goods in second-hand markets drives down prices, an instance of the phenomenon known as "adverse selection." The importance of adverse selection in many markets was further developed by Rothschild and Stiglitz (1976), Bond (1982), van Cayseele (1993), and Hendel and Lizzeri (1999b). Waldman (2003) provided a comprehensive overview of the literature on durable goods.

Examples of Second-Hand Markets

Beyond a few particular markets, data on second-hand markets are sparse. As a point of reference, what data are available indicate that, in the United States, material flow in second-hand markets is comparable to that in some recycling markets, although the economic value of second-hand markets is considerably larger than the value of recycled materials (table 1).

The potential for second-hand markets to decrease demand for new goods has been observed in a number of cases. One example is the international used clothing market. Although the U.S. market for used clothes is estimated to be about $1 billion per year, the impacts of the second-hand market can more clearly be seen in the $0.2 billion export market (table 1). Clothing exports have been widely reported to reduce demand for new clothing in the receiving countries. In response, many developing countries and some developed countries discriminate against the import of second-hand clothing, imposing import bans, licensing requirements, or higher tariff rates (Navaretti et al. 2000). In Zambia, for example, imports of used clothing have reportedly "decimated" the local textile industry (Hansen 2000; Jeter 2002). Mexico requires import licenses for used clothes, whereas South Africa bans the import of worn clothing, except for humanitarian donation.

Many countries also impose tariffs and other restrictions on the import of used cars (table 1). In Latin America alone, significant restrictions against used car imports are imposed by Argentina, Brazil, Chile, Colombia, Ecuador, Jamaica, Mexico, Paraguay, Peru, Trinidad and Tobago, Uruguay, and Venezuela. Some countries claim safety and environmental motivations for restricting these imports. But Pelletiere and Reinert (2002, 2003) have shown that the most restrictive countries are those with domestic automobile industries, indicating that protection of new automobile production is a key motivation for restricting the second-hand market.

Another example is the used book market. In the United States, the number of books purchased from used book stores is reported to have increased from 33 million in 2001 to 57 million in 2002, an increase of 70%. This increase is attributed to the sales of used books on the Internet; many professional book dealers sell used books through Amazon.com and other on-line services (Ipsos 2003). Anecdotal evidence indicates that Internet sales of used books are cutting into sales of new books (Ipsos 2001). In 2002, a book-industry organization charged that the Internet-based used book market on Amazon.com was driving down demand for new books (Kirkpatrick 2002).

Table 1 U.S. second-hand and recycled markets

Product	Mass Flow (million tons/yr)	Market Size (billion $/yr)
Second-Hand Goods		
Used merchandise stores[1] (U.S. DOC 1997)	–	4.1
Books[2] (Ipsos 2003)	0.06	0.2
Office furniture (Murphy 1992)	0.5	–
Clothing stores, domestic (Lewthwaite 1997; Wilson 1997)	1	–
Clothing exports (Lewthwaite 1997; Green 2001)	1	0.2
Garage sales (Hermann and Soiffer 1984)	–	1
Medical equipment (Gertzen 2000)	–	1
Construction equipment[3] (Shih 1999)	–	100
Used corporate assets (Johnson 2000)	–	100
Automobiles, domestic[4] (U.S. DOC 2002)	50	100
Automobiles, exports (Green 2001)	–	0.9
Recycled Materials		
Recycled paper[5] (U.S. DOC 2002)	40	1
Recycled plastic[6] (U.S. DOC 2002)	0.7	0.01

[1]Includes apparel, books, furniture, music, records, sporting goods, but not pawnshops or antique shops.

[2]0.06 billion books were sold used in 2002. The mass flow was derived assuming 1 kg/book; the market size was derived assuming $3/book.

[3]Data are for the U.S. market only and do not include exports.

[4]Assumes an average car mass of 1.3 tons.

[5]Market size estimated from mass flow assuming an average price of $25/ton as of 2002.

[6]Market size estimated from mass flow assuming an average price of $20/ton as of 2002.

Factors Affecting Used Goods Markets

The development of Internet-based markets has put downward pressure on transaction costs not only in used goods markets, but also more broadly. In the stock market (which can be considered a second-hand market), the introduction of on-line trading has brought a significant reduction in brokerage fees. In real estate (existing home sales can be considered a second-hand market), Internet-intensive real estate brokerages such as Your Home Direct (⟨www.yourhomedirect.com⟩) offer transaction costs of 2%, significantly less than the standard 6% fee. The continuing development of Internet-derived efficiencies is expected to drive overall cost reductions in the real estate industry (Baen and Guttery 1997). On-line markets, including not only eBay (⟨www.eBay.com⟩) but also a range of business- and industry-focused services, have allowed consumers and businesses to sell their used assets directly (Shih 1999; Johnson 2000).

