Durable Goods Theory for Real World Markets

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Durable goods constitute an important part of economic production. In 2000, personal consumption expenditures on durables exceeded $800 billion. In the manufacturing sector in the United States in the year 2000, durable goods production constituted roughly 60 percent of aggregate production.

Durable goods pose a number of questions for microeconomic analysis. One set of questions involves durability choice and the related issue of "planned obsolescence." For example, do firms have an incentive to reduce durability below the efficient level so that units break down quickly? Also, to what extent do firms have an incentive to introduce new products that make old units obsolete? A second set of questions revolves around timing issues. How are current prices and marketing strategies affected by a producer's actions tomorrow that affect the future value of units the producer sells today? A third set of issues revolves around information asymmetry. In many durable goods markets, buyers are unable to judge the quality of durable units offered for sale. As a result, the problem of adverse selection can arise, where sellers withdraw high-quality units from the market because consumers are unable to perceive high quality and are thus unwilling to pay a high price for it.

The early 1970s witnessed three major advances in the microeconomic theory of durable goods. Oddly enough, one of these was mainly followed up in the 1970s, one was largely pursued in the 1980s, and the other was investigated only in the 1990s. In a series of papers in the early 1970s, Peter Swan considered the question of optimal durability (Swan, 1970, 1971; Sieper and Swan, 1973). Most of the work

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in the 1970s on durable goods theory focused on the generality of Swan’s results. A second major advance in the early 1970s, by Ronald Coase (1972), involved time inconsistency. The focus here is on difficulties that arise because durable units sold tomorrow affect tomorrow’s value of units sold today, with the result that the producer’s sequence of outputs may not maximize the firm’s overall profitability. Much of the work on durable goods theory in the 1980s focused on Coase’s insights. The third contribution was George Akerlof’s (1970) analysis of asymmetric information and adverse selection. This work was not originally perceived as being especially relevant to durable goods theory, but after all, Akerlof’s primary application was the used car market. By the late 1990s, these insights were being incorporated into models of durable goods.

Each of these advances identified an important issue concerning durable goods markets. But each also considered simplified models that gave very incomplete pictures of most actual durable goods markets. For example, Swan (1970, 1971) and Sieper and Swan (1973) made unrealistic assumptions concerning substitutability between new and used units. Coase (1972) assumed both output and price are not contractible. Akerlof (1970) focused on secondhand markets and ignored the market for new units. Since many of the extensions of these analyses maintained these strong assumptions, our understanding of certain classes of theoretical models was significantly advanced, but our understanding of real world markets for durable goods was not advanced as far.

The situation has changed over the last ten years. A number of authors, including Igal Hendel, Alessandro Lizzeri and me, have moved beyond those initial fundamental analyses and considered more realistic models of durable goods markets. As a result, we now have a clearer understanding of a variety of phenomena concerning durable goods markets. For example, in contrast to Swan’s (1980) initial thinking on the subject—but consistent with what publishers actually say (in private)—one role played by the introduction of a new edition of a textbook is indeed to “kill off” the market for used textbooks. Another example is a better understanding of the role (and recent growth) of leasing in the market for new cars, which a number of authors have argued is a response to adverse selection in the market for used cars. A third example is a better understanding of why firms sometimes monopolize aftermarkets for their own products, as has been alleged in court cases involving firms such as Kodak, Data General, Unisys and Xerox. Finally, we now better understand the upgrade process that is common in the software industry and, in particular, a tool used by Microsoft. In this paper, I discuss the intellectual journey of the microeconomic theory of durable goods over the last 30 years, with an emphasis on recent contributions.

Before proceeding, it is worth noting that much of the following discussion concerns monopoly producers of durable goods selling to consumers. This should not be interpreted to mean that the insights from the analyses discussed only apply to such settings. Even though most durable goods producers are not monopolists, most do have market power, and monopoly analyses should provide useful insights. Similarly, the problems faced by durable goods producers selling to firms should be
similar to problems faced by durable goods producers selling to consumers, and thus the analyses that follow should help us better understand the issues faced by the producers of durable intermediate inputs.

**Three Classic Contributions to Durable Goods Theory**


**Optimal Durability**

In the late 1960s, a number of authors considered whether a durable goods monopolist would choose the same durability as competitive producers or, similarly, whether such a firm would choose the socially optimal level of durability. The general theme of this literature was that a monopolist would choose less durability than would competitive producers or, similarly, an inefficiently low level of durability (for example, Kleiman and Ophir, 1966; Levhari and Srinivasan, 1969; Schmalensee, 1970). In a series of papers in the early 1970s, however, Swan showed this conclusion was incorrect (Swan, 1970, 1971; Sieper and Swan, 1973).

To understand Swan’s insight, think of the case where a unit provides the same stream of services for the first $T$ periods and then becomes useless. The choice of durability is then simply the choice of $T$. A real world product with roughly this feature is light bulbs. Thus, think of a monopolist that sells light bulbs to consumers, and consider the monopolist’s choices of output and durability from a steady-state perspective. If consumers only care about the amount of light consumed and not directly about how long a bulb lasts, then the monopolist will choose output and durability such that the light provided is produced at minimum cost. In other words, although the monopolist produces less than the socially optimal level of light because of standard monopoly incentives to produce less than the efficient amount, there is no distortion in terms of durability since the monopolist will produce at minimum cost. But this is the same as saying that (taking as fixed the amount of light produced) the monopolist chooses the socially efficient durability level. Further, in many cases, this also means the monopolist chooses the same durability as a competitive industry would choose.

Swan did not just show this result for situations in which a product provides the same stream of services until it wears out, but rather showed it holds given the common assumption dating back to Wicksell (1934) that “service flow is proportional to the stock on hand.” To understand what this means, consider a monopolist who has two choices. The monopolist can produce units that depreciate so that after one period they are equivalent of half of a new unit and after two periods are worthless. Alternatively, the firm can produce units that after one period are equivalent of a quarter of a new unit and after two periods are worthless. From the
standpoint of the steady state, the service stream provided per period is the same whether the monopolist produces ten of the former type of unit per period or twelve of the latter. Swan showed that, given this assumption that some number of used units is a perfect substitute for a new unit, the same logic as above holds, and thus, the monopolist chooses the durability level that produces the desired service stream at minimum cost.

