Durable Goods Price Cycles: Theory and Evidence from the Textbook Market

By Eric W. Bond and Toshiaki Iizuka

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Abstract: We develop a model of the monopoly pricing of a durable good when there are heterogeneous buyers. Our durable good has the features of a textbook: each period new consumers enter the market and the introduction of a new edition kills off used goods. We show that, unlike the traditional Swan-type models, durable good prices could go up over the life of an edition if consumers are heterogeneous. Our empirical analysis using textbook pricing data supports our model: textbook prices increase as the share of used textbooks increases and the last period of the current edition arrives. In contrast, we find no evidence that textbook prices fall over the life of an edition.

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Author affiliation: (Bond) Economics Department, Vanderbilt University. Email: eric.w.bond@vanderbilt.edu. (Iizuka) Graduate School of International Management, Aoyama Gakuin University. Email: toshi.iizuka@gmail.com

In this paper we develop a model of the monopoly pricing of a durable good when there are heterogeneous buyers. We examine a market in which the durable good has the features of a textbook: each period new consumers enter the market with the demand for the use of the good in that period. At the end of the period, purchasers have the option of continuing to hold the good or to sell it in the used market. Our emphasis is on how the price of the good varies over the life of an "edition" of the good, where it is assumed that the introduction of a new edition will kill off the used market value of a previous edition of the good. We then test the implications of the model for the pricing of economics textbooks over the life of an edition of a book.

Our analysis is motivated by the observation that the price of an edition of a textbook does not seem to decline over the life of the edition, as would be suggested by the standard model of durable goods pricing where consumers are homogeneous. Following the seminal work of Swan (1970), it is normally assumed that consumers factor the expected resale value of a durable good into their willingness to pay for a new good. This model would predict that the value of the new good should decline as the end of an edition approaches, because the expected resale value will be lower. If consumers know the time at which the edition will end with certainty and a book can be resold only once, it is only the one period ahead resale value that matters and the model would suggest a significant drop in consumer valuation of a new edition in the last period of its life. If a good can be resold more than once or the end date of the edition is uncertain, the decline in valuation of a new good by a representative consumer would be spread over the life of the edition. However, data on pricing of new textbooks at college bookstores does not provide evidence of such a decline with the age of a textbook edition or a dramatic reduction in price in the last period of the life of an edition.

Our theoretical model assumes that there are two types of consumer. One type is a Swan type consumer who will purchase the good for current use and then resell in the used market. For these consumers, the willingness to pay will decline as the anticipated end of the edition approaches. The other type of consumer in the market will buy and hold the good. For these consumers, the valuation of a new good is unaffected by the existence of a used market and the valuation of the good is constant over the life of an edition. We then examine the optimal pricing policy of a monopoly seller in a stationary model in which a fixed number of buyers of each type enter the period to buy a textbook, and each edition of the textbook has an exogenously given life of two periods. Under the assumption that those who plan to keep the textbook place the highest value on the new good in the last period, we show that the price of a new textbook may either fall, remain constant, or rise over the life of an edition. Not surprisingly, a falling (constant) price over the life of the edition occurs when the consumers who plan to sell (keep) the book after its use dominate the market. The most interesting case is that of a rising price of a textbook, which occurs when the monopolist finds it optimal to sell to all consumers in the first period, but to only sell to the high valuation buyers who will keep the good in the second period.

We also show that the possibility of a rising price over the life of an edition extends to the case in which those who keep the good have higher absolute valuations on both new and used in the last period, but a larger relative preference for new goods. We also extend the model to the case in which the edition lasts for three periods, and show that it may be optimal to "write off" the low valuation buyers who resell the good in either the second or third period, depending on the preference parameters and relative number of buyers who will resell. The common feature of each of the cases that we consider is that the pricing policy of the monopolist has a threshold feature when there are two types: it is optimal to sell new goods only to high valuation buyers who keep the good when the supply of used goods is sufficiently high. The level of this threshold is higher in early periods of the life of the good, since the low valuation buyers who will resell will pay more in the early period of the good's life.

Our empirical analysis tests whether increases in the supply of the used books and the reaching of the end of the edition create an incentive for the seller to raise price to sell only to the high valuation buyers. We obtained a panel data set from college bookshops that contain price and quantity information for all economics textbooks (397 titles) in each semester between 1996 and 2000. We estimate simple reduced form pricing equations with textbook fixed effects. Instrumental variables are also used to account for the potential endogeneity of a regressor. We find that textbook prices increase as the share of used textbooks increases and the last period of the current edition arrives. In contrast, we find no evidence that textbook prices fall over the life of the edition. Thus, our results suggest that textbook pricing cycles are consistent with the prediction of the price discrimination model with heterogeneous consumers but not with that of the traditional Swan type models with homogeneous consumers.

The possibility of cycles in the pricing of a durable good by a price discriminating monopolist in our model can be distinguished from other forms of intertemporal pricing policies that have been analyzed in the literature. Stokey (1979) has examined the conditions under which a monopolist introducing a new good will engage in intertemporal price discrimination. In contrast to our model, Stokey assumes that all consumers enter the market in the initial period and choose the time at which to purchase the good. Conlisk, Gerstner, and Sobel (1987) generate cyclical pricing in a model in which new consumers enter the market each period, but they also assume that consumers can postpone purchase in order to take advantage of lower prices in the future. They show that low valuation buyers will postpone purchase in order to take advantage of periodic sales by the monopolist.[1] Both of these models also differ from the present one in that there is no resale market. [2]

Our results can also be distinguished from those in the literature on the Coase conjecture for a durable good monopolist. Bulow (1981) examined a 2 period model of a monopolist selling a non-

[1] Sobel (1991) considers a similar model to Conlisk, Gerstner, and Sobel (1984), but does not allow commitment by the monopolist to the length of a pricing cycle. He examines subgame perfect equilibria and shows that if consumers are sufficiently patient, any positive average profit level less than the maximum profit can be achieved.

[2] Pesendorfer (1995) develops a model of fashion cycles in which the value of a new durable declines over its life. In his model, consumers demand the good in order to increase the probability that they are matched with a high type consumer. His model is similar to ours in that resale is allowed, but differs in that the demands of consumer for a durable depend on the fraction of high types that own the good.

depreciating durable good with no entry of consumers in the second period. He showed that with Swan type consumers, the monopoly seller suffers from the inability to commit to future output levels.[3] This result arises because price cuts are less costly to the seller in the second period, when some of the loss from a price cut falls on consumers who purchased in the first period. The monopolist suffers under a sales policy because the willingness to pay of first period consumers, who anticipate the second period price cuts, is then reduced. As in Bulow's model, we assume that the seller can commit to the life of the durable, but not to output levels. However, our model differs due to the entry of new consumers each period and imperfect substitutability between new and used goods resulting from consumer heterogeneity. The existence of a stock of used goods makes the demand for new goods less elastic in the second period in our model, so that the monopolist has an incentive to raise (rather than reduce) the second period price. Note that the increased second period price of new goods does not raise the second period value of used goods in our model because the buyers of used goods are specialized to the used market.[4]

The rest of the paper is organized as follows. In Section I, we introduce our model. Section II describes the empirical analysis. Section III concludes the paper.

I. The Model

We examine a model of a monopoly producer of a durable good that has the basic features of a textbook. Each period a new cohort of buyers enters the market with a demand for the services of the durable good to be consumed in that period. At the end of the period, the owner can choose to sell the

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[3]Bond and Samuelson (1984) show that this effect continues to hold when there is replacement demand due to depreciation of the durable good.

[4]We maintain the assumption that the life of an edition is exogenously determined throughout this paper. Another question that has been addressed in the literature on durable goods is whether a monopolist has an incentive to alter the life of the good from the socially optimal level in order to kill off the used market. Waldman (1996) provides a good discussion of the issues. This question of whether the monopolist would choose the socially optimal life of an edition with our specification of consumer demands is beyond the scope of this paper, and is addressed in a companion paper (Bond and Iizuka (2004)). Iizuka (2004) also empirically analyzes whether textbook publishers introduce new textbook editions to avoid competition with previous units.

good in the used market or to keep it. However, the introduction of a new version of the durable drives the used market value of the previous version to 0, so a purchaser in the last period of the current version's life will have no resale option. We examine the optimal pricing over the life of a durable good that has an exogenously given life of two periods and a constant marginal cost of production, c.