The development of these Internet markets for used goods mirrors the garage-sale phenomenon that developed in the 1960s and 1970s in the United States, which also provided new opportunities for consumers to sell their used goods (Ratcliffe 1966; Why garage sales are sweeping U.S. 1974). And during the 1980s and 1990s a number of state environmental agencies supported the development of waste exchanges and materials exchanges. The U.S. EPA supported the development of a "recyclables exchange" at the Chicago Board of Trade. Many of these waste exchanges failed, others flourished, and the overall concept can be thought of as precursor of Internet auctions (U.S. EPA 1994; DePietro 1994; Parris 1996).

Efforts toward global trade liberalization are reducing the barriers to second-hand markets. As mentioned above, many countries restrict imports of used cars and used clothing. The U.S. Trade Representative reports that China prohibits the import of used cars and used clothing and Colombia bans the import of almost all used goods. Peru bans the import of used clothing, shoes, and tires and places restrictions on the import of used cars. Venezuela prohibits the import of used cars, used clothing, and used tires; however, Ecuador has committed to the World Trade Organization to lift bans on the import of used clothing, cars, and tires. Hungary, in preparation for joining the European Union, lifted restrictions on used car imports. In Nicaragua, removal of restrictions on used goods imports was a condition of implementation of World Trade Organization agreements (USTR 2000).

Product labeling can also facilitate the development of second-hand markets (Saar and Thomas 2003). The on-line market Half.com (⟨http://half.ebay.com⟩), one of the most heavily trafficked Web sites in the United States, indicates the potential use of labels and bar codes for second-hand markets. At Half.com, people can post their used goods for sale simply by typing in the bar code numbers on their books, recordings, toys, and so on. Half.com has a large database of products organized by the uniform product code (used for most products) and international standard book number (used for books), so by typing in the bar code number, people can see a picture of the new product, the retail price of the new product, and all used versions of that product that other people have put up for sale along with descriptions of the condition and sales price for each.

All of the factors influencing the cost and difficulty of buying and selling used goods, from trade restrictions to information technology, can be thought of as influences on transaction costs. It is plausible that as transaction costs are reduced, both through trade liberalization and through continued development of information technologies, second-hand markets will grow.

Another important factor in second-hand market development is product lifetime, which can be increased or decreased through technological developments. For example, within the United States, the average lifetime of cars has risen by 50% since 1975. During this time, new car sales have remained roughly constant, but used car sales have risen by a factor of 2 (U.S. DOC 2002). On the other hand, technological obsolescence has limited the value of older electronics products, with faster computers and modems and larger memories replacing slower, older systems. "Planned obsolescence," in which producers design products so they must be frequently replaced, has been alleged in the case of computers, which need to be frequently replaced in order to use new software. Allegations of planned obsolescence have also been made in the case of textbooks, for which frequent publication of new editions limits the viability of the second-hand market (Rust 1986).

The purpose of this article is to provide a basis for understanding the effect of second-hand markets on the demand for new goods, through development of a theoretical model, and to open up the potential for additional exploration of the environmental implications of second-hand markets. The model is meant to serve as a basic example; variants would need to be developed to replicate the features of specific second-hand markets and to allow examination of the role of different parameters. The model is used to explore the effect of changes in transaction costs, as well as the effect of changes in product lifetime. The article concludes with a discussion of how different second-hand markets reflect different values of the model parameters.

Model

Anderson and Ginsburgh (1994) developed a model that allows explicit calculation of the demand impacts of second-hand markets. An expansion of this model that allows explicit consideration of changes in product lifetime is used here. To keep the model simple, the options available to the consumer are more restricted that in the original model. This section largely follows Anderson and Ginsburgh; the following sections develop the implications for physical material consumption.

