Price discrimination via second-hand markets*

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February 1991
(Revised August 1992)

Abstract

Consumers have heterogeneous tastes for new and used goods, and second-hand markets involve transactions costs. A monopoly seller may gain or lose from the existence of a second-hand market: locally it may prefer lower transactions costs, but globally, it may prefer high transactions costs so it can strangle the used market. The monopolist uses the second-hand market as an indirect device to achieve a form of second-degree price discrimination. If the monopolist can control the quality of its product when used, it may wish to deteriorate this quality to worthless, or else to have it "as good as new."

JEL Classification: 022.

Published *European Economic Review* 38 (1994), 23-44.

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Introduction

Is the exercise of monopoly power helped or hindered by the existence of a competitive second-hand market for the monopolist's product? According to Rust (1986, p. 65)), "the 'conventional wisdom' is that a secondary market provides close substitutes for new durable goods limiting profits of the monopolist in the primary market." This view suggests profits will be smaller the less the impediment (in the form of transaction costs) to trading the product in the second-hand market. Further reflection suggests this is not the whole story. Indeed, a second-hand market may serve to increase primary demand for a monopolist's product if consumers anticipate a secondary resale value. However, at the same time, those consumers buying used goods constitute lost customers in the primary market. Swan (1980, p. 78) argued that "it is not the existence of a second hand market per se which need imply any restraint on the profitability or pricing decision of the monopolist (...); the pure monopolist (...) is paid an amount which reflects the net present value of the stream of (...) services to possibly a whole host of future owners." This argument relies on the assumption in the Swan (1970, 1972 and 1980) papers and in Rust (1986) that consumers have homogeneous preferences. If instead, different consumers have different valuations of the new and used products, then the second-hand price is the valuation only of the *marginal* second-hand buyer, the individual indifferent between buying second-hand and not buying at all. Introducing heterogeneous consumers also explains endogenously the segmentation of the market by consumer type into those buying new and those buying used, etc.

We consider a specific model, based on Mussa and Rosen (1978), in which consumers have heterogeneous preferences over new and used goods. The second-hand price is determined by transaction costs and the interaction of demand and supply of used durables, with both of these variables depending on the new price. In the face of this, the monopolist, in choosing its price, determines the extent and even the nature (e.g. whether it exists at all) of the secondary market. The answer to the original question then depends on the interaction of several factors which we aim to untangle in this paper.

Mussa and Rosen show (in a model without second-hand markets) that a monopolist may wish to produce several qualities in order to segment the market into different consumer types according to their preference for quality. This is a form of *direct* second-degree price discrimination. In our model, the monopolist uses the second-hand market to practice a form of *indirect* second-degree price discrimination. The second-hand market induces a segmentation of consumer types into different classes of

willingness to pay. Even though the monopolist does not sell directly to consumers buying used, it benefits from them through increased primary demand.

Most of the literature on second-hand markets (Swan (1970, 1972), Miller (1974), Liebowitz (1982) and Rust (1986)) models the demand side by a representative consumer[1] and assumes that transaction costs are zero. One problem with this approach is that the representative consumer is indifferent between all options in equilibrium; this consumer buys both new goods and used goods each period and essentially sells the used good to herself. Thus, there is no distinction between consumers buying new and keeping for the lifetime of the good, and consumers buying new or used every period. The size of the second-hand market is therefore indeterminate in this model. Moreover, if there were even a tiny transaction cost, the representative consumer would never trade with herself: she would just keep for the duration. This means that no second-hand markets would exist. One advantage of our approach, with heterogeneous consumer tastes, is that market segments can be distinguished and their sizes can be determined. Furthermore, transaction costs are easy to introduce and do not cause the second-hand market to be completely shut down.