We assume that there are two types of consumers, denoted by K and S, that are potential consumers of the good. Each period an exogenously given number N_i of type $i \in \{K, S\}$ consumers enter the market each period. Type K consumers will buy and keep the durable, with V_K^N (V_K^U) denoting the present value of returns that the type K consumer earns from purchasing the new (used) good. Note that since the type K consumer is not concerned about the resale value of the book, the type K consumer will place the same valuation on new and used goods in the second period of the life as in the first period. In the textbook case, type K consumers are those who hold onto the book after the class is completed. These could be students who major in the subject and use the text as a reference in the future, or students for whom the transactions costs of going to the used market to sell the good are high.

Type S consumers are those who value the good primarily for its service flow in the current period, and will sell the good with probability $\alpha \in (0, 1)$ in the used market in the subsequent period if it has value. A type S consumer will receive a piece of information with probability $(1 - \alpha)$ which results in the good not being sold in the used market. Examples of such information might be damage to the good that prevents its resale, high transactions costs in the used market, or a change in preferences that result in a preference for keeping the good. All type S consumers are identical ex ante, and correctly anticipate that the good will be resold with probability α. The expected surplus of a type S consumer of buying a new good will be $V_S^N + \alpha\beta p_2^U$, where V_S^N is the expected value placed by a type 2 consumer on the flow of service from a new good, β is the discount factor, and p_2^U is the price of a used good in the second period. It is assumed that used goods have no value following the second period, so the value to a type S consumer of the new good in the second period is simply V_S^N . The value of a used good to an S consumer in the second period is denoted V_S^U.

The preference parameters of the respective types can be used to characterize the demand for new and used goods in each period. In the second period, a type i consumer will buy used goods if the surplus from buying a used good is non-negative ($V_i^U \geq p_2^U$) and exceeds that available from purchasing a new good ($V_i^U - p_2^U \geq V_i^N - p_2^N$). Similarly, a new good will be purchased if $V_i^N \geq p_2^N$ and $V_i^N - p_2^N \geq V_i^U - p_2^U$. Combining these results, we obtain the reservation price for a used (new) good by type i in period 2, R_{i2}^U (R_{i2}^N), to be

$$R_{i2}^U = \min\left[V_i^U, V_i^U - V_i^N + p_2^N\right] \qquad R_{i2}^N = \min\left[V_i^N, V_i^N - V_i^U + p_2^U\right] \tag{1}$$

We will impose two restrictions on the taste parameters of the two types. The first gives type K the greatest absolute value for new goods and S the greatest absolute value for used goods:

(A.1) $V_K^N > V_S^N > V_S^U > V_K^U \geq 0$

Applying (A.1) to (1), we have $R_{S2}^U > R_{K2}^U$ for all p_2^N. This assumption reduces the number of cases to be considered since it ensures that type S will always be the high valuation buyers in the used market. This assumption seems plausible for the case of textbooks, since a student planning to hold on to the book will place a higher valuation on having a high quality copy and making careful use of the book. On the other hand a student wanting the book only for the purpose of getting through the course is likely to find the used book to be a much better substitute for the new good.[5]

The second assumption relates the taste parameters of the S buyers to the marginal cost of production

(A.2) $V_S^N > c > V_S^N - V_S^U$

[5](A.1) is clearly stronger than is necessary to have type S buyers purchase in the used market in the second period. For example, with $V_K^U > V_S^U$ and $V_K^N - V_K^U > V_S^N - V_S^U$, type S buyers will have the higher reservation price for used goods as long as $p^N < V_S^U - V_K^U + V_K^N$. We consider how the analysis is altered by making this assumption in section C.

The left hand inequality restricts attention to cases in which type S buyers have a sufficiently large willingness to pay for the services of the good that they would purchase a new good in the second period if it was priced at marginal cost. Utilizing the right hand inequality in (A.2), we have $R_{S2}^U > 0$ for all $p_2^N \geq c$. Since sellers will only choose prices that are no less than marginal cost, there will be a positive price in the second period as long as supply is less than N_S. An implication of this assumption is that it is not socially efficient to kill off the used market, since the used market would exist under a seller pricing at marginal cost.

Letting X_2 denote the stock of used goods in the second period, this analysis yields

Lemma 1: If $X_2 \leq N_S$, $p_2^N \geq c$, *and assumptions (A.1) - (A.2) hold,* $p_2^U = \min\,[V_S^U, V_S^U - V_S^N + p_2^N] > 0$.

Under the assumption that type K buyers always keep their goods and that the number of consumers is constant in each period, this is the relevant case for consideration here since the maximum possible second period supply is αN_S. For the benchmark case of a durable being supplied by perfectly competitive sellers, $N_K + N_S$ units of the good would be sold in the first period and $N_K + N_S(1 - \alpha)$ units in the second period. Used market sales in period 2 would be αN_S units at a price of $V_S^U - V_S^N + c > 0$.

A. Monopoly Pricing of the Durable Good

We now turn to the analysis of the optimal pricing policy for a monopoly seller of the durable good. Since the first period valuations of type S buyers depend on the seller's second period pricing policy, we solve the problem using backward induction. In period 2, the seller chooses the price for a new good given a stock X_2 of used goods resulting from sales in the previous period. If $p_2^N \leq V_S^N$, then it follows from (1) and Lemma 1 that type S buyers will buy both new and used goods and type K buyers will purchase new goods. If $p_2^N \in (V_S^N, V_K^N]$, then type K buyers will receive non-negative surplus from new goods and type S buyers will purchase only used goods. This indicates that the monopolist will choose between two pricing strategies: selling to only type N buyers at a price of V_K^N and selling to both types at a price of V_S^N. The former strategy yields a profit of $(V_K^N - c)N_K$, while the latter yields a profit of

$(V_S^N - c)(N_K + N_S - X_2)$. Letting $\lambda_K \equiv N_K/N_S$ and $x_2 \equiv X_2/N_S$, the strategy of selling only to type 1 will be more profitable if $\lambda_K \geq (V_S^N - c)(1 - x_2)/(V_K^N - V_S^N)$. This result can be used to established a critical value for the normalized stock in the second period

$$\tilde{x} \equiv \max\left[1 - \lambda_K\left(\frac{V_K^N - V_S^N}{V_S^N - c}\right), 0\right] \tag{2}$$

such that the seller will sell only to type K buyers if the normalized stock of used goods exceeds $\tilde{x}$.

These results on the optimal second period strategy can be summarized as:

Lemma 2: Under (A.1) and (A.2), the optimal policy of the monopolist in the last period of the editions is:

(a) $p_2^N = V_K^N$ *and* $\pi_2^*(x_2) = (V_K^N - c)\lambda_K$ *for* $x_2 \geq \tilde{x}$

(b) $p_2^N = V_S^N$ *and* $\pi_2^*(x_2) = (V_S^N - c)(1+\lambda_K - x_2)$ *for* $x_2 < \tilde{x}$.

In either case, $p_2^U = V_S^U$.

Note that Lemma 2 indicates the existence of a positive link between the stock of used goods and the price that a monopoly seller charges for new goods, since a larger used stock makes it more attractive to adopt the strategy of selling only to the high valuation buyers.