Consider a product that is used by the purchaser for only one period (for example, 1 yr), but which has an additional lifetime L, so that the total lifetime of the product is $1 + L$ periods. After the purchaser has used the product for one period, he can sell it, store it, throw it away, or give it away. The price for a new product is p_N. If the product is sold after the first period, the used price is p_S, which the seller receives, plus a transaction cost τ, which must be paid by the buyer and includes search costs, delivery costs, and so on. Even if $p_S = 0$ (if there is insufficient demand for the used product and the seller is willing to give it away free), the buyer is still required to pay the transaction cost. Disposal is assumed to entail neither financial costs nor benefits. The value of the service provided by a used product is v, and the value provided by a new product is $v + k$, where k is the extra benefit of newness. Consumers have different valuations of these services according to a parameter θ that is between zero and one, with higher θ denoting individuals with higher willingness to pay.

The options available to the individual are N, buy new and sell/give away/store/throw away; U, buy or find used; and Z, do not consume the product (the zero option). The utility V a consumer derives under each of these options is as follows.

$$N{:}\; V_N = \theta(v + k) - p_N + p_S \tag{1}$$

$$U{:}\; V_U = L\theta v - (p_S + \tau) \tag{2}$$

$$Z{:}\; V_Z = 0 \tag{3}$$

With the basic assumption that each consumer θ chooses the option that maximizes his utility, these three equations comprise the model. As is explicitly shown below, the relative values of the parameters determine the characteristics of the second-hand market.

L represents the lifetime of the used product. If L is less than one, the used buyer benefits from the product for only part of the period; if L is greater than one, the used buyer receives proportionally greater utility from the product. L is restricted to being less than $1 + k/v$; otherwise the used product could have a greater utility than the new product at high values of θ. For practical interpretations, L should be considered to be not much greater than 1.[1] Also, this model does not include time discounting, which could become increasingly important as L increases. $L = 1$ provides a simplified version of the model.

Equations (1) to (3) are shown in figure 2 as a function of the consumer's valuation θ for an illustrative choice of the parameters. Note that the V intercepts of these lines are negative, which means that each line crosses the θ axis at some nonnegative value of θ. Assuming each consumer maximizes his utility, all consumers that have a θ higher than the point at which V_N crosses V_U choose the option N of buying new. That crossing point is defined as θ_{NU}. θ_{UZ} is defined similarly.

From the definitions of N, U, and Z, the values of θ at which the N, U, and Z lines cross are as follows:

$$\theta_{NU} = \frac{[p_N - 2p_S - \tau]}{[k + v(1 - L)]} \tag{4}$$

$$\theta_{UZ} = (p_S + \tau)/Lv \tag{5}$$

The U line may also be below the N line for all positive values of θ, in which case U is never a utility-maximizing option; there is no second-hand market, and the second-hand price is zero. In this case, consumers either buy new or not at all and the relevant crossing point is

$$\theta_{NZ} = p_N/(v + k) \tag{6}$$

To make calculations simple, it is assumed that consumers θ are uniformly distributed between zero and one.

When there is a second-hand market, the demand for new goods is given by

$$\begin{aligned} N &= 1 - \theta_{NU} \\ &= 1 - \frac{[p_N - 2p_S - \tau]}{[k + v(1 - L)]} \end{aligned} \tag{7}$$

and the demand for used goods is given by

$$\begin{aligned} U &= \theta_{NU} - \theta_{UZ} \\ &= \frac{[p_N - 2p_S - \tau]}{[k + v(1 - L)]} - \frac{(p_S + \tau)}{Lv} \end{aligned} \tag{8}$$

When there is no second-hand market, the second-hand price is zero and the demand for new goods is given by

$$\begin{aligned} N &= 1 - \theta_{NZ} \\ &= 1 - p_N/(v + k) \end{aligned} \tag{9}$$

When there is a second-hand market, the second-hand price p_S can be explicitly derived by equating supply and demand. Equating the number of people who buy new $(1 - \theta_{NU})$ with the number buying used $(\theta_{NU} - \theta_{UZ})$ yields the market-clearing price of