The 1970s saw numerous investigations of the robustness of Swan’s conclusions to relaxation of the specific assumptions he employed. For example, Barro (1972) allowed consumers and the firm to have different discount rates, Schmalensee (1974) and Su (1975) introduced a maintenance decision, and Auernheimer and Saving (1977) introduced short-run nonconstant returns to scale. Schmalensee (1979) surveys Swan’s papers and the literature that followed. The conclusion of this literature, not surprisingly, is that Swan’s findings are robust to relaxing some of his assumptions, but not others.

However, one of the assumptions that received limited attention in this literature is that some number of used units is a perfect substitute for a new unit. Later, I argue that this assumption is unrealistic for most durable products, and a more realistic assumption that captures imperfect substitutability between new and used units yields significantly different conclusions.

**Time Inconsistency and Durable Goods**

Coase (1972) argued that a durable goods monopolist faces a problem of time inconsistency. The problem arises because durable goods sold in the future affect the future value of units sold today, and in the absence of the ability to commit, the monopolist does not internalize this externality.

To understand Coase’s argument, it is easier to start with the later analysis of Bulow (1982). Bulow considers a monopolist of a perfectly durable good who sells output in each of two periods. In this model, if the firm in the first period can commit to a production level for the second period, then the firm’s profit-maximizing first-period choices are to commit first to selling zero in the second period and then to produce the monopoly output level and sell it at the monopoly price. But what if commitment is not possible? Then, if the firm tries to sell the monopoly output in the first period, consumers will be unwilling to pay the monopoly price. The reason is that consumers fear the firm will collect the monopoly price in the first period and then produce additional units in the second period, thus driving down the second-period value of the used units that the consumers own. The result is each consumer’s willingness to pay in the first period is reduced, and overall monopoly profitability falls. Bulow further shows that the monopolist can avoid this problem by leasing as opposed to selling. The logic here is that leasing means the monopolist owns the used units at the beginning of the second period, and thus the monopolist internalizes how its second-period actions affect the value of those units.

Looking back, it seems a bit surprising (at least to me) that Coase in his 1972 paper did not consider a relatively simple case like the one considered by Bulow
(1982). Rather, Coase considered the more technically challenging case of a durable goods monopolist who sells output in an infinite-period setting and cannot commit to future production levels. Coase does not analyze the problem formally but rather conjectures that, given rational consumer expectations, the monopolist’s price will fall immediately to marginal cost. (Coase also argued, as affirmed by Bulow, that leasing would avoid the problem.) Much of durable goods theory in the 1980s focused on whether this conjecture was correct (for example, Stokey, 1981; Gul, Sonnenschein and Wilson, 1986; Ausubel and Deneckere, 1989).¹ The main result is that Coase is correct if buyers’ strategies do not depend on past behavior, so that reputation formation by the seller is not possible. However, as Ausubel and Deneckere show, if reputation formation is possible and marginal cost is equal to or above the value the lowest valuation consumer places on the product, then equilibria exist in which the monopolist regains some or all of its monopoly power.

Much of the rest of durable goods theory in the 1980s and early 1990s focused either on the robustness of Coase’s conjecture to changes in the assumptions or on tactics other than leasing that a durable goods monopolist can use to avoid the problem. On the former topic, Bond and Samuelson (1984) show that depreciation and replacement sales reduce the monopolist’s tendency to cut price, Kahn (1986) shows a similar result when an upward-sloping marginal cost schedule is substituted for the assumption of constant marginal costs, while Bagnoli, Salant and Swierzbinski (1989) and Levine and Pesendorfer (1995) consider what happens when output comes in discrete units. On the latter topic, Bulow (1986) extends his earlier analysis by showing that a durable goods monopolist can reduce its time inconsistency problem by reducing the durability of its output (this analysis is thus related to the discussion of the previous subsection). Butz (1990) shows that contractual provisions such as best-price provisions or most-favored-customer clauses can ameliorate the problem, while Karp and Perloff (1996) and Kutsoati and Zabojnik (2001) consider whether a monopolist can reduce the problem by initially using an inferior high-cost technology.

As I look back over the literature on Coase’s time inconsistency problem, I feel its focus was misplaced to some extent. Most of this literature assumes commitment about future prices and quantities is not possible, but in fact, consistent with Butz’s analysis, commitments on future prices and quantities are common. Think of a firm that sells commemorative coins. It sells a good that is basically perfectly durable, and it can sell the good today or at any later date. But in contrast to Coase’s conjecture, the price does not fall immediately to cost. One important reason is that the firm can contractually commit to an upper bound on future quantities through what is called a limited edition. In other words, Coase’s argument is important for understanding a variety of contractual provisions that allow firms

¹ A closely related literature is the literature on bargaining with one-sided uncertainty where only the uninformed party makes offers. Important papers in this literature are Sobel and Takahashi (1983), Fudenberg, Levine and Tirole (1985) and Ausubel and Deneckere (1989). Ausubel and Deneckere’s paper includes a discussion of the relationship between the two literatures.
to avoid the time inconsistency problem that he identified, but analyses that assume no commitment at all is possible miss many of the important real world implications.

In addition, Coase’s argument is also important because the implications of time inconsistency are much broader than the specific problem he identified. Rather than time inconsistency only applying to future output, it applies to any future action by the firm—such as an R&D decision or the choice of a repurchase price—that affects the future value of used units. Hence, as discussed in later sections, Coase’s insight has implications for durable goods markets that are far from his original discussion.

Adverse Selection and Durable Goods

Akerlof’s (1970) analysis of adverse selection is well known as one of the papers that launched the vast literature on the role of asymmetric information in markets. Until recently, however, the implications of Akerlof’s argument for durable goods markets were pretty much ignored. But Akerlof’s main example was the used car market, so clearly the argument is potentially important for durable goods markets.