The profit function and used price solution from Lemma 2 can now be used to solve for the first period optimization problem for the seller. Since the monopolist's pricing strategy will depend only on the relative abundance of type K buyers, as in Lemma 2, we can simplify the notation by normalizing all quantities by the the number of type S buyers. The discounted normalized profits of the firm over the life of the good will be

$$\Pi = (p_1^N - c)\, y_1(p_1^N) + \beta\pi_2^*(x_2(p_1^N)) \tag{3}$$

where $y(p_1^N)$ is the normalized first period demand and $x_2(p_1^N)$ is the second period stock resulting from the firm's first period price choice. The normalized second period stock will equal α if type S consumers buy in period 1 and 0 otherwise, which from Lemma 2 yields

$$x_2(p_1^N) \quad \begin{cases} 0 & \text{for } p_1^N > V_S^N + \alpha\beta V_S^U \\ \alpha & \text{otherwise} \end{cases} \qquad \textbf{(4)}$$

The first period reservation values of the two types are given by $V_S^N + \alpha\beta V_S^U$ and V_K^N. Note that the ranking of these reservation prices is not guaranteed by (A.1). Although the type K consumer places a higher value on the good in the absence of a used market, the type S might have a higher valuation in the presence of a used market if resale is sufficiently high and the goods are particularly close substitutes to S buyers. Therefore, we have two cases depending on whether V_K^N is greater or less than $V_S^N + \alpha\beta V_S^U$.

We denote as Case I the situation where $V_K^N > V_S^N + \alpha\beta V_S^U$. The firm's first period choice can be simplified to choosing between setting a price of V_K^N and selling λ_K units or setting a price of $V_S^N + \alpha\beta V_S^U$ and selling $(1 + \lambda_K)$ units.[6] If the seller chooses to serve only high valuation buyers in the first period, there will be no second period stock of used goods and normalized profits will be $(V_K^N - c)\lambda_K + \beta\pi_2^*(0)$. If the seller chooses to sell lower the price to sell to both types, the profits will be $(V_S^N + \alpha\beta V_S^U - c)(1 + \lambda_K) + \beta\pi_2^*(\alpha)$. Comparing the payoffs from these strategies, we can obtain the critical values of λ_K for which the respective strategies will be optimal.

Proposition 1: In case I ($V_K^N > V_S^N + \alpha\beta V_S^U$), the optimal strategy for the monopolist will be:

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[6]It is straightforward to show that if it is profitable for the monopolist to sell to some consumers of type i, then it is profitable to sell to all consumers of type i. This holds for type K buyers because if $y_1 < \lambda_K$, marginal revenue from type K buyers is $V_K^N - c > 0$. In the case of sales to type S buyers, marginal revenue will depend on whether first period sales affect the quantity of second period sales. For $y_1 < \lambda_K + \tilde{x}/\alpha$, additional period 1 sales will reduce period 2 sales to type S and marginal revenue is $(1 - \alpha\beta)(V_S^N - c) + \alpha\beta V_S^U > 0$. For $y_1 > \lambda_K + \tilde{x}/\alpha$, additional period 1 sales have no impact on period 2 sales and marginal revenue is $V_S^N + \alpha\beta V_S^U - c > 0$. Thus, it is sufficient to compare the profitability of selling to all of type K with that of selling to all of both types.

a. sell to type K consumers only in both periods at $p_1^N = p_2^N = V_K^N$ *if* $\lambda_K > \dfrac{V_S^N + \alpha\beta V_S^U - c}{V_K^N - V_S^N - \alpha\beta V_2^U}$.

b. sell to both types in period 1 but sell only to type K in period 2, $p_1^N = V_S^N + \alpha\beta V_S^U < p_2^N = V_K^N$

$$\text{if } \lambda_K \in \left(\frac{(V_S^N - c)(1-\alpha)}{V_K^N - V_S^N}, \frac{V_S^N + \alpha\beta V_S^U - c}{V_K^N - V_S^N - \alpha\beta V_S^U}, \right).$$

c. Sell to both types in both periods, $p_1^N = V_S^N + \alpha\beta V_S^U > p_2^N = V_S^N$*, if* $\lambda_K < \dfrac{V_S^N - c}{V_K^N - V_S^U}$.

If the population consists of a sufficiently large fraction of type K buyers, the optimal pricing policy is to set a constant price for new goods in each period that extracts all surplus from type K buyers. In this case there will be no used market and type 2 obtain zero surplus. When the fraction of type K is sufficiently low, the optimal price for new goods declines over time to extract all surplus from type S buyers. Used markets are active in each case, and type K buyers earn a positive surplus in each period on purchases of new goods. The interesting case arises for intermediate values of λ_K, in which the price of new goods rises in the last period of the good's life. In this case, a sufficiently large fraction of type S buyers purchase goods in the used market that the seller writes off that segment of the market and sells only to type K buyers.

Case II arises where $V_K^N < V_S^N + \alpha\beta V_S^U$, so that the type S buyers are high valuation buyers in period 1. The profit from selling only to type 2 in the first period is $(V_S^N + \alpha\beta V_S^U - c) + \beta\pi_2^*(\alpha)$, while the profit from selling to both types in the first period is $(V_K^N - c)(1+\lambda_K) + \beta\pi_2^*(\alpha)$. In this case the seller will always sell to type S in period 1, so the optimal second period strategy is independent of the first period price and is obtained by a comparison of α and $\tilde{x}$ from Lemma 2. The critical value of λ_K for which the firm sells only to type S in the first period is then solved for by equating the first period profits under the respective strategies. This comparison yields the following result

Proposition 2: In Case II, the optimal sales policy in the first period will be to set $p_1^N = V_K^N$ *if* $\lambda_K > \dfrac{V_S^N + \alpha\beta V_S^U - V_K^N}{V_K^N - c}$ *and* $p_1^N = V_S^N + \alpha\beta V_S^U$ *otherwise. The second period sales policy is to set* $p_2^N = V_K^N$ *if* $\lambda_K > \dfrac{(V_S^N - c)(1 - \alpha)}{V_K^N - V_S^N}$ *and* $p_2^N = V_S^N$ *otherwise.*

In this case the price could be constant over time (if the firm sells to both types in period 1 and only to type 1 in period 2) or decreasing over time. Due to the reversal of rankings in the two periods, the firm will always sell to type S in period 1 and to type K in period 2.

B. A Three Period Edition

Proposition 2 established conditions under which the price of a new durable good would be higher in the second period than in the first period of an edition. In this section we examine how pricing behaves when we extend the edition to 3 periods. The extension to 3 periods allows us to examine the question of whether the rising price is a “last period” effect that occurs just before a new edition is introduced, or whether it is a “used market” effect that occurs as soon as used goods appear in the market. We simplify by assuming that all used goods (i.e. whether one period old or two periods old) are perfect substitutes. In light of the large number of cases that can arise in the three period model we limit discussion to Case I, which generated the rising price of the new good in the two period model.

We begin by deriving the pricing rules for the monopolist in periods 2 and 3 as a function of the exsting stock of used goods, and then discuss the equilibrium price paths. As in the 2 period model, the analysis proceeds by backward induction. The firm's optimal pricing policy in the third period is obtained from Lemma 2, since this is the last period of the edition and there is no future used market value for the durable. Specifically, the firm will choose to set $p_3^N = V_K^N$ if $x_3 > \tilde{x}_3$ and $p_3^N = V_S^N$ otherwise, where

$\tilde{x}_3 = \max\left(1 - \lambda_K (V_N^K - V_S^N)/(V_S^N - c), 0\right)$ from (2). The used price will be $p_3^U = V_S^U$ in either case.