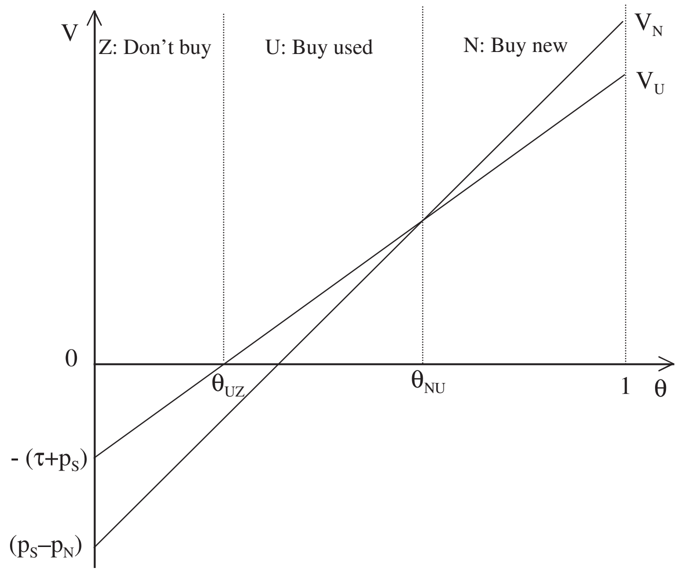

Figure 2 Equilibrium utility levels under the different strategies *N, U,* and *Z*. *Source:* Adapted from Anderson and Ginsburgh (1994). Reprinted from *European Economic Review,* Vol. 38, Anderson and Ginsburgh, Price discrimination via second hand markets, Pages 23–44, Copyright (1994), with permission from Elsevier.

$$p_S = \frac{2Lvp_N - \tau(k + v + Lv) - Lv(k + v - Lv)}{3Lv + k + v} \tag{10}$$

If the demand for used goods is smaller than the supply of used goods, however, then the second-hand price falls to zero. In that case, the amount of goods being thrown away or stored per period (the waste) is given by the number of people buying new ($1 - \theta_{NU}$) minus the number of people taking used items ($\theta_{NU} - \theta_{UZ}$). When there is no second-hand market, the waste is equal to the number of people buying new, $1 - \theta_{NZ}$.

Second-Hand Markets as a Function of Transaction Costs

The size of the markets for second-hand and new goods depends on the parameters τ, v, k, L, and p_N. This section focuses on transaction costs τ, and the next section focuses on product lifetime parameter L.

Figure 2 can illustrate how market segmentation changes as the transaction cost τ changes. For the case of $p_S = 0$, if τ increases, the V_U line shifts downward while keeping the same slope, θ_{UZ} shifts to the right, and θ_{NU} shifts to the left, so that fewer consumers buy used, more consumers do not buy at all, and more buy new. When the second-hand market price p_S is positive, however, the situation is different because, as shown in equation (10), p_S is a function of τ. If τ decreases, p_S increases, which moves the V_N line up and the V_U line down somewhat. Thus, when p_S is positive, a decrease in τ both increases demand for second-hand goods and increases demand for new goods.

Figure 3 shows explicitly how market segmentation and material consumption change as τ changes. Figure 3a shows the fraction of consumers buying new (N), those buying used (U), and those not buying (Z). Figure 3b shows the "waste" used goods as a function of τ, which is defined as those used goods that are not taken up by second-hand buyers, but instead are either thrown away or left unused in storage. Figure 3c shows the total material consumption, which is proportional to N, the consumption of new goods. Total material consumption of course includes manufacturing and production wastes as well as the material in the product, which is taken to be proportional to N. Because decreasing transaction cost is typically of most interest for environmental policy, the figure may most easily be read from right to left. Above a certain maximum transaction cost τ_m, the second-hand market (U) does not exist. As the transaction cost decreases below τ_m, the second-hand market grows and the number of people buying new decreases. But as τ continues to decrease, the waste is used up. When τ falls to τ_0, there are no more waste used goods and the supply of used goods