Previous models of second-hand markets have concentrated (individually) on several issues. One is Akerlof's (1970) lemons problem, which has recently been considered by Kim (1985) and Ireland (1989). Treating the price in the primary market as parametric, Kim (1985, p. 842) has shown that "the Lemons Principle need not hold: average quality of traded used cars may be higher that that of nontraded cars." Furthermore, Bond (1982), in an empirical study of the pickup truck market, rejected the lemons hypothesis. With this as our excuse, we shall ignore the problem of asymmetric information, leaving it for a future extension of the model.[2]

Another strand of literature concerns the question of the optimal durability of the monopolist's product (see for example Swan (1970), Liebowitz (1982), Rust (1986) and the references therein). One interesting possibility noted by both Liebowitz and Rust is that the monopolist may wish to sell goods which last only one period, thus killing off the

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[1] Models of consumer heterogeneity in second-hand markets have been considered by Ireland (1989) and Kim (1985), but these authors treat the price in the primary market as parametric.

[2] The lemons problem is one of adverse selection whereby quality may differ across durables exogenously. A similar problem of asymmetric information between buyers and sellers is due to moral hazard. The transaction cost in our model can be viewed as a measure of the hazard problem. To be more concrete, suppose that taking care of a durable in one's possession entails a small cost, whereas taking no care causes its quality to deteriorate by τ (where τ is the same for all potential buyers). Buyers of used durables cannot tell whether care has been taken (the oil in a car has been changed often enough, for example). However, buyers rationally anticipate that no seller will bother to take care, since each seller's quality has a zero measure effect on the average quality of traded used durables.

used goods market. We treat second period quality as an index of durability, and show that the producer may either wish to increase or to decrease that quality.

In the next section, we present the model and determine the partition of the parameter space into the different demand regimes (existence or not of a market for used goods, etc.); we also construct the (kinked) demand function for new products. In section 2, we consider the consequences for the second-hand market of a monopolist in the primary market, and discuss the role of transaction costs. Section 3 deals with the durability issue. Section 4 suggests some conclusions and further extensions of the model.

1. The model

We shall use a simple framework to model the interaction between the markets for new and used versions of the same good. Specifically, products which are purchased at a new price of p_N, are assumed to last for two periods only. After two periods, they are worthless to everybody. They can however be sold and bought after the first period, at which point they become "used." The quality of the flow of services per period from a used product is v, whereas a new product generates a quality flow of $v + k$. Hence k can be viewed as the extra benefit of newness. Consumers differ with respect to their valuations of these service flows according to a parameter $\theta \in [0,1]$, with higher θ denoting individuals with higher willingness to pay. We shall further assume that each consumer wishes to consume the services of at most one unit of the product per period (think of washing machines for instance). Each consumer will then choose among the available purchase options in order to maximise utility.

We assume that buyers in the second-hand market are the only ones to incur transaction costs, an amount τ per second-hand purchase, on top of the purchase price p_S which the sellers receive. Disposal for scrap is supposed to entail neither costs nor benefits, so that if there is insufficient demand for second-hand products, and $p_S = 0$, then those wishing to dispose of used products are willing to give them away to anyone interested. However, the "buyer" in this case is still required to pay the transaction cost τ. The transaction cost is meant to include search costs, delivery costs plus any tax (as well as vehicle registration in the case of cars), etc. Similar costs could be included for buyers of new durables, but these do not affect the main conclusions and have therefore been omitted.[3] The essential point is that transaction costs drive a wedge between buyer and

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[3] A tax on the new product is equivalent to a constant marginal cost: it shifts the demand curve down by the amount of the tax.

seller prices in the second-hand market; they can be viewed as the degree of friction in trading used goods.

Over a two-period span, the options available to individuals are :

N : buy new and sell at the end of each period (or give away if $p_S = 0$),
K : buy new and keep,
U : buy used each period (or pick up free if $p_S = 0$),
Z : do not consume the product (the zero option).

For simplicity, we assume there is no discount factor. If the prices p_N and p_S are expected to prevail indefinitely, the two-period (indirect) utility V a consumer derives under each of these options is:[4]

N : $V_N = 2[\theta(v+k) - p_N + p_S]$,
K : $V_K = \theta(2v+k) - p_N$,
U : $V_U = 2[\theta v - (p_S+\tau)]$,
Z : $V_Z = 0$.