Akerlof’s (1970) model can be thought of as a supply-demand problem. The suppliers are individuals, each of whom initially owns one used car and each knows the quality of that used car. The demanders are individuals, each of whom initially owns no used car and does not know the quality of any specific used car, although these individuals do know the average quality of used cars offered for sale. Akerlof assumes that demanders have a higher value for used cars than do suppliers, so under full information, all used cars are traded. Akerlof shows that, given the asymmetry of information assumed, not all used cars are traded, so trade is less than the efficient amount. The reason is that the used car price reflects the average quality of used cars offered for sale, so a supplier with a high-quality used car keeps it rather than sell it at a price that does not reflect its quality.

In addition to predicting less than the efficient level of trade in used car markets, this perspective explains an interesting aspect of those markets. Although many used cars are traded through a middleman, there are also many trades between friends, relatives and acquaintances. In a world of full information, such trades would be puzzling, because used car trades should move the cars to their

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3 Akerlof (1970) considers a specification in which under asymmetric information there is no trade at all. But this is neither required for the argument nor a general feature of the type of model he considers (Wilson, 1980).
highest-value use, and there is little reason to believe that when someone wants to sell a used car, the new highest-value user would be a friend, relative or acquaintance. Given asymmetric information and adverse selection, however, this feature of used car markets is not at all surprising. As discussed above, in the absence of information concerning used car quality on the part of buyers, only low-quality used cars are traded, and prices reflect the average quality of used cars offered for sale. But this means owners of high-quality used cars prefer to trade (only trade) with buyers who know the quality of the seller’s used car, which is most likely when the buyer is a friend, relative or acquaintance.

Although Akerlof’s (1970) analysis has had a huge impact on economics as a whole, the analysis initially had little impact on durable goods theory. However, this has changed recently as a number of authors have started to incorporate this argument into rich models of new and used durable goods.

**Three Recent Contributions**

Recent contributions to durable goods theory have served to extend and refocus the theory so that it is more applicable to real world markets. I focus here on recent contributions in three areas: durability choice, introductions of new products and applying adverse section to a full model of new and used durable goods.

**Durability Choice in Real World Markets**

Most of the literature concerning durability choice has followed Swan’s lead and assumed that service flow is proportional to stock on hand. Sieper and Swan (1973, p. 334) describe the assumption this way:

> In common with Wicksell (1934) and most subsequent treatments of product durability, we shall assume that there exists a definition of product services such that units of service are perfect substitutes in consumption (or production) irrespective of the age or the durability of the product from which they are derived. The power of this undoubtedly heroic abstraction is that it allows a multiplicity of distinct products, classified by age and durability, to be analyzed in terms of a single market for product services.

This approach has two problems. First, for most durable goods, it is not at all realistic. For products such as automobiles, televisions, refrigerators and toasters, a consumer cannot combine “service units” derived from a number of used units to create a perfect substitute for a new unit. Second, since with this assumption all consumers place the same relative value on new and used units, it allows no important role for secondhand markets.

An alternative approach employed in Waldman (1996a) and Hendel and Lizzeri (1999a) is to assume new and used units are imperfect substitutes that vary
in terms of quality, where durability is modeled as the speed with which the quality of a unit deteriorates (see also Kim, 1989; Anderson and Ginsburgh, 1994). These models also assume consumers who vary in their valuations for quality and a secondhand market where used units are traded. Note that, both here and in papers discussed later, one reason for assuming that consumers vary in their valuations for quality is that it creates a role for secondhand markets. As units age and fall in quality, the units are traded from high-valuation to low-valuation consumers.

The main conclusion of these analyses is that a durable goods monopolist typically underinvests in durability, with the result that the quality of used units is less than the efficient level.⁴ The logic is that because new and used units are substitutes—albeit imperfect ones—the price of a used unit on the secondhand market constrains the monopolist in terms of the price it charges for new units. By reducing durability below the efficient level and thus the quality of used units below that level, the monopolist reduces the substitutability between new and used units, which, in turn, allows the firm to increase the price of new units.⁵

As explained in detail in Waldman (1996a), these analyses are similar to the classic analyses of Mussa and Rosen (1978) and Maskin and Riley (1984) of a monopolist who sells a product line of different qualities to consumers who vary in their valuations for quality. In those papers, the monopolist reduces the quality sold to low-valuation consumers below the socially optimal level, because this allows the firm to charge more for high-quality units sold to the high-valuation consumers. In the durable goods problem, one can think of the monopolist as producing a product line over time, where new units are the high-quality units while the different vintages of used units are the lower qualities in the product line. Thus, reducing durability and in turn the quality of used units in my analysis and Hendel and Lizzeri’s is similar to the finding in the product line pricing literature that a monopolist reduces the quality sold to low-valuation consumers.

The above logic has implications beyond durability choice. The general point is that a durable goods producer with market power wants to lower the quality of used units because this translates into a higher price for new units. One way to achieve this is by reducing the physical quality of the product by reducing the durability built into new units. Another way is to introduce frequent style changes that reduce the “perceived” quality of used units. To see this, suppose consumers

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⁴ In Waldman (1996a), durability chosen is always below the efficient level, while Hendel and Lizzeri (1999a) provide two different comparisons. They show that durability can be either above, below or equal to the first-best level. My feeling, however, is that a more important comparison is to the second-best level defined by the firm’s actual choice of outputs. For this comparison, they find that durability chosen is always below the efficient level.

⁵ In Hendel and Lizzeri’s (1999a) analysis, there is a second reason that the monopolist distorts durability. This second reason is that socially optimal durability is a function of the average valuation for quality of the used good consumers, while the secondhand market price is determined by the valuation for quality of the marginal consumer of used goods. This second reason is related to the analysis of Spence (1975) concerning monopoly quality choice of a firm that sells a single quality level to consumers who vary in their valuations for quality.
prefer goods with the latest style. In such a world, style changes might be common not because consumers of new goods demand them, as in Pesendorfer (1995), but because style changes make used units less substitutable for new units and thus allow producers to increase the price of new units. Later in this paper, I discuss another implication that concerns whether durable goods producers ever have an incentive to reduce or even to eliminate the availability of used units on the secondhand market.

New Product Introductions

Most of the durable goods literature ignores introductions of new products. This omission is significant, in that almost every durable goods market is characterized by products that improve and/or change over time. Indeed, new product introductions have a variety of implications for durable goods markets. A number of authors have recently started to consider this issue.