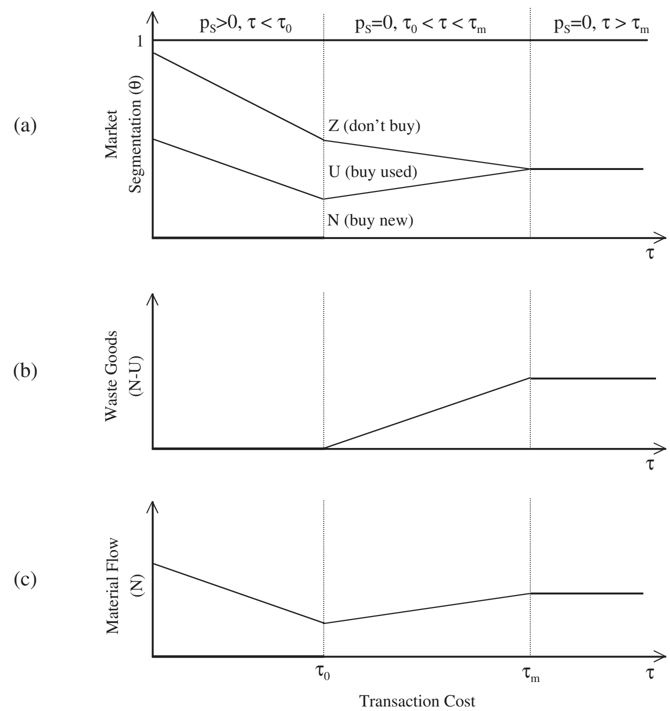

Figure 3 (a) The fraction of consumers who buy new each year (N), who buy used (U), and who do not buy (Z). (b) The waste used goods is proportional to $N - U$. (c) Material flow is proportional to the consumption of new goods, N. When transaction costs are greater than τ_m, there is no second-hand market U. As τ decreases below τ_m, the second-hand market grows, and both the number buying new and the number who do not buy decreases, so total two-period demand for new goods decreases. As τ decreases below τ_0, there are no more waste used goods. The further growth of the second-hand market for τ less than τ_0 comes entirely from the increased purchases of new goods.

exactly equals demand. As τ continues to decrease below τ_0, the second-hand market continues to grow, but the market for new goods also grows, because the thriving second-hand market stimulates demand for new goods.

The phenomena shown qualitatively in Figure 3 can be derived explicitly. The transaction cost τ_m at which the second-hand market disappears entirely can be derived by evaluating $\theta_{NZ} < \theta_{UZ}$, where θ_{NZ} and θ_{UZ} are given by equations (5) and (6). This occurs when the transaction cost is greater than

$$\tau_m = vLp_N/(v + k) \tag{11}$$

The value of τ at which there are no more waste goods and supply exactly equals demand is the value at which the second-hand price becomes positive. From equation (10), this is

$$\tau_0 = \frac{Lv(2p_N - k - v + Lv)}{(k + v + Lv)} \tag{12}$$

Thus, if the second-hand market is increasing because the transaction cost is decreasing, then the second-hand market growth will reduce primary demand until all waste goods are used up. If the second-hand market continues to grow beyond this point, demand for new goods is stimulated. The amount of increase or decrease in demand for new goods can be calculated explicitly. From equations (7), (9), and (10), the derivative of N with respect to τ is

$$\begin{aligned}\frac{dN}{d\tau} &= \frac{\partial N}{\partial \tau} + \frac{\partial N}{\partial p_s}\frac{\partial p_s}{\partial \tau}\\ &= -1/[3Lv + k + v] \quad \text{for } p_s > 0,\ \tau < \tau_0\\ &= 1/[k + v(1 - L)] \quad \text{for } p_s = 0,\ \tau_0 < \tau < \tau_m\\ &= 0 \quad \text{for } p_s = 0,\ \tau_m < \tau\end{aligned} \tag{13}$$

Equation (13) shows the slope of the N line in Figure 3a, which is the same as the overall material flow shown in Figure 3b.

From equation (8) and (10), the derivative of the second-hand demand U with respect to τ can be obtained. As shown in equation (14), it is negative for both $p_S = 0$ and $p_S > 0$. Thus the second-hand market always grows as the transaction cost decreases.

$$\frac{dU}{d\tau} = \frac{\partial U}{\partial \tau} + \frac{\partial U}{\partial p_s}\frac{\partial p_s}{\partial \tau}$$
$$= \frac{-(v + k)}{Lv(k + v - Lv)} \text{ for } p_s = 0,\ \tau_0 < \tau < \tau_m \qquad (14)$$
$$= \frac{-1}{(3Lv + k + v)} \text{ for } p_s > 0,\ \tau < \tau_0$$

A key question is the extent to which increases in second-hand demand affect primary demand. This can be determined from the derivative of the primary demand with respect to the second-hand market demand, allowing τ to vary while k, v, L, and p_N are held constant. From equations (13) and (14), for $p_S = 0$,

$$\left.\frac{dN}{dU}\right|_{k,L,v,p_N \text{ constant. } p_s=0} = \frac{\partial N}{\partial \tau}\frac{\partial \tau}{\partial U} = \frac{-Lv}{v + k} \qquad (15)$$
$$\rightarrow 0 \quad \text{for } k >> v$$
$$\rightarrow -L \quad \text{for } k << v$$

Equation (15) shows that when $p_S = 0$ and the value of newness k is high, increases in second-hand market activity have essentially zero impact on primary demand. This occurs because almost all new second-hand sales are coming from Z, the consumers who previously did not buy. Equation (15) also shows that when the value of newness is low, each second-hand sale can replace, at most, L sales on the primary market. When k is 0, new and used goods are perfect substitutes for each other.