This two-period setup is consistent with two interpretations. The first is that consumers live forever. An alternative is an overlapping generations framework: here, a new generation of consumers enters the market each period, and an old generation (of equal size) leaves. The entering generation may buy used or new; the used good may be bought from either the generation which leaves the market or from the one which turns old; the new good may be kept for the duration of its lifespan, or sold at mid-life to other consumers (new incomers or members of the same generation turning old).[5]

Throughout the paper, we assume that the interaction in the second-hand market is perfectly competitive (this seems likely for most consumer durables, such as cars); hence p_S, the price in the second-hand market, is an endogenous variable determined by the equality of supply and demand for used products. Notice that $p_S \geq 0$, since those individuals buying new can always freely dispose of their used durable at the end of the period. Because of the transaction cost, it is not necessarily the case that consumers will wish to pick up free, even if $p_S = 0$.

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[4] Note that no consumer will wish to "cross" these options (for example, buying used then new or new then not at all) since the "pure" options dominate in utility terms.
[5] The analysis is unchanged as long as each generation stays in the market for an even number of periods.

Consider first the case when there exists a second-hand market with $p_S > 0$. Let θ_{NK} denote the consumer indifferent between options N and K. It is clear that N is preferred to K for all $\theta > \theta_{NK}$ and K is prefered to N otherwise.[6] Define θ_{KU} and θ_{UZ} similarly. From the definitions of N, K, U and Z, we have:

$$\theta_{NK} = (p_N - 2p_S)/k, \tag{1}$$

$$\theta_{KU} = [p_N - 2(p_S+\tau)]/k, \tag{2}$$

$$\theta_{UZ} = (p_S + \tau)/v. \tag{3}$$

These values are illustrated in Figure 1, where we have $0 < \theta_{UZ} < \theta_{KU} < \theta_{NK} < 1$ and the mass of consumers choosing each option, obtained as a result of utility maximization, can be read from the θ-axis.

[Insert Figure 1]

Equations (1)-(3) also apply when $p_S = 0$, as long as some consumers pick up free second-hand goods. In Figure 1, this means that the mass of consumers in $[\theta_{NK},1]$ is larger than the mass in $[\theta_{KU},\theta_{UZ}]$ (demand for used goods exceeds supply). If nobody picks up free, then there is no U segment of the market. For this to occur, we require $\theta_{KZ} < \theta_{UZ}$, where θ_{KZ} is the individual θ indifferent between strategies K and Z and whose identity is given by $\theta_{KZ}(2v + k) - p_N = 0$, or

$$\theta_{KZ} = p_N/(2v + k). \tag{4}$$

When this is the case, the V_U line in Figure 1 is below the V_K line whenever V_K is positive; θ_{UZ} and θ_{KU} are no longer relevant and θ_{KZ} is defined as the intersection between V_K and the horizontal axis. Then, the consumers who buy new every year is the mass between θ_{NK} and 1; the mass between θ_{KZ} and θ_{NK} represents those who buy new and keep, and the mass between 0 and θ_{KZ} those who do not buy.

We now give some intuition on comparative statics based on Figure 1. Consider first the case with $p_S = 0$. If τ goes up, only the V_U locus shifts down: θ_{UZ} shifts to the right and θ_{KU} to the left, so that fewer consumers will pick up free and more keep for two periods. If p_N goes up, both the V_K and the V_N loci shift down, but the second goes down twice as much: both θ_{KU} and θ_{NK} move right and the fraction of consumers picking up used goods increases, while the fraction of those who buy new every period decreases. If p_N rises sufficiently, p_S becomes positive.

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[6] To see this, note that $[\partial V_N/\partial q] = 2(v+k) > [\partial V_K/\partial q] = 2v+k$. See also Figure 1.