In the second period pricing problem, the firm faces a (normalized) stock x_2 of used goods inherited from period 1 buyers. The seller chooses p_2^N maximize $(p_2^N - c)\, y_2(p_2^N, x_2) + \beta\pi_3^*(x_3(p_2^N, x_2))$,

where $y_2(p_2^N, x_2)$ is the demand for new goods in period 2 and $x_3(p_2^N, x_2)$ is the stock of used goods carried over to the third period. It is straightforward to show that under assumptions (A.1) and (A.2), type S buyers will purchase all of the used goods in period 2 for $x_2 < 1$.[7] This yields a result analogous to Lemma 1, in that $p_2^U = \min [V_S^U + \beta\alpha V_S^U,\ V_S^U - V_S^N + p_2^N]$. With this result, we can characterize the demand for new goods in period 2. Type K consumers will have a reservation price for new goods of V_K^N and type S consumers have a reservation price of $V_S^N + \alpha\beta V_S^U$. For $p_2^N \in (V_S^N + \alpha\beta V_S^U, V_K^N]$, demand for the new good is λ_K and $x_3 = \alpha x_2$. The highest profits obtained from selling only to type K occurs at $p_2^N = V_K^N$, which yields a profit of $(V_K^N - c)\lambda_K + \beta\pi^*(\alpha x_2)$. For $p_2^N \in (V_S^N + \alpha\beta V_S^U - V_S^U, V_S^N + \alpha\beta V_S^U]$, demand for the new good is $1 + \lambda_K - x_2$ and $x_3 = \alpha$. The highest profit from selling to both types is $(V_S^N + \alpha\beta V_S^U - c)(1 + \lambda_K - x_2) + \beta\pi_2^*(\alpha)$.

It is shown in the Appendix that the optimal policy in period 2 is such that the there exists a threshold value $\tilde{x}_2(\alpha)$ such that the firm sells only to type k if $x_2 > \tilde{x}_2(\alpha)$. This threshold value will be a function of α because a higher value of α is associated with a higher valuation for type S buyers and a larger stock of third period supply. The following result establishes the impact of α on the threshold

[7] The reservation values for used goods in the second period in this case are given by $R_{2K}^U = \min [V_K^U, V_K^U - V_K^N + p_2^N]$ and $R_{2S}^U = \min [V_S^U + \beta\alpha V_S^U, V_S^U - V_S^N + p_2^N]$. It follows from (A.1) that $R_{2S}^U > R_{2K}^U$ for all p_2^U in Case I and $R_{2S}^U > 0$ for $p_2^N \geq c$, so type S buyers will purchase all of the used goods for $x_2 < 1$.

value.

Proposition 3: If Case I holds and $\alpha \in [0,1)$, there exists an $\tilde{x}_2(\alpha) \in [0,1)$ such that the firm's optimal policy is to set $p_2^N = V_S^N + \alpha\beta V_S^U$ if $x_2 < \tilde{x}_2(\alpha)$ and $p_2^N = V_K^N$ if $x_2 > \tilde{x}_2(\alpha)$.

(a) $\tilde{x}_2(0) = \tilde{x}_3$

(b) $\tilde{x}_2(\alpha)$ *is non-decreasing in* α*, and is strictly increasing for* $\tilde{x}_2(\alpha) > 0$.

Part (a) follows from the fact that when $\alpha = 0$, the valuation of both type K and S is the same as in period 3, and used sales in period 2 have no effect on the third period stock. For $\alpha > 0$, there are two differences between the period 2 and period 3 problem. The first is that selling to type S buyers is more attractive in period 2 because their reservation value is higher. The second is that selling to type S buyers has a larger potential impact on third period profits because the used stock is larger. Part (b) of the Proposition shows that the former effect will always dominate, making it more attractive to sell to type S in the second period than in the third period. As a result, the threshold stock for selling only to type K is higher in the second period.

Proposition 3 will be useful in answering the question of what pricing patterns can be observed in equilibrium. We first consider whether it is possible to observe the price of the edition rising between period 1 and period 2. Suppose we consider the case in which $\alpha = 1$. Since $\tilde{x}_3 \le \tilde{x}_2(1) < 1$ by Proposition 3, it follows that the monopolist will set $p_2^N = p_3^N = V_K^N$ if it is profitable to sell to both types in period 1. The condition for the monopolist to sell to both types in period 1 is $(V_S^N + \beta(1+\beta)V_S^U - c)(1+\lambda) > (V_K^N - c)\lambda$. If the parameters also satisfy $V_S^N + \beta(1+\beta)V_S^U < V_K^N$, the equilibrium price path will satisfy $p_1^N = V_S^N + \beta(1+\beta)V_S^U < p_2^N = p_3^N = V_K^N$. With these parameter values, type K buyers are the high valuation buyers for new goods in all 3 periods. The monopolist finds it optimal only to sell to the type S buyers in the first period. Type S buyers then purchase only in the used market in the remaining periods, as they are priced out of the new market. It is also possible to construct an example in which monopolist finds it optimal to continue to sell to type S buyers in both the first and second periods, but sells only to type K in the third period. Since $x_2 = \alpha$ when the monopolist sells to both types in the first period, a necessary condition for this to happen is $\tilde{x}^3 < \alpha < \tilde{x}_2(\alpha)$.

These examples show that the phenomenon of a rising price of a new good is not necessarily confined to the last period of the durable's useful life before introduction of a new edition. Sellers will be more hesitant to raise price in earlier periods, in the sense that the threshold level of the used stock required to raise the price is higher, because of the higher willingness to pay of consumers who plan to resell the good. However, sellers may choose to raise the price in earlier periods if a sufficiently large fraction of the type S sellers resell their goods.

C. Higher Valuation for type K on both New and Used Goods

The results of the two period model that generate cycles in the pricing of goods over the life of an edition are based on the assumption that type K buyers have an absolute preference for new goods and type S have an absolute preference for used goods (i.e. $V_K^N > V_S^N$ and $V_K^U < V_S^U$). In this section we show that a rising price of the good in period 2 can also arise if we modify (A.1) to

(A.1') $V_K^N > V_S^N$, $V_K^U > V_S^U$, and $V_K^N - V_K^U > V_S^N - V_S^U$.

Assumption (A.1') captures the case in which the K buyers value both new and used goods more highly, but have a relative preference for new goods.[8]

The possibility that type K buyers can outbid type S buyers for used goods creates 3 possible outcomes in period 2. If the monopolist sets a price of V_K^N to extract all surplus from type K buyers, then

[8]This might be thought of as reflecting a case in which type K are high income, high transaction cost buyers. A high income would be associated with a relatively higher valuation The fact that high income buyers do not sell in the used market could be associated with a high time cost for used market transactions.

the reservation price of K for used goods, V_K^U, will exceed the reservation value of type S buyers from (1). This yields normalized second period profits of $(V_K^N - c)(\lambda_K - x_2)$, because the monopolist loses some sales from type K buyers to the used market. Type S buyers purchasing neither new nor used in the second period. If the monopolist sets a price for new goods of $V_K^N - V_K^U + V_S^U$, the reservation price for used goods of type K buyers is reduced to V_S^U. In this case the monopolist earns a profit of $(V_K^N - V_K^U + V_S^U - c)\lambda_K$ from sales to type K buyers and type S buyers purchase in the used market. The third option is to reduce the price of new goods to V_S^N, which makes type S indifferent between new and used goods. Type K will not purchase used goods, because their reservation price is below that of type S for $p_2^N < V_K^N - V_K^U + V_S^U$. Profits from this strategy will be $(V_S^N - c)(1 + \lambda_K - x_2)$.

Comparing the profits from the first option (K indifferent between new and used) with the third (S indifferent between new and used), it follows that the latter option will be preferred for all $x_2 \in [0,1]$ if $\lambda_K < (V_S^N - c)/(V_K^N - V_S^N)$. This restriction requires that the type S be sufficiently abundant in the market that it never pays for the monopolist to set the price of new goods so high that type S are driven out of both the new and used markets. Comparing the profits from selling new goods to both types with those from selling only to type N, we obtain a critical value $\hat{x}_2 = 1 - (V_K^N - V_K^U + V_S^U - V_S^N)/(V_S^U - c)$ such that the monopolist sells to both types at p_2^N if $x_2 < \hat{x}_2$. If $x_2 > \hat{x}_2$, the monopolist sells new goods only to type K at a price $V_K^N - V_K^U + V_S^U$. This result is similar to that in Lemma 2, in that the firm will switch from selling to both types to selling only to the high valuation buyers in period 2 if the stock of used goods is sufficiently high. One difference in this case is that the monopolist must leave some surplus to the high valuation buyers of new goods when $x_2 > \hat{x}_2$, because they are also the high valuation buyers of new goods.