For $p_S > 0$, the extent to which a growing second-hand market increases primary demand is given by

$$\left.\frac{dN}{dU}\right|_{k,L,v,p_N \text{ constant. } p_s>0} = \frac{\partial N}{\partial \tau}\frac{\partial \tau}{\partial U} = 1 \qquad (16)$$

Equation (16) shows that when the second-hand price is greater than zero, any growth in second-hand sales must be derived from additional sales of new goods.

Second-Hand Markets as a Function of Product Lifetime

Rather than considering the system variation as a function of transaction cost, it is possible to investigate the role of product lifetime on the size of the second-hand market, as indicated by the variable L. Figure 4 shows how market segmentation changes with L. The figure shows that as product lifetime increases, the development of a second-hand market slows the development of the market for new goods, until the point at which all waste has been absorbed, after which both the new and second-hand markets continue to grow.

The value of L above which the second-hand price is positive can be derived from equation (10). Above L_0, increasing product lifetime increases the relative value of used goods with respect to new goods and thus supports the second-hand price.

The value L_m, below which the second-hand market disappears, can be derived in exact parallel to the derivation of equation (9), by evaluating $\theta_{NZ} < \theta_{UZ}$, where θ_{NZ} is given by equation (6). The result is

$$L_m = (k + v)\ \tau/v\ p_N \qquad (17)$$

The derivatives of N and U with respect to L can be derived similarly to equations (13–16).

$$\frac{dN}{dL} = \frac{\partial N}{\partial L} + \frac{\partial N}{\partial p_s}\frac{\partial p_s}{\partial L}$$
$$= 0 \qquad \text{for } p_s = 0, L < L_m \qquad (18)$$
$$= -(p_n - \tau)v/(k + v - Lv)^2 \text{ for } p_s = 0, L_m < L < L_0$$
$$= \frac{v[3(p_n + \tau) - 2(v + k)]}{(3Lv + k + v)^2} \qquad \text{for } p_s > 0, L_0 < L$$

$$\frac{dU}{dL} = \frac{\partial U}{\partial L} + \frac{\partial U}{\partial p_s}\frac{\partial p_s}{\partial L}$$
$$= 0 \qquad \text{for } p_s = 0, L < L_m$$
$$= \frac{(p_n - \tau)v}{(k + v - Lv)^2} + \frac{\tau}{L^2 v} \qquad \text{for } p_s = 0, L_m < L < L_0 \qquad (19)$$
$$= \frac{v[3(p_n + \tau) - 2(v + k)]}{(3Lv + k + v)^2} \text{ for } p_s > 0, L_0 < L$$

When the second-hand price is zero, equations (18) and (19) show that increasing the product lifetime always increases the second-hand demand and decreases the demand for new goods. When the second-hand price is positive, however, increasing product lifetime results in increased sales in the primary market.

When product lifetime changes, the relation between changes in second-hand market de-