When p_S is positive, the arguments above are more subtle, because there is an induced effect through p_S. If τ rises, the wedge between the demand and supply curves for used goods increases, which will lead to a decrease in p_S. The "first-round" effect is as above: the fraction of consumers who demand used goods goes down; this causes downward pressure on p_S which must adjust to clear the market, moving the V_N locus down (since reselling is now a less attractive prospect), while the V_U locus moves back up somewhat. The case for p_N rising can be treated in a similar fashion.

Changing τ and p_N changes the relative locations of the critical θ values in Figure 1 (equations (1)-(4)). Different configurations lead to different regimes as described below, and represented in Figure 2.

[Insert Figure 2]

Zero transaction costs

If $\tau = 0$, the market divides into those who buy new and sell (or give away, for $p_S = 0$), those who consume used each year, and those who abstain. This can be seen from equations (1)-(3) where $\theta_{NK} = \theta_{KU}$ for $\tau = 0$. The segment K disappears; no one will buy new and keep, so that we have:

Proposition 1. If the transaction cost is zero, second-hand markets will always exist (possibly with a zero price) and no consumer will buy new to keep.

With no impediments, the market perfectly sorts consumers into those with relatively high preference for newness and those with relatively low willingness to pay for newness. Hence the existence of individuals buying new and keeping reflects a market equilibrium which is not Pareto optimal. Put another way, if some individuals are observed to not be trading, there must be some market friction.

Positive second-hand price (region F)

The precise value of p_S is determined as the price that clears the second-hand market. It is not transparent to work with a general consumer taste distribution. We therefore assume henceforth:

Assumption U. Consumer types θ are uniformly distributed on [0,1].

The supply per period is the number of consumers buying new each period, $1 - \theta_{NK}$. The demand per period consists of those consumers buying used, $\theta_{KU} - \theta_{UZ}$. Equating supply and demand yields the market clearing price as

$$p_S = [2vp_N - \tau(2v+k) - kv]/(4v+k). \qquad (5)$$

For this regime to apply, we need $p_S > 0$ and a positive demand for new goods ($\theta_{NK} < 1$). The implied bounds are illustrated in Figure 2.

Zero second-hand prices (region G)

The parameter values for which consumers can obtain used goods at price $p_S + \tau = \tau$ can be found by setting $p_S = 0$ in (1)-(3), requiring demand for used goods to be smaller than supply ($1 - \theta_{NK} > \theta_{KU} - \theta_{UZ}$) and that some consumers are still willing to pay τ for used goods ($\theta_{KU} > \theta_{UZ}$). These conditions define the boundaries of region G in Figure 2.

No second-hand markets (regions Z, K and L)

When no consumers buy used, there are two possibilities: either all (active) consumers buy new and keep (region K) or else, they choose between buying new and keeping or buying new every period and disposing of the one period-old good (region L). The boundary between these two cases is given by the valuation of the consumer with highest willingness to pay, for buying new (which gives utility $2(v+k-p_N)$ over keeping (in which case utility is $2v+k-p_N$). Hence, for $p_N > k$, all (active) consumers will buy to keep. Finally, if p_N exceeds the valuation $2v + k$ of the $\theta = 1$ consumer, nobody will buy the product at all (region Z).

If k goes to zero (newness is not valued per se), only the K and Z regions will exist in Figure 2 (the $p_N = k$ locus is now on the horizontal axis, and the $p_N = (2v+k)(1-2\tau/k)$ locus becomes vertical). Obviously, if newness has no intrinsic value, no consumer would buy new every period. If v goes to zero, the used product has no value, no second-hand markets will exist and only the L and Z regions will remain in Figure 2.

This discussion leads to the following proposition (which clearly does not depend on Assumption U):

Proposition 2. No second-hand markets will exist if one of the following conditions is satisfied: (a) transaction costs τ are large enough; (b) newness is not valued ($k = 0$); (c) used products have no value ($v = 0$).