There are a number of papers that focus on pricing given new product introductions (for example, Levinthal and Purohit, 1989; Fudenberg and Tirole, 1998; Lee and Lee, 1998). The most thorough of these analyses appears in Fudenberg and Tirole’s paper. They consider a two-period monopoly setting in which output is perfectly durable, but second-period new units are higher quality than first-period new units. Further, consumers in their model vary in their valuations for quality. Focusing on what happens given a secondhand market, the fundamental result in their analysis is closely related to the durability analyses discussed above. In the durability analyses, new and used units are imperfect substitutes because quality deteriorates as units age. This creates a linkage between prices of new and used units, which leads to various results, including the one concerning durability described above. In Fudenberg and Tirole’s analysis, new and used units are imperfect substitutes because new units improve over time. They show a similar linkage between prices of new and used units and derive various implications concerning price and output decisions.

Another important idea is that of planned obsolescence, which was initially developed in Waldman (1993, 1996b; see also Choi, 1994; Fishman and Rob, 2000; Kumar, 2002). The key insight here is that introductions of new products are subject to a time inconsistency problem similar to that discussed by Coase (1972). The Coase insight was that, because in later periods the firm will not internalize

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6 The term planned obsolescence is sometimes used to refer to the behavior of a firm that underinvests in durability from a social welfare standpoint (for example, Swan, 1972; Bulow, 1986; Carlton and Perloff, 1994). But Bulow (1986, p. 747) also states: “Perhaps the greatest weakness of this paper is that it follows in the tradition of using durability as a proxy for obsolescence. . . . But planned obsolescence is much more than a matter of durability; it is also and perhaps primarily about how often a firm will introduce a new product, and how compatible the new product will be with older versions . . . .” The papers I discuss above follow this suggestion of Bulow and treat planned obsolescence in terms of new product introductions, rather than the durability decision. See Grout and Park (2001) for a recent paper that uses the term planned obsolescence to refer to durability choice.
how its output choice affects the value of units previously sold, a monopoly seller of a durable good who cannot commit has an incentive to sell “too many” units in later periods, and this reduces overall profitability. The recent papers concerning planned obsolescence show a similar logic operates for new product introductions. The introduction of a new product can lower the value of used units by making them obsolete. Hence, just as a durable goods monopolist has an incentive to sell too many units in later periods with the result that its own profitability is reduced, the firm also has too high an incentive to introduce new products in later periods that make used units obsolete, with the result again that overall profitability is reduced.

To see this more concretely, consider Waldman (1996b), which analyzes a model similar to Fudenberg and Tirole’s (1998) model, but endogenizes the quality of new units in the second period (related analyses appear in Nahm, 2001; Ambjørnsen, 2002). In particular, there is a research and development decision at the beginning of the second period, where the probability the monopolist sells new higher quality units in the second period is increasing in the R&D investment. When the firm introduces higher-quality new units in the second period, the second-period market value of used units is reduced because the units are traded from high-valuation to low-valuation consumers (such trades do not occur if higher-quality units are not introduced). In this setting, if the monopolist cannot commit in the first period to its second-period R&D level, then it invests more in R&D than if it could commit. The result is that, because first-period consumers anticipate this and are thus willing to pay less for new units, this overinvestment in R&D lowers the firm’s overall profitability. Again, as was true for Coase’s time inconsistency problem, the firm can avoid the problem by leasing its output.

The time inconsistency problem concerning new product introductions shows one way in which Coase’s (1972) insight is more than an insight about output choice. Any action that affects the value of used units previously sold—such as an R&D decision that affects whether used units become obsolete—can be subject to time inconsistency. Indeed, the problem of time inconsistency is potentially more important for other choices than for output. As argued earlier, contractual provisions allow firms to commit at least to some extent to future outputs and prices. In contrast, the size and nature of R&D investments—along with a range of other future actions—would seem to be much more difficult to specify in contracts in an enforceable manner.

**Adverse Selection in a Model of New and Used Goods**

Akerlof (1970) considered adverse selection in an analysis of used durable goods, but did not incorporate new durables into his analysis. Hendel and Lizzieri (1999b) consider a model of new and used durable goods where the market for used units is characterized by adverse selection. Their results confirm Akerlof’s
analysis that adverse selection can result in too little trade on the secondhand market, and they also find other interesting results.\footnote{Kim (1985) is an earlier analysis that considers adverse selection in a model with both new and used durable goods. That analysis incorporates a maintenance decision with the main result that, in contrast to what was argued by Akerlof (1970), the used units traded on the secondhand market can be either higher or lower in quality than the used units that are kept for a second period. Kim does not address whether, as in Akerlof’s (1970) analysis, the volume of trade given asymmetric information is above or below the full information level.}

One of the more interesting features of their analysis is the reason for trade in the secondhand market. In Akerlof’s (1970) analysis, all individuals have a valuation for a single used unit that depends on its quality. If trade occurs, it consists of used units moving from individuals with low valuations who initially own the units to those with high valuations who initially do not. In Hendel and Lizzeri’s (1999b) analysis, each individual has a valuation for a single unit—new or used—that depends on its quality. As a result, high-valuation consumers buy new units and sell used units to low-valuation consumers. In other words, although the sellers of used units have higher valuations for quality, they find it optimal to sell their used units because they place a higher value on purchasing a new unit once the used unit is sold.

Modeling the new and used markets this way allows the analysis to capture important links between these markets. For example, similar to earlier discussions, the price at which used units trade on the secondhand market affects the willingness of consumers to pay for new units. That is, an increase in the price at which a consumer can sell a used unit increases the amount consumers are willing to pay for a new unit, since buying new and selling used are complementary activities.

Another important link concerns the effect of adverse selection in the used unit market on the operation of the new unit market. Inefficiency in the market for used units limits the price that buyers of new units will pay. As a result, profit-maximizing sellers of new units will want to limit the extent to which their units are subject to adverse selection when they become used. This link is not emphasized in Hendel and Lizzeri (1999b) because they do not consider the profit-maximization problem of sellers of new units (in that analysis, they ignore market structure and just assume a constant flow of new units come onto the new unit market each period). However, as I will discuss later, this perspective has been emphasized in recent papers that argue that the role of leasing in the new car market is that it limits adverse selection in the used car market.