It is shown in the Appendix that with $\lambda_K < (V_S^N - c)/(V_K^N - V_S^N)$, the optimal first period policy will be to sell to both types in the first period at a price of $p_1^N = V_S^N + \alpha\beta V_S^U$. In order for the price of new goods to be higher in the second period than in the first, two additional conditions must be satisfied.

The first is that $\alpha > \hat{x}_2$, so that the firm will find it optimal to sell only to type K in the second period. The second condition is that the parameters are such that $p_2^N = V_N^K - V_K^U + V_S^U > p_1^N = V_S^N + \alpha\beta V_S^U$. This condition is more stringent than required in Proposition 1 under assumption (A.1), which required only that $V_N^K > V_S^N + \alpha\beta V_S^U$. The condition is stricter in the present case because type K buyers are earning a surplus on new goods in the second period in the present case. It is possible to construct examples under assumption (A.1') in which there is a region of parameter values generating a rising value of used goods over time.

These results can be summarized in the following result:

Proposition 4: If (A.1') and (A.2) hold in Case I and $\lambda_K < (V_S^N - c)/(V_K^N - V_S^N)$, the optimal first period policy is to sell to both consumer types. The optimal second period policy is to sell only to type K if $\alpha > 1 - (V_K^N - V_K^U + V_S^U - V_S^N)/(V_S^U - c)$. This will result in a rising price of new goods over the life of the edition if $V_N^K - V_K^U + V_S^U > V_S^N + \alpha\beta V_S^U$.

Proposition 4 shows that the threshold effect of the used stock and the rising price of new goods over time can both be observed in the model in which type K buyers have an absolute preference for new and used goods, as long as the fraction of type K buyers is not too high.

If $\lambda_K > (V_S^N - c)/(V_K^N - V_S^N)$, then the seller will find it optimal to set a price of V_K^N when the supply of used goods is quite small under assumption (A.1'). When the share of type K buyers is sufficiently large, the seller will find it optimal to price type S out of both new and used markets. As the stock of used goods rises, it will become profitable to lower the price of new goods to prevent type K buyers from purchasing used goods. This example generates a difference from the previous case, in that it results in a negative relationship between the price of stock of used goods and the price of new goods.

II. An Empirical Analysis of the Textbook Market

In this section we use data from sales of new economics texbooks to test hypotheses regarding the pricing of textbooks over the life of an edition. The solution of the model for the equilibrium price paths utilized strong assumptions such as the stationarity of demand and cost parameters, that are unlikely to be met in the data. Therefore, we concentrate on the pricing rules for a seller facing a given stock of used goods from past sales decisions. Specifically, the theoretical model suggests estimating a relationship of the following form:

$$p_\tau^N = f(X_\tau, T - \tau) \qquad \textbf{(5)}$$

where p_τ^N is the price of a new textbook in the τth period of the current edition, X_τ is the stock of used goods for the edition at age τ, and T is the expected life of the current edition. If the market for textbooks consists of homogeneous buyers who plan to sell the book, like the type S buyers of the theoretical model, then the primary determinant of the price of the book should be the remaining life of the edition. As in Proposition 1c, the price of the book will fall over the life of the edition because the expected value of the good in resale will be lower. The price discrimination model with heterogenous buyers in Lemma 1 and Propositions 3 and 4 suggests a positive relationship between the stock of used goods and the price of new goods, since the policy of raising price of new goods to sell only to high valuation buyers of new goods becomes more attractive as the number of low valuation buyers purchasing in the used market rises. In addition, raising the price will be more attractive the shorter the remaining life of the edition.

In order to estimate equation (5) we must also allow for the possibility of changes over time in marginal cost or the valuations of buyers and the potential endogeneity of the stock of used goods. Since these issues are potentially important in the data, we must also address these issues before we estimate (5). We first describe the data that was used in the estimation, and then discuss how (5) was modified to estimate theses effects.

A. Data

Our textbook pricing data come from college bookshops. For each semester, Monument

Information Resource (MIR) collects information on the number of textbooks sold (new vs. used), average prices (new vs. used), edition number, year and month of publication, author name, textbook categories, publisher name, and the ISBN code. For this study, we use only economics textbooks that appear in the MIR database between 1996 and 2000. MIR collects data twice a year, and this gives us ten semesters' observations for each textbook.[9] We refer to these semesters as fall and spring semesters. MIR estimates that their data cover approximately 46 per cent of the total college textbook market in the U.S. in 2000.[10]

For the ten semesters between 1996 and 2000, we have a total of 2,496 observations. An observation is a title-edition-semester. It is common for publishers to revise textbook editions over time, using almost identical names for the textbooks. A "title" refers to the name of a textbook. There are 397 unique textbook titles in the data set. On average, each title has 1.6 editions in the data set, and we observe a total of 284 edition revisions. Study guides, custom textbooks, government publications, and Canadian editions were excluded from the analysis.[11]

As a measure for textbook price, we focus our analysis on the price of textbook that is sold as a stand-alone textbook. That is, we do not use the "package" price of a textbook in our estimation, which contains supplementary materials such as study guide, software, and CD-Rom. This is mainly because textbook bundles are much less frequently observed in the data than stand-alone textbooks. Thus, comparing the prices for stand-alone textbooks is more reliable for examining the textbook pricing cycles.[12] In our preliminary analysis, however, we also estimated the model by using average textbook

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[9] The textbook sales during summer are combined with the spring sessions. Ideally, one would like to observe the "summer" period separately from the spring semester. Unfortunately, MIR does not collect data separately for spring and summer sessions.

[10] MIR's data coverage increased between 1996 and 2000. We used these coverage rates to recover the number of total used and new textbooks sold for each title in each semester.

[11] We do not include study guides since their revision decisions are primarily determined by the revision decisions of accompanied textbooks. Custom textbooks usually do not have used markets, and thus are excluded. Canadian editions of a textbook were not included. We do not observe many of these editions since MIR does not cover much of the Canadian market.

[12] In rare cases, different versions of stand-alone textbooks are available given a semester. We computed a weighted average of prices for these cases.

prices that include both packages and stand-alone textbooks. The results were very similar in this case. Thus the results do not appear to be sensitive to the definition of prices.

We identify the entry of a new edition when we observe a new edition of a textbook in the MIR data. For those textbooks introduced before spring 1996, the month of the new edition entry was identified using the MIR data, Amazon.com, and Barnesandnobles.com. We also searched the latter two databases to find out whether a new edition of a title was introduced immediately after the fall 2000 semester, when our data set is truncated.[13] Sometimes, an old edition of a title is sold even after a new edition of the same title is introduced. These "overlapping" observations were dropped from the data set. Table 1 presents summary statistics. An average textbook price for our samples is $55, and the quantity share of used textbooks is 42%. The average age of textbooks in the data set is 5.4 semesters. All prices are deflated using the Consumer Price Index and expressed in 1996 dollars.