Moving between regimes

In this section we have treated p_N, the price of new goods, as a parameter. If the primary market is perfectly competitive with constant returns to scale, then p_N equals the unit production cost (plus any applicable tax or transaction cost in buying new). The regime for any given transaction cost τ can easily be determined from Figure 2.

When the price of the new good is high ($p_N > k$), all markets exist if the transaction cost on the second-hand market is low enough (relative to v, the one period valuation of the second-hand good). When τ gets too large, second-hand markets will vanish. For $p_N \geq k$, buying new twice is attractive even to the $\theta = 1$ consumer only if there is a positive resale price. If τ is so large that it drives the second-hand market out of existence, all consumers of new products will keep, and we move from region F with full markets, to region K with keepers only. When $p_N < k$, there will always be consumers who buy new every period, although the level of τ determines whether they get a positive resale price p_S or not.

Hence, one might expect second-hand markets to be rare for goods with low (relative to p_N) newness premium k and high transaction cost τ, such as electrical appliances and ballpoint pens. If k is large and v (the second period quality) is not too small, such as for cars, full second-hand markets will exist as long as τ is not too large. Clothes can be divided into two types. Expensive and highly fashionable garments are often sold second-hand in specialist shops after they have been worn only a few times. Here, k can be viewed as a "fashion" premium and an item with quality v as "last year's model." Less expensive and more casual clothing (with low k) is often given away to jumble sales, Oxfam shops, the Salvation Army and goodwill stores. This last case corresponds to region G, where donors of used goods get nothing for them (except perhaps for some benefit from giving to charity), but buyers must pay a positive price.

Shrinking of the F region when τ goes up

One property of the model is that the likelihood of full second-hand markets existing declines as the transaction cost τ rises. This can be seen from Figure 2, which shows:

Proposition 3. Under Assumption U, the full markets region F shrinks from above and below as τ increases.

The intuition behind these results is as follows. The boundary between regions F and G is characterized by $p_S = 0$ and the quantity of used goods demanded is exactly equal to the supply, which is in turn identical to the quantity of new goods held by their first owners for one period only. When τ increases, the quantity of used goods demanded falls. In order to keep the used market in exact balance at $p_S = 0$, the supply of used goods must fall. Equivalently, the fraction of consumers buying new every period must fall. This happens if p_N rises. Hence, the boundary between F and G must be upward sloping. A similar argument holds for the boundary between G and L.

On the boundary between F and K, the $\theta = 1$ consumer is just indifferent between buying new every period and keeping, and the second-hand market exactly clears with zero quantity demanded and supplied. If p_N decreases, the $\theta = 1$ consumer will prefer to buy new in every period; in order to bring the second-hand market back to equilibrium with no trades, τ must increase to dissuade second-hand buyers. Hence this boundary is downward sloping. Since the arguments above have not made use of Assumption U, Proposition 3 holds more generally.

Demand in the market for new goods

For given τ, there are at most five different regimes in Figure 2 and the expression for (the two-period) demand D in each of these is different. Using the labelling of regions given in Figure 2, we have :

$Z : D = 0,$
$K : D = 1 - \theta_{KZ},$
$F : D = 1 - \theta_{UZ},$
$G : D = 2(1 - \theta_{NK}) + (\theta_{NK} - \theta_{KU}),$
$L : D = 2(1 - \theta_{NK}) + (\theta_{NK} - \theta_{KZ}).$

For example, in region F, demand is obtained as follows. There are $(1 - \theta_{NK})$ individuals buying new each period and $(\theta_{NK} - \theta_{KU})$ individuals who buy new and keep for two periods. Since $p_S > 0$ in region F, $(1 - \theta_{NK}) = (\theta_{KU} - \theta_{UZ})$ so that $D = 2(1 - \theta_{NK}) + (\theta_{NK} - \theta_{KU}) = 1 - \theta_{UZ}$. Similar arguments lead to the other expressions. Replacing the various θ's by (1) to (3) for region F (with $p_S > 0$ given by (5)) and the values appropriate to each region otherwise, leads to the following demand structure :