**Specific Firm and Industry Practices**

In this section, I discuss theoretical models used to explain specific firm and industry practices. I focus mostly on models that build on analyses discussed earlier. The specific topics covered are the following: the role of sales in durable goods...
markets; practices that limit availability of used goods; the role of leasing in the new car market; models of Microsoft’s behavior; and aftermarket monopolization.

Sales in Durable Goods Markets

Most markets including durable goods markets are characterized by sales; that is, temporary price decreases employed to increase quantity sold. Why might firms employ sales in durable goods markets?  

Conlisk, Gerstner and Sobel (1984) address this question with an infinite period model of a durable goods monopoly in which new consumers enter the market each period. These new consumers are assumed to have the same distribution of high and low valuations for the monopolist’s product as consumers already in the market. Further, as in many of the models discussed earlier, the good is infinitely durable, so a consumer who purchases the good leaves the market forever. They analyze this model assuming no commitment; that is, each period’s output is chosen at the beginning of the period. For most periods, the monopolist sets price equal to the willingness-to-pay of high-valuation consumers. However, after a number of periods, a sufficiently large number of low-valuation consumers are in the market that the firm reduces the price and sells to low-valuation consumers. Thus, in most periods, the price is high and only high-valuation consumers purchase, but there are also periodic temporary price reductions targeted at low-valuation customers.

This equilibrium is an intuitively plausible description for why we observe periodic sales in durable goods markets. However, what happens if firms can commit to future prices and/or quantities? Sobel (1991) analyzes this issue using the same model investigated in Conlisk, Gerstner and Sobel (1984) (in this paper, Sobel also further analyzes the no-commitment case). He finds that with commitment, there are no sales. Rather, when the proportion of high-valuation consumers is high, the firm sets a high price each period and sells only to these consumers, while when the proportion is low, it sets a low price each period and sells to both groups. One might wonder why in the former case the firm does not periodically reduce the price and sell to the low group. The reason is that offering a low price, even just periodically, lowers high-valuation consumers’ willingness to pay enough that it is more profitable never to sell to the low group.

Sobel (1984) also extends Conlisk, Gerstner and Sobel’s (1984) analysis, where the focus is oligopoly. In this paper, Sobel shows the existence of equilibria similar to that described above for the monopoly and no-commitment cases. That is, in most periods, a firm prices high and sells only to high-valuation consumers, but periodically the firm reduces its price and sells to low-valuation consumers. The logic here is similar to that given above. As the number of low-valuation consumers in the market rises, the profitability of selling to the low group rises, and each firm thus eventually decreases its price.

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8 Salop and Stiglitz (1982) offer a model of sales in nondurable goods markets.
Reducing the Availability of Used Units

Does a durable goods producer ever have an incentive to reduce the availability of used units? The standard argument concerning this issue is due to Swan (1980; see also Rust, 1986). Swan argued that since a good’s initial price reflects the price at which it will change hands in the secondhand market in the future, the availability of used units does not reduce the overall profitability of a monopoly seller. For example, Swan (p. 77) wrote: “[T]he pure monopolist selling such a durable item as an automobile is paid an amount which reflects the net present value of the stream of automobile services to possibly a whole host of future owners. Competitive secondhand auto dealers (or scrap merchants and recyclers in the case of aluminum) can then buy and sell the item indefinitely without in any way restricting the power of the monopolist as the original seller.”

Several recent papers show this argument misses an important aspect of the problem (Waldman, 1996a, 1997; Fudenberg and Tirole, 1998; Hendel and Lizzeri, 1999a). The argument of these papers is closely related to the earlier discussion of durability choice. Because of potential substitutability across different vintages, the availability of used units lowers the monopolist’s new unit price. One response is for the monopolist to reduce the durability of new units. This reduces the substitutability between new and used units and allows the firm to increase the price for new units. The point here is that another possibility is that the firm reduces or even eliminates the availability of used units, where the return is again a higher new unit price.9

One real world practice along these lines is the lease-only policy; that is, the policy of leasing and refusing to sell output. This practice is not widely prevalent among durable goods producers, but there are a number of prominent instances each associated with a manufacturer that had significant market power: United Shoe in the market for shoe machinery; IBM in the computer market; and Xerox in the copier market.10 Waldman (1996a, 1997) and Hendel and Lizzeri (1999a)

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9 A similar argument appears in the earlier analyses of Benjamin and Kormendi (1974), Miller (1974), Liebowitz (1982) and Levinthal and Purohit (1989). Those papers start by specifying demand functions and show that under certain conditions reducing the availability of used units increases the firm’s profitability. However, since these analyses start with demand functions, one is left wondering whether the required conditions are plausible or even possible. The more recent papers listed above start with consumer utility and show that the conditions on demand functions necessary for the reduced availability of used units to increase profitability are quite easy to satisfy. Finally, Anderson and Ginsburgh (1994) in a setting similar to the papers mentioned above consider the related issue of whether a monopolist has an incentive to increase the transaction costs of trading in the secondhand market and shows that it does sometimes. Hendel and Lizzeri (1999a) also consider this issue in their analysis.

10 Prior to 1953, United Shoe employed a lease-only policy in marketing its shoe manufacturing machines. In 1953, the courts ruled a variety of the firm’s practices to be illegal, and, in particular, it was prohibited from using the lease-only practice (Kaysen, 1956). Prior to 1956, IBM employed a lease-only policy in marketing its computers, while in 1956, it agreed to a Justice Department consent decree requiring it to sell as well as lease its machines. However, even after the consent decree, IBM offered prices for the two options such that most consumers chose to lease rather than buy (Soma, 1976; Fisher, McGowan and Greenwood, 1983). In 1975, Xerox and the Federal Trade Commission entered into a consent decree that stated that one of Xerox’s violations of antitrust law was its use of a lease-only policy.
argue that these firms employed the lease-only policy as a way of reducing the availability of used goods. That is, employing this policy allows firms to scrap some or all of the used units that are returned and in this way reduce used unit availability.\textsuperscript{11}

One interesting question is why would a firm use the lease-only policy to reduce the availability of used units, rather than repurchase and scrap the used units it wants to remove from the market. I analyze this question in my 1997 paper and show that if the firm cannot commit to the subsequent repurchase price when it sells new units, then the repurchase-and-scrap strategy does not work because of time inconsistency. At the date that repurchases need to take place, the firm has an incentive not to repurchase and instead to allow the units to be available for consumption. Further, even if the firm can contractually commit to a high repurchase price, the lease-only policy is still preferred as long as there is a positive probability of bankruptcy. The logic is that any positive probability of bankruptcy means “full” commitment is impossible, so lease-only is preferred.