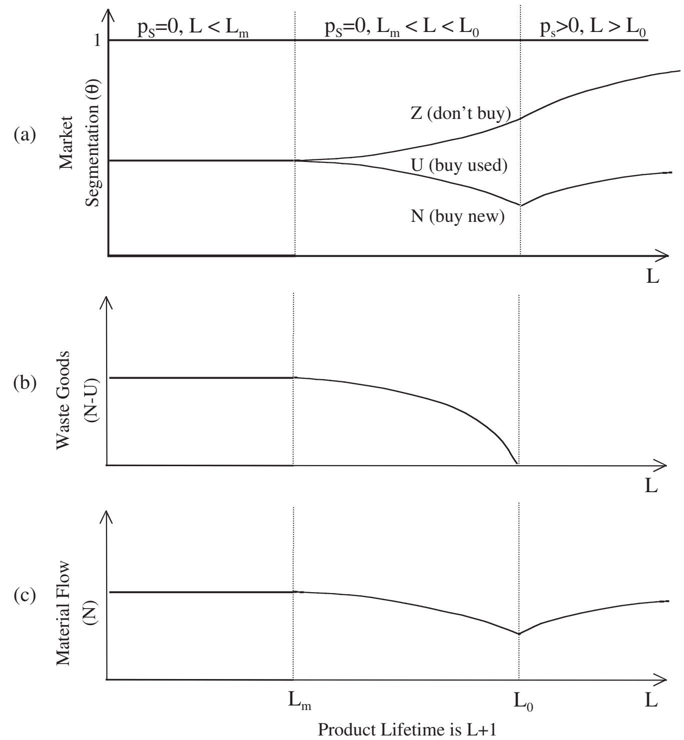

Figure 4 (a) The fraction of consumers who buy new each year (*N*), who buy used (*U*), and who do not buy (*Z*), as a function of the product lifetime parameter *L*. (b) The waste used goods is proportional to $N - U$. (c) Material consumption is proportional to the consumption of new goods, *N*. When *L* is less than L_m, there is no second-hand market *U*. As *L* increases above L_m, the second-hand market grows, and the number buying new decreases. When *L* increases above L_0, all used goods are absorbed by the second-hand market and purchases of new goods again increase.

mand due and the demand from new goods can be derived from equations (18) and (19).

$$\left.\frac{dN}{dU}\right|_{k,\tau,v,p_N \text{ constant. } p_s>0} = \frac{\partial N}{\partial L}\frac{\partial L}{\partial U} = 1 \qquad (20)$$

$$\left.\frac{dN}{dU}\right|_{k,\tau,v,p_N \text{constant. } p_s=0} = \frac{\partial N}{\partial L}\frac{\partial L}{\partial U} = \frac{-v(p_n - \tau)/(k + v - Lv)^2}{(\tau/L^2 v) + v(p_n - \tau)/(k + v - Lv)^2} \rightarrow 0 \quad \text{for } k>>v \qquad (21)$$

Equation (20) shows that when the second-hand price is greater than zero, increases in second-hand market demand result in corresponding increases in demand for new goods. Equation (21) shows that when the second-hand price is zero, increases in second-hand market demand result in decreased demand for new goods. This effect is most pronounced when newness is not important ($k < v$). When new goods provide significantly more value than used goods ($k > v$), the second-hand market becomes decoupled from the market for new goods.

Discussion

This model provides a framework for exploring the potential for second-hand markets to affect the demand for new goods. Second-hand demand can be stimulated by decreasing transaction costs, by increasing the lifetime of the product, or by reducing the benefit of newness. Transaction costs can be reduced through freer trade in general or by Internet markets in particular. The lifetime of goods can be increased through improved technological reliability and robustness. The benefit of newness can be reduced through development of upgradable, or repairable, systems.

The model defined by equations (1–3) is only one of a range of possible models. This model was chosen to be as simple as possible and yet provide insight into the potential for dematerialization through second-hand markets. The original model of this type, developed by Anderson and Ginsburgh (1994), was developed to explore a somewhat different set of issues, and correspondingly was defined somewhat differently. The Anderson-Ginsburgh model did not include product lifetime as a variable, although the ratio

v/k was explored as a measure of how well the product holds up during its lifetime. The Anderson-Ginsburgh model included the option for consumers to keep their products through the entire two-period lifetime of the product, as an alternative to buying new, used, or not at all. Despite these differences, the basic behavior of the model is the same. For example, for $L = 1$, the second-hand price shown in equation (10) is the same as that derived by Anderson and Ginsburgh.

Some of the model results are a direct reflection of the specific details of equations (1–3). In particular, the model of equations (1–3) assumes that the first owner keeps the product for only one time period even if the total lifetime of the product increases. In the Anderson-Ginsburgh model, consumers have the option of keeping the product for its entire lifetime, and as a consequence, $\partial N/\partial U$ is typically less than one for $p_s > 0$, in contrast to equations (16) and (20).

The model also assumes that second-hand owners may own more than one of the product and that the price for new goods is exogenous. These assumptions are unlikely to characterize all second-hand markets of interest. By changing equations (1–3) to develop new models, the implications of different market behaviors could be explored. Data on how consumers and markets react to changes in the lifetime of products, transaction costs, or product obsolescence would allow the development of models that reflect observed market behaviors.

The basic implication of the model presented here is that when valuable goods are being thrown away or left unused in storage, growth of the second-hand market can reduce demand for new goods. This is likely to be more effective for goods that have steady long-term value, such as furniture. But for goods such as computers that depreciate rapidly, little or no reduction in demand for new goods can be expected from an increase in second-hand market demand. In addition, the model provides a basis for estimating the size and direction of the change in demand for new goods that would be induced by a change in second-hand demand.