$Z : D = 0,$ for $p_N \geq 2v+k,$

$K : D = 1 - p_N /(2v+k),$ for $2v+k \geq p_N \geq k$, with $p_N \geq (2v+k)(1-2\tau/k),$

$F : D = (4v+2k-2\tau-2p_N)/(4v+k),$ for $(2v+k)(1-2\tau/k) \geq p_N \geq k/2+\tau(1+k/2v),$

$G : D = 2(k-p_N+\tau)/k,$ for $k/2+\tau(1+k/2v) \geq p_N \geq \tau(2+k/v),$

$L : D = 2[1-p_N(k+v)/k(2v+k)],$ otherwise.

The bounds defining the various regions are taken from Figure 2.

The demand function is given by the solid line in Figure 3 for the case in which all regimes exist (i.e. $0 < \tau < v/(2v+k)$, see Figure 2). The kinks in the function occur when the regime changes. There are two kinks outward (between K and F, and F and G) and one kink inward (between G and L).

[Insert Figure 3]

Consider first the kink between K and F. Since the market offers more opportunities in region F, demand increases at a faster rate there : the introduction of the second-hand market increases demand for new goods.[7] This result contradicts the view that second-hand markets reduce demand for new products. Even though consumers buying used durables directly reduce demand for new products (as they are consuming substitutes), indirectly, they increase demand from other consumers who anticipate a positive resale price, and this induced effect dominates.

At the kink between F and G, p_S goes to zero. In region F, every one dollar decrease in p_N is associated with a fall in p_S of less than one dollar (and hence the number of consumers who buy new every period rises as p_N falls); at the kink, the free disposal assumption stops p_S from falling, so that the direct benefit of a decrease in p_N on utility is larger (as it is not offset by a drop in p_S) and the demand curve kinks outward.

Finally, there is an inward kink between G and L. This is best explained by thinking of a price rise from region L to region G. Once we reach region G, there are consumers who pick up used goods for free and this directly detracts from demand. In this situation, the existence of second-hand markets reduces demand.

In Figure 3 we have also represented, in dashed lines, the demand curve for the case $\tau \geq v/(2v+k)$. There, regimes F and G do not exist, and the demand curve consists of

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[7] Note that in region F, the equilibrium mass of consumers buying new to keep is independent of p_N ($\theta_{NK} - \theta_{KU} = 2\tau/k$). This result appears to be an artefact of the uniform consumer density assumption.

segments K and L only. As should be clear from our discussion above, the demand curve in the presence of second-hand markets may be above or below the one when such markets fail to exist. Increases in τ result in moving the kink points between K and F, and between G and L towards $p_N = k$, along the dashed lines.

2. Monopoly in the new products market and the role of transaction costs

Until now, we have considered p_N (the price of new durables) as a parameter. We now assume that this price is set by a monopolist which takes into account the effects of the second-hand market on its own demand. The interesting question is to examine whether and under which circumstances the monopolist has an incentive to encourage or to wipe out the second-hand market. This analysis is made difficult since the kinks in the demand curve may cause the profit function of the monopolist not to be quasi-concave - indeed, the marginal revenue curve may cross the horizontal axis more than once.

In order to keep the number of parameters from becoming too large, we set the marginal production cost equal to zero. We also assume that the monopolist sets its price once for all (it chooses its price p_N given the two-period demand curve). This latter assumption has been explicitly invoked by Swan (1980, section IV) and Rust (1986, assumption A3) and allows us to avoid Coase type problems of intertemporal inconsistency (see Jean Tirole (1988) for further discussion) and to concentrate on the issue of price discrimination.