Another setting in which the argument of this subsection applies is the textbook market. The argument there is that publishers of popular textbooks introduce frequent new editions where the goal is reducing the value of used copies to zero; that is, firms eliminate used unit availability by introducing new editions and making used copies worthless. At first, this setting may seem inconsistent with the thread of the discussion. After all, the textbook market is typically quite competitive, while the above argument depends on significant market power. However, the textbook case is in fact consistent with the argument because of an unusual feature. The person who decides which textbook to use, the professor, is different than the person who decides whether to use the book, the student. From the standpoint of the professor, there are typically alternative texts, but once a professor has chosen a text, the student typically has little choice. As a result, in selling to students (as opposed to marketing to professors) a textbook publisher has substantial market power, and thus, it is quite plausible that publishers use new editions to kill off the market for used copies.\textsuperscript{12}

\textsuperscript{11} A number of other explanations for the lease-only policy have been put forth. Two of these are worth mentioning. First, Posner (1976) suggests that the lease-only policy may be a response to the Coase time inconsistency problem. However, avoiding the Coase problem requires short-term leases (DeGraba, 1994), while United Shoe, for example, employed long-term leases lasting 17 years. Second, Wiley, Rasmusen and Ramseyer (1990) and Masten and Snyder (1993) ignore the monopoly aspect of the cases and put forth efficiency rationales more consistent with a competitive market. However, given the practice is not widely prevalent among durable goods producers, but instead has been observed in a number of instances of firms with significant market power, this perspective seems suspect.

\textsuperscript{12} The difference between the argument here and the earlier argument involving obsolescence and new product introductions concerns whether the firm is choosing the privately optimal frequency of new editions. Here I am assuming that the firm chooses the privately optimal frequency so when it introduces a new edition overall profits rise. In the earlier argument the firm faced a time-inconsistency problem with the result that the firm introduced new products too frequently and, as a consequence, overall profits fell. Since textbook publishers are in the market for many periods and can thus establish a reputation for how often new editions are introduced, I feel that assuming that they choose the privately optimal frequency of new editions is likely to be the more accurate approach.
Leasing in the New Car Market

Over the last 20 years, there has been dramatic growth in new car leasing. For example, between 1990 and 1998, the percentage of new cars leased in the United States grew from 7.3 percent of the market to 29.2 percent.\textsuperscript{13} What is the role of new car leasing?\textsuperscript{2}

There are two standard explanations, but both have problems. First, the business press argues that leasing is a way for consumers to lower their monthly payments (for example, Woodruff, 1994). That is, either because of consumer myopia or imperfect capital markets, leasing is perceived as a way of making new cars more affordable. But this argument suggests that, since high-income consumers are likely both to be less myopic and have better access to capital markets, leasing should be negatively related to consumer income. This prediction, in turn, is problematic, since evidence indicates that leasing is positively related to consumer income (for example, Aizcorbe and Starr-McCluer, 1997). Second, another explanation is that the Tax Reform Act of 1986 included a number of changes that made automobile leasing more attractive (for example, Crocetti, 1988; Auster, 1990). The problem here is that this explanation predicts growth in leasing after 1986, but only until the new car market achieved a new equilibrium, while the evidence indicates substantial growth long after 1986.

An alternative explanation is that leasing in the new car market is a response to adverse selection in the used car market. Hendel and Lizzi (2002) approach the problem mainly from the perspective of a monopolist, while Johnson and Waldman (2002) focus on competition. However, the basic logic of these analyses is similar. Adverse selection in the used car market arises from the private information of used car sellers, but this means leasing should avoid the problem, because with leasing, used cars are returned to dealers and dealers have no private information.\textsuperscript{14} In the monopoly case, this results in leasing, because avoiding inefficiency in the used car market increases consumers’ willingness to pay and thus also increases firm profits. In the competitive case, this results in leasing because avoiding inefficiency improves consumer welfare, so consumers prefer it. (In the competitive case, consumers receive any increase in social welfare because firms earn zero profits in equilibrium.)

This argument matches well with empirical evidence concerning the operation of markets for new and used cars. For example, since leasing but not purchasing avoids adverse selection, this argument predicts used cars that were leased when new should sell for more than used cars that were purchased when new.

\textsuperscript{13} The source for these figures is CNW Marketing Research.

\textsuperscript{14} To be precise, the assumption that dealers have no private information concerning the used cars that are returned is sufficient but not necessary for leasing to avoid the adverse selection problem. The reason is that adverse selection arises when new cars are sold because of asymmetric information and because potential sellers of used cars have the option of driving their used cars. Hence, even if leasing does not eliminate the private information, it avoids the adverse selection problem as long as dealers have no alternative use for the used cars that are returned.
Remember, adverse selection means only low-quality used cars are traded, but if adverse selection is avoided, then high-quality used cars are traded, too. This prediction is consistent with evidence found in Desai and Purohit (1998). Similarly, since leasing avoids adverse selection and should thus increase the volume of trade, this explanation predicts the average length of time a new car is held before changing hands should be shorter for leased cars. This prediction is consistent with evidence found in Sattler (1995).

This perspective on new car leasing suggests two interesting questions. First, what is the role of the buy-back price in lease contracts for new cars, where the buy-back price refers to the price typically included in lease contracts at which the lessee can purchase the car at the end of the lease period? Hendel and Lizzeri (2002) explain this in terms of efficient matches in the used car market. That is, having buy-backs means used cars do not look completely homogeneous from the standpoint of used car buyers, and as a consequence, in their analysis the monopolist increases its profits by employing buy-backs because it results in better matching between used car buyers and the used cars purchased.