B. Empirical Model

We now turn to the estimation of (5) to explain the changes in the price of a textbook over the life of an edition. The dependent variable in the regression is the new price for a textbook title-edition i during semester t, denoted p_{it}. In our theoretical model, the primary change over the life of an edition is due to the fact that the used market value of the good declines as the end of the edition approaches. A second effect of time in an edition is that the material in a textbook may become more dated as the textbook ages, reducing its value. We included two variables to capture these effects. The first is Age_{it} which is the age of the textbook-edition in semester t. The second is Rev_{it}, which is a dummy variable that is equal to 1 if the textbook-edition i is revised in the following semester. Homogeneous consumer models in which consumers capitalize the used market value of the good market into their demand for a new good would

[13] That is, if a new edition was introduced in spring 2001, we code revision decision=1 for fall 2000 (discussed in detail below).

predict a negative effect of the age of an edition and no effect of a coming revision on the willingness to pay for the new book. The declining value of a good due to the aging of information in the text would also suggest a negative coefficient on Age_{it}. In contrast, the model with price discrimination and heterogeneous buyers raises the possibility of a rising price of the textbook with age and/or an increased price in the last period of the edition. The other factor affecting the pricing policy in (5) is the stock of used goods. In order to adjust the stock for the size of the market, we define $UsedRatio_{it}$ to be the quantity share of used textbooks for title-edition i during semester t.[14]

As the base model, we estimate the following simple fixed-effects model:

$$\ln(p_{it})=\alpha UsedRatio_{it} + \beta Rev_{it} + \gamma Age_{it} + Time_t + TitleEdition_i + \epsilon_{it} \qquad (6)$$

where $\ln(p_{it})$ is a natural logarithm of new price for textbook title-edition i during semester t. In addition to the log-linear specification, we also estimate the linear-linear specification. In addition to the explanatory variables obtained from (5), we have added

$TitleEdition_i$: textbook fixed effects at the textbook title-edition level. That is, if there are two editions of the same title, these two editions are assumed to have separate intercepts.

$Time_t$: We include nine dummies corresponding to each semester between 1996 and 2000.

The time dummy variables control for factors such as input costs that might vary with calendar time and affect the pricing of new textbooks.

C. Instrumental Variables

In addition to the base model presented above, we estimate a model that recognizes the potential endogeneity between the dependent variable and a regressor. Specifically, we are concerned that the market share for used textbooks (i.e., UsedRatio) and textbook prices may be jointly determined. We

[14] All textbooks, including textbooks sold as part of packages, are included when computing this variable.Textbooks originally sold as part of packages may be sold separately in the used textbook market as stand-alone textbooks. In fact, while we observe many “new” packages in the data, there are few “used” packages. Combining all observations of the same title-edition allows us to compare the quantity of used and new units sold over a given time period.

attempt to solve this issue by constructing two instrumental variables for UsedRatio. The first instrument utilizes the fact that economics courses vary in their proportions that economics and non-economics majors take the course. In general, economics courses that attract a large number of students, such as introductory economics, tend to have a higher share of non-economics majors. Since these non-economic majors are likely to sell their textbooks after the course is over, we would expect UsedRatio is higher for these courses. To capture the extent that non-economics majors dominate the subject area, we use the number of textbooks sold in each category in each semester (CategSize). Following the MIR's classification, we compute CategSize in 32 textbook segments. We expect that UsedRatio is higher in the categories where a larger number of textbooks are sold in each semester.

We construct the second instrument by exploiting the differences in transaction costs incurred by textbooks in order to change hands in the used textbook market. Typically, college bookshops buy back textbooks from students only if they know the textbook will be used in the same college in the next semester. Otherwise, they pay the wholesale price to students, which is substantially lower than the buy-back price. This suggests that, due to higher transaction costs, textbooks that are used only occasionally have fewer textbooks in the used textbook market. Accordingly, we would expect that UsedRatio to be lower for these titles. We construct an instrumental variable (PrevUsed) that captures this idea: a dummy variable that equals 1 if the title-edition was used in the previous period, and 0 otherwise.[15] [16] We expect that UsedRatio to be higher if a title-edition be used in the previous semester.

D. Estimation Results

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[15] While we construct this dummy variable at the aggregate level and not campus specific, it can still capture the frequency of textbook adoption. Some textbooks show up in our data set only in specific semesters, such as the fall semester, and are not used in all semesters. Also, some not-so-popular textbooks do no appear to be used consistently in all semesters.

[16] Note that the dummy variable captures not only the infrequency of adoption but also the introduction of a new edition. Thus, we also estimated a model that includes the new edition dummy as part of instruments. The qualitative results do not change due to this addition.

Table 2 presents the estimation results for the baseline model. In the first two columns, we look at the simple time trend by estimating the fixed-effects model with only time dummies. The omitted category is spring 1996. The results show that textbook prices steadily increased between 1996 and 2000. On average, textbook prices rose 17.5% (column 1) or $11.2 (column 2) during this period. That is, textbook prices increased 3.3% annually in real term during the five years. This confirms the general concern that the increase of textbook prices has outpaced other goods and services.[17]

The next two columns show the results from our base model. The results are similar regardless of the specification. First, the coefficient for UsedRatio is positive and statistically significant, suggesting that textbook prices increase as the market share of used books increases relative to new books. Second, the coefficient for the revision indicator Rev is positive and significant in both cases. This suggests that textbook prices tend to jump up before the entry of a new edition. Third, we find that the coefficient for semester age Age is not statistically different from zero at the five percent confidence level. This suggests that, although the majority of textbooks do revise editions eventually, aging of textbooks *per se* does not lower textbook prices, holding all other factors constant.

Estimated coefficients suggest that textbook prices increase on average 1.1% or $0.7 as the share of used books within title-edition increases by 20%. Also, textbook prices increase on average 2.2% or $1.1 immediately before the introduction of a new edition. While these numbers are not necessarily big relative to the time trend, they are precisely estimated. The semester dummy variables become insignificant after adding the three time varying variables, although we reject the null hypothesis that the coefficients for the time dummies are jointly zero at the 5% confidence level.[18] The coefficients for the time dummies are comparable to the results shown in columns 1-2.

To check the robustness of the results, we have also estimated a number of additional runs by

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[17] See, for example, *USA Today*, “Group Wants Textbook Costs Kept in Line,” February 3, 2004

[18] Corresponding F-Statistics are 2.22 and 2.33, respectively.

dropping some of the variables (such as UsedRatio and Rev) from the right-hand-side of the model (not reported). The qualitative results are the same regardless of these changes. In particular, while the coefficients for Rev and UsedRatio are positive and significant in all cases, the coefficient for Age never becomes statistically significant, confirming the results presented in Table 2.

Overall, estimation results suggest that textbook prices increase as a revision of the textbook approaches and used textbooks accumulate. However, aging of textbooks do not appear to affect textbook pricing. These results are in stark contrast with the prediction of the pure-Sawn type models that the price of a durable good should go down as the economic life of the product is shortened. In contrast, this pricing pattern can be generated from our theory model. Indeed, rising prices over time are not necessarily surprising if consumers are heterogeneous and durable goods producers sell the good to different customer segments over time.

We now turn to the analysis that utilizes instrumental variables. First, we examine the validity of instruments. Table 3, columns 1-2 show the results from the first-stage regressions where the dependent variable is UsedRatio and independent variables are instruments. The two columns present the results with and without the excluded instruments, i.e., category-level market size (CategSize) and an indicator that shows whether the title-edition was used in the previous semester (PrevUsed). A comparison of these columns indicate that the partial R-squared corresponding to the excluded instruments is 0.11, suggesting that the excluded instruments have reasonable explanatory power. Also, first-stage F-statistics (i.e., 130) indicates that instruments can explain UsedRatio well. Thus, these statistics suggest that the instruments are promising. Note that CategSize and PrevUsed are positively correlated with UsedRatio. This is consistent with our prior expectation that UsedRatio would be higher when the size of a textbook category is larger and the title edition was used in the previous semester.

The next two columns present the results from the instrumental variable estimation. The qualitative results are identical to the previous results regardless of the use of instruments. In particular, we find that UsedRatio affects textbook prices positive and significantly. That is, textbook prices go up as the proportion of used textbooks increases within title-edition. Also, textbook prices increase in the period immediately before the introduction of a new edition. As before, there is no evidence that textbook prices change over time simply due to the aging of the textbook, holding all other factors constant. Since we have two excluded instruments for one endogenous variable, we conducted the overidentification restrictions test. The test statistics is 0.23, which is much smaller than the critical value of 3.84, and thus overidentifying restrictions are not rejected at any reasonable level. To check whether the choice of instruments affect results, in Table 3, columns 5-6, we report the results when we use only PrevUsed as the instrumental variable. Essentially, the results are identical to the results presented in columns 3-4. In sum, the results we obtained from the basic fixed-effects models (i.e., Table 2, columns 3-4) are robust regardless of the use of instrument, choice of instruments, and the specific choice of functional forms.