Monopoly pricing

To calculate the monopolist's optimal price choice, we proceed by first inverting the demand function of the previous section and determining the profit-maximizing price, conditional on regime. These prices are :

$$K : p_N^K = (2v + k)/2, \tag{6}$$

$$F : p_N^F = (2v + k - \tau)/2, \tag{7}$$

$$G : p_N^G = (k + \tau)/2, \tag{8}$$

$$L : p_N^L = k(2v + k)/2(v + k). \tag{9}$$

Clearly, the optimal prices in regions K and L are independent of τ. In region F, increasing τ reduces the optimal p_N. This is because higher τ, *ceteris paribus,* reduces the second-hand price and thus also reduces the value of new goods to those consumers

buying new every year. The monopolist therefore lowers its price to (partially) offset this effect. Note that in this region, once we account for the monopolist's actions, increases in τ reduce the equilibrium utility of both those buying new every year and those buying used every year (as the second-hand market through which they interact has more friction). On the other hand, those consumers buying new and keeping benefit from increased τ due to the monopolist's price reaction.

In region G, p_N increases with τ. Here, the monopolist benefits from the fact that larger τ means less consumers picking up used goods free ($p_S = 0$ here), so that it is able to exploit this larger demand with a higher price. Note that all consumers are worse off as τ rises in this region.

It can readily be verified that optimal profits, conditional on regime, are given by the following expressions :

$$K : \Pi^K = (2v + k)/4, \tag{10}$$
$$F : \Pi^F = (2v + k - \tau)^2/2(4v + k), \tag{11}$$
$$G : \Pi^G = (k + \tau)^2/2k, \tag{12}$$
$$L : \Pi^L = k(2v + k)/2(v + k). \tag{13}$$

Note that profit decreases with τ in region F and increases in region G. The reason is the same as that given for the comparative statics on p_N.

We must now determine the optimal global choice of p_N by the monopolist, for given τ, by comparing profits across regimes and taking explicit account of the parameter restrictions defining each regime. We did this by finding the regime which yielded maximal profit and then checking whether the optimal price in that regime was feasible, given the demand curve. If so, the selected region is the optimal one (as the profit function is strictly concave in each region). If not, we looked for the next best region, etc. Clearly neither of the outward kinks can be an optimum, but the inward kink between regions G and L may constitute a possible corner situation, which we also checked. At the corner solution (henceforth denoted C), the optimal price is (as can be seen from Figure 3)

$$p_N^C = \tau(2 + k/v)$$

with

$$\Pi^C = 2\tau(2 + k/v)(1 - \tau/k - \tau/v).$$

Note that Π^C is increasing in τ for $\tau < kv/(2(v + k))$, at which point the regime changes from C to L.

[Insert Figures 4 and 5]

The results of the profit comparison are illustrated in Figure 4 in τ-v space, where we have normalized k = 1.[8] It is clear from the figure that all regions are possible. For certain values of v, some regions never occur, regardless of τ. For instance, for v = 0.9, regions G and K are not encountered. In Figure 5, we take a cross-section of Figure 4 at v = 1/2 to illustrate the equilibrium price p_N as a function of τ. This price is at first decreasing with τ in region F and then exhibits a jump down into region G. Since profits are constant at this point, the monopolist finds it as profitable to set a high price which encourages a second-hand market with a positive price, as to set a low price which eliminates resale value completely. Note also that, consumer surplus increases across the jump and we have the counterintuitive result that total welfare increases with increasing transaction costs.[9]

In region G, the price increases with τ until the corner is reached and then continues to rise with τ at the demand kink, which corresponds to the boundaries between regions G and L (region C in Figure 4). Since a higher transaction cost prevents second-hand users picking up free, the monopolist is able to raise its price. In region L, it is more profitable to set a price independent of τ (in region L). Figures 4 and 5 respectively show the two parts of the next proposition:

Proposition 4. Under Assumption U, (a) depending on v, k and τ, the monopoly price p_N may be in any of regions F, G, K and L, or on the boundary between regions G and L (region C), but not on the other boundaries; (b) for given v and k, the monopoly price p_N may consist of up to four distinct segments, depending on the value of τ.