In contrast, Johnson and Waldman (2002) provide an explanation based on efficient buy-backs. They consider a competitive model where, in contrast to Akerlof’s (1970) analysis, the deterioration in quality of the highest-quality used cars is so small that it is efficient for these cars not to be traded. In turn, buy-backs are employed because they move the equilibrium toward this outcome, since they allow the highest-quality used cars to be bought back at the end of the lease contract. Note, since only the highest-quality used cars should be bought back, this argument predicts very high buy-back prices, which is consistent with evidence Johnson and Waldman collected from advertisements that appeared in the Sunday New York Times during 1998.

The second question is this: why has new car leasing grown so dramatically during the last 20 years? Hendel and Lizzeri (2002) argue that this growth may be the result of improved durability of new cars over this period. The logic here is that because a driver of a new car is more likely to drive a car when it becomes old if its quality has not fallen too much, improved durability will aggravate the adverse selection problem. Thus, since leasing reduces the adverse selection problem, it is used more often as durability rises.

In contrast, Johnson and Waldman (2002) discuss an extension of their model that incorporates a moral hazard problem concerning inadequate consumer maintenance associated with leasing. In this extension, leasing rises when new cars become more reliable or trouble-free because more reliable new cars means this moral hazard problem is small. The logic is that some aspects of the moral hazard problem are avoided by including scheduled maintenance activities in lease contracts, and when new cars become more reliable or trouble-free there is less need for maintenance outside of these scheduled activities. Johnson and Waldman then argue that the growth in leasing may be the result of the improved reliability of new cars over time.
Microsoft’s Behavior

Since computer software is durable, some of the literature concerning Microsoft’s behavior is relevant for understanding durable goods markets. In this section, I discuss two issues: Microsoft’s practice of frequent upgrades and Microsoft’s low-price strategy in marketing Windows.15

In the earlier discussion of planned obsolescence, I argued that from the standpoint of its own profitability, a durable goods monopolist that cannot commit will introduce new products that make used units obsolete too frequently. Waldman (1993) and Choi (1994) show, in particular, that a monopolist selling a durable good characterized by network externalities may practice planned obsolescence by introducing new products that are incompatible with old ones. Recently, Ellison and Fudenberg (2000) extended those analyses to investigate excessive upgrades in software markets. They consider a two-period model characterized by network externalities in which a monopolist can introduce a higher quality new product in the second period that is “backwards compatible” only. Backwards compatibility means consumers who purchase the new good in the second period derive a network benefit from consumers who purchased the old good in the first, but a first-period purchaser only benefits from second-period purchasers if the first-period purchaser buys the new product in the second. Ellison and Fudenberg show that if the monopolist cannot commit in the first period to whether it will upgrade in the second, then both from the standpoint of its own profitability and from that of social welfare, it upgrades too frequently. The reason is that in the second period, the monopolist does not internalize how its product choice affects the second-period value of units it sold as new in the first period.

This analysis suggests Microsoft lowers its own profitability with its frequent upgrades, but if true, then Microsoft would have an incentive to choose actions that constrain its own ability to introduce upgrades. Since Microsoft does not seem to be taking any such actions, it is possible that a different perspective would be more accurate.

Ellison and Fudenberg (2000) also provide a second analysis. This analysis also assumes an upgrade that is backwards compatible only, but, importantly here, they assume commitment is possible so no time inconsistency problem exists. Also, this analysis (but not the earlier one) has heterogeneous consumers. Here they show that from a social welfare standpoint there may again be excessive upgrades. The logic, related to Spence (1975), focuses on the distinction between marginal and average consumers. When the monopolist thinks about upgrading given it can commit in advance, it takes into account the negative impact the upgrade has on the marginal consumer of the original product. But social welfare depends on the

15 Because of the ongoing court case, another behavior that has generated significant attention is Microsoft’s tying of Windows and Internet Explorer. Because most analyses of that issue do not focus on the durable nature of the products, I do not discuss that literature here. For papers related to the tying of Windows and Internet Explorer, see Whinston (1990, 2001), Farrell and Katz (2000), Choi and Stefanidis (2001) and Carlton and Waldman (2002).
negative impact on the average consumer, so the firm will upgrade too often when that negative impact is higher for the average consumer than for the marginal consumer.

The second aspect of Microsoft’s behavior I consider is its pricing strategy for Windows. During the ongoing court case, various observers noted that Microsoft’s price for Windows is below what a pure monopolist would charge; for example, Richard Schmalensee (1999) stated that “a real monopolist—one who extracted the last dollar of profit from consumers—would charge hundreds of dollars more for the software that runs modern PCs . . .” Building on the earlier work of Bucovetsky and Chilton (1986), Hoppe and Lee (2002) provide an explanation for this behavior based on the durability of the product. They argue that Microsoft charges a low price to deter entry, or in other words, it limit prices. That is, because of the durable nature of the product, the firm prices low and sells a large quantity. The reason is that an individual who already owns an operating system has a lower willingness to pay for a competing operating system than an individual who does not. Hence, charging a low price can deter future entry because it lowers the potential profitability of a rival investing in research and development and subsequently introducing a competing operating system.

Aftermarket Monopolization

A series of court cases involving firms such as Kodak, Data General, Unisys and Xerox concern the issue of aftermarket monopolization. Aftermarkets refers to markets for complementary goods and services such as maintenance and replacement parts that may be needed after a consumer has purchased a durable good. Aftermarket monopolization means the original durable goods producer stops alternative producers from offering the complementary good or service, with the result that the original producer monopolizes the aftermarket. For example, in Eastman Kodak Co. v. Image Technical Services (504 U.S. 451 [1992]), the U.S. Supreme Court heard a case in which Kodak refused to sell spare parts to alternative maintenance suppliers with the result that consumers of Kodak’s products had no option but to purchase maintenance from Kodak. In-depth discussions of aftermarket monopolization appear in Shapiro (1995), Chen, Ross and Stanbury (1998) and Carlton (2001). Here, I lay out the major theories.