A key factor in this model is whether the second-hand price is or is not effectively zero. Examples of second-hand markets with nonzero second-hand price might include markets for cars, housing, and some books. In these markets, buyers of new goods may buy more readily and at higher prices because they can resell the goods later. Examples of second-hand markets with effectively zero second-hand price might include the markets for electronics, clothing, and garage-sale items. For these items, most of the price that a second-hand buyer pays is effectively the transaction cost. People who buy these items new rarely expect to recoup any of their outlay by selling second hand.

The model indicates that in markets with positive second-hand price, such as the market for cars, housing, and some book markets, increased second-hand sales would not correspondingly decrease sales of new goods. If all other variables remain constant, increased second-hand sales in these markets can increase sales of new goods and increase material consumption.

On the other hand, in markets with zero second-hand price, such as markets for electronics, furniture, clothing, and garage-sale items, increased second-hand sales can be expected to decrease the demand for new goods. This is typically not a one-for-one trade-off between new goods and second-hand goods. The relation between the increase in second-hand sales and the decrease in sales of new goods reflects, basically, the extent to which the increase in second-hand sales are coming from consumers who previously bought new or from consumers who previously did not buy. If the service provided by a new good is significantly higher than the service provided by a used good, that is, if $k >> v$, then an increase in second-hand demand has little effect on the demand for new goods. In such a case, almost all of the increased demand for second-hand goods comes from those who previously did not buy.

Figures 3 and 4 should be interpreted with some care. Figure 3c might be misinterpreted to imply that transaction costs must be kept above a certain level if increased material consumption is to be avoided. Similarly, figure 4c might be misinterpreted to imply that product lifetimes must be kept below a certain level in order to avoid increased material consumption. As transaction costs decrease or as product lifetimes increase, a number of variables are likely to change, including the price of new goods, the relative value of new versus old goods (k/v), and the time that first owners keep their goods. Although the figures do imply that there are limits to the dematerialization that can be achieved through second-hand markets, those limits are functions of a number of variables.

The model presented here has implications for extended producer responsibility and the substitution of services for products. It has been argued that firms would have an incentive to be more efficient with materials and energy if products were leased rather than sold to consumers (Stahel 1994; Braungart 1994); however, it has also been argued that one motivation of the lease-only strategy of firms, including IBM in the market for computers and Xerox in the market for copiers, is to restrict second-hand market activity (Waldman 1997). Moreover, a series of antitrust court cases involving Kodak, Data General, Unisys, and Xerox have focused on manufacturers' restrictions on availability of replacement parts (Carlton and Waldman 2001). The argument in essence is that these product-leasing strategies, rather than promoting efficient use of materials, in fact impede materials efficiency by restricting second-hand market activity.

Although the emphasis here has been on the environmental implications of second-hand markets, the growth of any second-hand market increases overall economic welfare (as defined in the economics literature), regardless of whether these markets stimulate demand for new goods. For this reason, economic and social policy might broadly favor the development of second-hand markets. The economic agenda for trade liberalization implies support for free operation of second-hand markets. On the other hand, although there is a tendency to think of second-hand markets as small-scale, local, rummage-sale-style activities, a number of second-hand markets are in fact global, large-scale economic powerhouses. As second-hand markets continue to grow, they will increasingly compete with inefficient producers of new goods, including those in developing countries.

Second-hand markets are likely to continue to grow through both trade liberalization and the development of information technology. These markets are increasingly international, and they will have significant environmental implications, as well as social and economic implications. In some cases, these developments will reduce overall material consumption. Even in these cases, however, detailed analysis is needed to evaluate the net environmental impacts, taking into account environmental differences between new and used products, as well as transportation impacts. The model presented here provides a basis for understanding how and to what extent the reuse of goods can reduce material consumption, and it provides a way to bridge economic evaluations of second-hand markets with physical evaluation of the production, use, and reuse of products.

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Note

1. If L is greater than $1 + k/v$ then the model is not well defined. If k is large compared to v then buyers of the used product would end up essentially stockpiling the product, which may not be a significant problem for the model per se, but it may be confusing. A situation in which this might happen could be the market for used dresses. Used dresses might have $k >> v$ (new dresses are typically valued much more than used dresses), but used dresses might also last a long time, so a used dress buyer might end up with many used dresses. The model assumes that the used goods buyer does not resell the used product.

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