III. Conclusion

This paper attempted to provide a new perspective on durable goods pricing. Since Swan (1970), durable goods literature has primarily focused on analyzing one type of buyers who purchase goods for current use and then resell in the used market. In this setup, if durable goods producers introduce new models periodically, the prices for new goods decline over time as the end of economic life of the product approaches. While the declining price over its life is commonly observed in various durable goods theories, it is not clear whether the price cycle is sustained when there is heterogeneity in buyers preferences.

In this paper, we developed a model of monopoly pricing of a durable good when there are heterogeneous buyers. We showed that, if some buyers continue to place values on the old durable good even after a new model is introduced, durable goods prices could increase over the life of the product. Using a panel data set that contains 397 economics textbooks, we test the prediction of the model. We found that new textbook prices increase overtime as the share of used books increases and the final period for the current edition arrives. In contrast, we found no evidence that textbook prices decline as the end of current edition approaches. The possibility of rising price of the durable good over its life is the unique feature of the model that is overlooked by the traditional Swan-type models. Our empirical evidence from the textbook market shows that such a pricing pattern indeed exists in practice and may be found in many other durable goods markets.

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Price	2496	55.084	21.942	5.420	102.937
Price (natural log)	2496	3.881	0.579	1.690	4.634
UsedRatio	2496	0.424	0.259	-0.004	0.999
Rev	2496	0.114	0.318	0	1
Age (in semesters)	2496	5.359	6.273	1	61
y96f	2496	0.105	0.307	0	1
y97s	2496	0.107	0.309	0	1
y97f	2496	0.107	0.309	0	1
y98s	2496	0.107	0.309	0	1
y98f	2496	0.097	0.297	0	1
y99s	2496	0.091	0.288	0	1
y99f	2496	0.097	0.295	0	1
y00s	2496	0.101	0.301	0	1
y00f	2496	0.098	0.297	0	1
CategSize (in 10,000)	2496	5.797	5.590	0.051	15.825
PrevUsed	2309	0.738	0.440	0	1

Prices are in 1996 dollars.

Source: MLM, authors' calculation.

Table 2: Basic Results from Fixed Effects Models

	(1) fixed effects model Dep Var= ln(p)	(2) fixed effects model Dep Var= p	(3) fixed effects model Dep Var= ln(p)	(4) fixed effects model Dep Var= p
UsedRatio			0.0527***	3.4722***
			(0.0114)	(0.5622)
Rev			0.0218***	1.0686***
			(0.0067)	(0.3326)
Age			-0.0117	0.0946
			(0.0198)	(0.9790)
y96f	0.0299***	1.7630***	0.0352	1.2865
	(0.0083)	(0.4140)	(0.0214)	(1.0565)
y97s	0.0440***	2.4668***	0.0586	1.7712
	(0.0084)	(0.4189)	(0.0403)	(1.9932)
y97f	0.0709***	4.0997***	0.0887	2.7926
	(0.0087)	(0.4323)	(0.0597)	(2.9499)
y98s	0.0927***	5.5259***	0.1204	4.0297
	(0.0090)	(0.4484)	(0.0794)	(3.9203)
y98f	0.1163***	7.1837***	0.1518	5.3434
	(0.0095)	(0.4734)	(0.0988)	(4.8794)
y99s	0.1151***	7.1820***	0.1564	4.9171
	(0.0098)	(0.4847)	(0.1185)	(5.8542)
y99f	0.1441***	9.0140***	0.1928	6.3761
	(0.0101)	(0.4996)	(0.1377)	(6.8027)
y00s	0.1461***	9.4470***	0.2009	6.3999
	(0.0102)	(0.5066)	(0.1573)	(7.7683)
y00f	0.1754***	11.2342***	0.2349	7.6297
	(0.0109)	(0.5400)	(0.1770)	(8.7432)
Constant	3.7885***	49.3370***	3.7962***	48.9588***
	(0.0070)	(0.3493)	(0.0196)	(0.9687)
Observations	2496	2496	2496	2496
R-squared	0.16	0.25	0.18	0.27

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Results Using Instrumental Variables

	(5) 1st-stage estimates Dep Var= UsedRatio	(6) 1st-stage estimates Dep Var= UsedRatio	(7) fixed effects model w/ iv Dep Var= ln(p)	(8) fixed effects model w/ iv Dep Var= p	(9) fixed effects model w/ iv Dep Var= ln(p)	(10) fixed effects model w/ iv Dep Var= p
UsedRatio			0.1250***	7.5009***	0.1183***	7.3542***
			(0.0285)	(1.4043)	(0.0286)	(1.4088)
Rev	0.0129	0.0238*	0.0229***	1.1040***	0.0229***	1.1059***
	(0.0144)	(0.0130)	(0.0071)	(0.3496)	(0.0071)	(0.3492)
Age	0.1631***	0.0960***	-0.0222	-0.4423	-0.0211	-0.4184
	(0.0406)	(0.0370)	(0.0205)	(1.0112)	(0.0205)	(1.0104)
y96f	0.0882*	0.0019	0.0315	0.5021	0.0320	0.5150
	(0.0511)	(0.0466)	(0.0253)	(1.2473)	(0.0253)	(1.2462)
y97s	-0.0661	-0.1168	0.0628	1.4075	0.0623	1.3978
	(0.0868)	(0.0787)	(0.0428)	(2.1096)	(0.0427)	(2.1076)
y97f	-0.1118	-0.1014	0.0942	2.4569	0.0935	2.4405
	(0.1254)	(0.1137)	(0.0618)	(3.0481)	(0.0617)	(3.0453)
y98s	-0.2659	-0.2012	0.1366*	4.2303	0.1348*	4.1913
	(0.1650)	(0.1498)	(0.0816)	(4.0237)	(0.0815)	(4.0201)
y98f	-0.3431*	-0.2251	0.1729*	5.7655	0.1706*	5.7152
	(0.2045)	(0.1855)	(0.1012)	(4.9887)	(0.1010)	(4.9843)
y99s	-0.4657*	-0.3043	0.1847	5.6953	0.1816	5.6270
	(0.2448)	(0.2222)	(0.1213)	(5.9777)	(0.1211)	(5.9724)
y99f	-0.5258*	-0.2663	0.2244	7.2761	0.2209	7.1990
	(0.2841)	(0.2579)	(0.1407)	(6.9355)	(0.1405)	(6.9295)
y00s	-0.6416**	-0.3698	0.2392	7.6356	0.2349	7.5415
	(0.3240)	(0.2943)	(0.1606)	(7.9175)	(0.1604)	(7.9106)
y00f	-0.6675*	-0.3596	0.2737	8.8460	0.2692	8.7481
	(0.3645)	(0.3312)	(0.1805)	(8.8985)	(0.1802)	(8.8907)
Constant	-0.1371***	-0.0841*	3.8040***	50.0749***	3.8031***	50.0548***
	(0.0368)	(0.0480)	(0.0186)	(0.9147)	(0.0185)	(0.9140)
CategSize		0.0091*				
		(0.0053)				
PrevUsed		0.1918***				
		(0.0101)				
Observations	2309	2309	2309	2309	2309	2309
R-squared	0.40	0.51	0.16	0.26	0.16	0.25

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

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Appendix

Proof of Proposition 1: First suppose that $\tilde{x} \leq 0$, which from (1) requires $\lambda_K \geq (V_S^N - c)/(V_{K1}^N - V_S^N)$. With $\tilde{x} \leq 0$ the monopolist sells only to type K in period 2 regardless of the first period sales policy, the desirability of selling to type S in the first period depends only on first period profits. Selling to type K only in the first period gives $(V_K^N - c)\lambda_K$ and selling to both types in the first period gives $(V_S^N + \alpha\beta V_S^U - c)(1+\lambda_K)$. It follows that selling to type 1 only is preferred if $\lambda_K > (V_S^N + \alpha\beta V_S^U - c)/(V_K^N - V_S^N - \alpha\beta V_S^U)$, which establishes part (a) of the proposition. Selling to both types will be optimal for $\lambda_K \in [\,(V_S^N - c)/(V_{K1}^N - V_S^N),\ (V_S^N + \alpha\beta V_S^U - c)/(V_K^N - V_S^N - \alpha\beta V_S^U))$.