Because the Supreme Court ruling in the Kodak case was that a durable goods producer with no market power that monopolizes an aftermarket for its own product can be guilty of an antitrust violation, much of the literature focuses on competition in the market for new units. I begin by discussing two closely related theories in which maintenance market monopolization allows competitive producers to exploit market power after consumers are locked in.

The first is referred to as the costly information theory. It holds that consumers are locked in once they purchase a new unit from a durable goods producer and that consumers ignore the cost of maintenance in their original purchase decisions. In this situation, producers exploit consumers’ locked-in positions by first stopping other firms from selling maintenance and then raising the maintenance price. The
result is a standard deadweight loss due to the monopoly pricing of maintenance, but no transfer between consumers and firms since competition in the market for new units causes the price of new units to fall so that a firm receives zero profits across the two markets in equilibrium.

A related theory is the lack-of-commitment theory developed in Borenstein, Mackie-Mason and Netz (1995). The difference here is that consumers anticipate whether the maintenance market will be monopolized and pay less for a new unit when they expect monopolization. In such circumstances, a durable goods producer would want to commit to allowing competition in the maintenance market, but monopolization occurs in this model because of an inability to commit. In this theory, as in the costly information theory, the cost of the practice is the deadweight loss due to the monopoly pricing of maintenance.16

Although these theories were put forth in response to the recent court cases, each has problems concerning applicability to those cases. The costly information theory assumes uninformed consumers, which seems unlikely in some of the cases in which consumers were sophisticated businesses and the cost of maintenance was a significant proportion of the total cost of using the product. The lack-of-commitment theory assumes commitment is impossible, but this assumption seems suspect because long-term maintenance contracts are quite common in many industries where the practice has been observed.

Because of these concerns, I find two other theories more appealing. First, the practice of aftermarket monopolization may be used to price discriminate more effectively, as argued in Chen and Ross (1993) and Klein (1993). This argument is similar to the explanation for tie-ins used, for example, to explain IBM’s one-time practice of requiring purchasers of its tabulating machines to also purchase its punch cards. In this theory, consumers with higher valuations for the durable goods producer’s product are heavy users of maintenance, with the result that the seller more effectively price discriminates by monopolizing the maintenance market and raising its price. This theory provides a clear rationale for maintenance market monopolization by firms with significant market power, but has difficulty explaining maintenance market monopolization by firms with little or no market power. Although Klein (1993) argues that since we observe significant price discrimination even in industries that are quite competitive, the price discrimination argument should not be ruled out as a possible explanation for why a firm would monopolize the maintenance market in such an industry.17

16 A third theory along these lines is the surprise theory. In this theory, consumers expect the maintenance market to be competitive and are surprised when monopolization occurs. Most discussions of this theory claim that, in addition to the deadweight loss associated with the other two theories, there is a transfer between the consumers and the firm. However, if competitive firms lower the price for new units until they receive zero profits in equilibrium, as occurs in the costly information theory, then there is no transfer and the costly information and surprise theories are equivalent.

17 Two other explanations for why a firm with significant market power would monopolize the maintenance market for its own product are put forth in Hendel and Lizzeri (1999a) and Morita and Waldman (2002). The former paper argues that maintenance market monopolization arises because it allows a
Second, an efficiency argument has recently been put forth that builds on the earlier work of Schmalensee (1974), Su (1975) and Rust (1986). Those papers show that a durable goods monopoly paired with competitive maintenance leads to inefficiency. That is, because the monopolist sets the price for new units above marginal cost while maintenance is priced competitively, consumers sometimes maintain used units when purchasing new units would be efficient. Carlton and Waldman (2001) and Morita and Waldman (2001) show that this translates into a reason for maintenance market monopolization both when the market for new units is monopolized and when it is competitive. The monopoly case is straightforward, since a monopolist of both markets can increase profits by setting prices that reduce the distortion. But the result also holds under competition when consumers bear switching costs from changing brands. Switching costs create market power in the market for new units at the time a consumer chooses whether to replace or to maintain a used unit, and thus, monopolizing the maintenance market again allows a firm to reduce the distortion. This latter argument is potentially important for a number of the court cases, including the Kodak case, because of the presence of significant consumer switching costs.

Conclusion

Early work on durable goods theory during the 1970s and 1980s established important fundamental principles. But because of some unrealistic assumptions, this literature made only limited progress in advancing our understanding of real world markets for durable goods. In the last ten years, however, the literature has started to consider more realistic models, with the result being significant advances in our understanding of these markets. For example, we now better understand durability choice and the issues associated with new products introductions. We also have a better understanding of a variety of specific practices employed in durable goods markets, such as those used to make goods produced in earlier periods obsolete, leasing in the new car market and aftermarket monopolization.

Although durable goods theory has made large advances in the last ten years, there are a number of areas where I believe further research could be fruitful. First, most of the literature assumes either monopoly or perfect competition, while clearly most real world markets are either oligopolistic or monopolistically competitive. It might be useful, therefore, to incorporate some of the recent advances into oligopoly and monopolistically competitive models. Second, outside of the literature on aftermarkets and the lease-only analyses of Waldman (1997) and

durable goods monopolist to raise the price for new units by more effectively controlling the speed with which the quality of its product deteriorates. The latter paper argues that, much like leasing, monopolizing the maintenance market can be used to avoid problems due to time inconsistency.

18 There is a small existing literature on durable goods oligopoly. See, for example, Sobel (1984), Gul (1987) and Esteban and Shum (2002). Bulow (1986) also contains some analysis of oligopoly.
Hendel and Lizzeri (1999a), there has been little research concerning the antitrust implications of the recent advances, and more such analyses would be useful. For example, Carlton and Gertner (1989) show, using a Swan-type analysis, that mergers lead to substantially smaller deadweight losses in durable good industries as opposed to nondurable good industries, and it would be useful to explore the robustness of this conclusion to the introduction of a more modern approach to modeling durability. Third, most of the recent literature focuses on consumer durables. But many durables are intermediate inputs used to produce consumer goods. Some of the work on the theory of the firm, such as Williamson (1975, 1985), considers this type of intermediate input, either implicitly or explicitly. But given the recent advances in the theory of durable consumer goods, it would be interesting to explore whether our understanding of markets for durable consumer goods has implications for durable intermediate inputs not captured by existing theory.

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