Now suppose that $\tilde{x} \in (0, \alpha)$, which requires that $\lambda_K \in [\,(V_S^N - c)(1 - \alpha)/(V_{K1}^N - V_S^N), (V_S^N - c)/(V_{K1}^N - V_S^N))$. If the firm sells to type 2 buyers in period 1, the supply of used goods in period 2 is αN_2. This exceeds the critical value for period 2, so that the firm sells only to type 1 buyers in period 2 and earns a discounted profit of $(V_S^N + \alpha\beta V_S^U - c)(1+\lambda_K) + \beta(V_K^N - c)\lambda_K$. If the firm sells only to type 1 buyers in period 1, the second period stock will be 0 and the firm will sell to both types in period 2. This yields a discounted profit of $(V_K^N - c)\lambda_K + \beta(V_S^N - c)(1+\lambda_K)$. Comparing these expressions, the monopolist will find it profitable to sell only to type 1 buyers in the first period if $[(V_K^N - V_S^N)(1 - \beta) - \alpha\beta V_S^U]\lambda_K > ((V_S^N - c)(1 - \beta) + \alpha\beta V_S^U)$. However, this inequality cannot be satisfied for any feasible values of λ_K. If $(V_K^N - V_S^N)(1 - \beta) - \alpha\beta V_S^U < 0$, this inequality cannot be satisfied for $N_1, N_2 \geq 0$. If $(V_K^N - V_S^N)(1 - \beta) - \alpha\beta V_S^U > 0$, the inequality requires $\lambda_K > (V_S^N - c)/(V_K^N - V_S^N)$ which lies outside the required range. Therefore, the seller will sell to both types in period 1 and only to type K in period 2 for λ_K in this range. Combining this result with that of the previous paragraph yields part b.

Finally, consider the case where $\tilde{x} > \alpha$, which requires that $\lambda_K < (V_S^N - c)(1 - \alpha)/(V_{K1}^N - V_S^N)$. If the firm sells to type 2 in the first period it will also sell to both types in the second period, yielding a return of $(V_S^N + \alpha\beta V_S^U - c)(1+\lambda_K) + \beta(V_S^N - c)(1 + \lambda_K - \alpha)$. If the firm sells only to type 1 in the first period, it $(V_K^N - c)\lambda_K + \beta(V_S^N - c)(1+\lambda_K)$. Selling to both types in period 1 is preferred if $(V_K^N - V_S^N - \alpha\beta V_S^U)\lambda_K > ((v_2 - c)(1 - \beta) + \alpha\beta\theta_2)N_2$. This condition will always be satisfied when Assumption 1 holds, which yields part d of the Lemma.‖

Proof of Proposition 3: Define $\Delta : [0,1]\times[0,1]\rightarrow\mathbb{R}$ to be the difference in profits between selling only to type K and selling to both types in the second period, which will be given by

$$\Delta(x_2, \alpha) = (V_K^N - c)\,\lambda_K + \beta\pi_3^*(\alpha x_2) - (V_S^N + \alpha\beta V_S^U - c)\,(1 + \lambda_K - x_2) - \beta\pi_3^*(\alpha)$$

Since π_3^* is continuous on [0,1] and differentiable everywhere but at $\tilde{x}_3$, Δ is continuous in x_2 on [0,1] and differentiable everywhere but at $\tilde{x}_3/\alpha$. For $x_2 > \tilde{x}_3/\alpha$, $\partial\Delta/\partial x_2 = (V_S^N + \alpha\beta V_S^U - c) > 0$. For $x_2 < \tilde{x}_3/\alpha$,

$\partial\Delta/\partial x_2 = (V_S^N - c + \alpha\beta(V_S^U - V_S^N + c)) > 0$, where the inequality follows from (A.1) and (A.2). Since $\Delta(1,\alpha) = V_K^N - V_S^N - \alpha\beta V_S^U > 0$ in case 1, it follows that either $\Delta(x_2, \alpha) > 0$ for $x_2 \in [0,1]$ or there exists a value $\tilde{x}_2 \in [0, 1)$ such that $\Delta(\tilde{x}_2, \alpha) = 0$. Defining $\tilde{x}_2 = 0$ for the case in which $\Delta(x_2, \alpha)$ bb> 0 on [0,1] establishes the first part of the Lemma.

To establish the second part, we first show that Δ is decreasing in α. Differentiating Δ yields

$$\partial\Delta/\partial\alpha = -\beta V_S^U(1 + \lambda_K - x_2) + \beta(\pi_3^{*\prime}(\alpha x_2)x_2 - \pi_3^{*\prime}(\alpha))$$

Since $\pi_3^{*\prime}(x_3) = -(V_S^N - c)$ for $x_3 < \tilde{x}_3$ and $\pi_3^{*\prime}(x_3) = 0$ for $x_3 > \tilde{x}_3$, there are three cases to consider in evaluating (B.2). For $x_2 > \tilde{x}_3/\alpha$, the monopolist sells only to type K in the third period in either case and $\partial\Delta/\partial\alpha = -\beta V_S^U(1 + \lambda_K - x_2) < 0$. For $x_2 \in \left(\tilde{x}_3, \tilde{x}_3/\alpha\right)$, the monopolist sells to both type in period 3 if it sells only to K in period 2 and $\partial\Delta/\partial\alpha = -\beta[V_S^U(1 + \lambda_K - x_2) + (V_S^N - c)x_2] < 0$. For $x_2 < \tilde{x}_3$, the monopolist sells to both types in period 3 regardless of the period 2 sales policy and $\partial\Delta/\partial\alpha = -\beta[V_S^U\lambda_K + (V_S^U - V_S^N + c)(1 - x_2] < 0$. Combining this result with the fact that Δ is decreasing in x_2 for $\tilde{x}_2(\alpha) > 0$, we have $d\tilde{x}_2/d\alpha > 0$ for $\tilde{x}_2(\alpha) > 0$. Finally, note that $\Delta(x_2,0) = (V_K^N - c)\lambda_K - (V_S^N - c)(1 + \lambda_K - x_2)$, so $\tilde{x}_2(0) = \tilde{x}_3$.

Proof of Proposition 4: It was established in the text that for $\lambda_K < (V_S^N - c)/(V_K^N - V_S^N)$, the optimal second period policy is to sell new goods to both types if $x_2 < \hat{x}$ and to sell only to type K buyers if $x_2 > \hat{x}$. The optimal second period profits can then be expressed as $\pi_2^*(x_2) = (V_K^N - V_K^U + V_S^U - c)\lambda$ for $x_2 < \hat{x}$ and $\pi_2^*(x_2) = (V_S^N - c)(1 + \lambda_K - x_2)$ for $x_2 > \hat{x}$. We can then define the profit differential between selling only to type K in period 1 and selling to both types in period 1(assuming case I) to be

$$\Gamma(\alpha) = (V_K^N - c)\lambda_K + \beta\pi_2^*(0) - (V_S^N + \alpha\beta V_S^U - c)(1+\lambda_K) - \beta\pi_2^*(\alpha)$$

Using the definition of π_2^*, it can be shown that this expression is strictly decreasing in α. Evaluating at $\alpha = 0$, we have $\Gamma(0) = (V_K^N - V_S^N - \alpha\beta V_S^U)\lambda_K - (V_S^N + \alpha\beta V_S^U - c) < -\alpha\beta V_S^U(1 + \lambda_K) < 0$ for $\lambda_K < (V_S^N - c)/(V_K^N - V_S^N)$. This establishes that the optimal policy will be to sell to both types in period 1 for all α, establishing Proposition 4.