Once again, Assumption U is not crucial to this proposition.

Changing transaction costs

Transaction costs are usually not controlled by the monopolist; there are however some examples where the producer can affect them; for instance, a car manufacturer may find it profitable to extend the warranty to the second-hand buyer : this can be seen as

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[8] The geometry of Figure 4 is essentially the same for every positive k. When k decreases, region K expands by moving Southwest. For k = 0, all other regions disappear.

[9] When v > k, we pass from region F to region K as τ rises. Since the optimal price schedules are $p_N^F = (2v+k-\tau)/2$ and $p_N^K = (2v+k)/2$, there must be a jump *upwards*, with profits remaining constant across the jump, and welfare decreasing as τ increases.

decreasing τ and hence increasing the monopolist's revenue (although the monopolist must also take into account the costs incurred by such a policy).

As noted before, profits are decreasing with τ in F until the jump, at which point they increase with τ until L is reached. This leads to the question as to whether the monopolist prefers τ = 0 to τ large - i.e., if the monopolist could choose τ, would it prefer a frictionless second-hand market or a value of transaction costs such that no second-hand market will exist? We can answer this by comparing Π^F with τ = 0 (note that the monopoly always chooses in F for τ = 0) with the maximum of Π^L and Π^K (the cases arising for τ large). From (10), (11) and (13), we have:

Proposition 5. Under Assumption U, then (a) for v > k/2 the monopolist prefers τ = 0 so that second-hand markets will always exist; (b) for v < k/2 the monopolist prefers so much friction that second-hand markets are driven out of existence; (c) for v = k/2, the monopolist is indifferent.

The precise critical value v = k/2 depends on Assumption U; other values will holds for different taste distributions.

The intuition underlying Proposition 5 is as follows. If v is small relative to k, then individuals place a high value on newness. Hence, a second-hand market entails a relatively low second-hand price so that the monopolist benefits little from the indirect demand effect that individuals selling used benefit from resale value. In this case, the monopolist prefers region L where many individuals buy new every year and then dispose of the good (which no other individuals then wish to use). On the other hand, when v is large relative to k, the second-hand price is relatively high and this value is capitalized into the new price the monopolist can charge. For τ large however, there are many individuals buying new and keeping so that the monopolist does not benefit so much from the few consumers (indeed, none in region K) who buy new twice.

Oligopoly in the new market

Let us briefly consider what happens if there is an oligopoly in the market for new goods. We do not give a full description of the case. One reason is that Cournot equilibrium will fail to exist for some parameter values: the outward kinks in the demand function may lead to discontinuities in the reaction functions. Meanwhile, if an equilibrium exists, then the candidate Cournot equilibrium prices are given by replacing the 2's in the denominators of equations (6) to (9) by n+1's where n is the number of

firms. It is then easy to check that the larger the number of firms, the less likely is the equilibrium to be in region F or K.[10]

3. Quality and durability

There are two qualities in the model : the quality is v+k in the first period and v in the second one. We can view second period quality as an indicator of durability - decreasing v while keeping v+k constant corresponds to a decrease in durability, in the sense that when $v = 0$, the product has no value after the first period and essentially only lasts one period. In that case, there will be two types of consumers: those who buy new twice and those who do not buy at all; so second-hand markets vanish. Analyzing how the monopolist reacts to changes in these quality indicators yields some insight into the situations in which the monopolist would like to see the second-hand market banned.

Increases in k (the newness premium) raise the monopolist's profit in every region. Since higher k increases the utility of individuals buying new once or twice, and the monopolist can appropriate some of the increased surplus. An increase in v increases both first and second period quality by the same amount; this benefits all types of consumers, *ceteris paribus*. Profits rise in every region, except in region G where $\partial\Pi^G/\partial v = 0$; this is the consequence of two effects which cancel each other out : demand increases for those consumers who buy new (once or twice) but, at the same time, consumers at the margin will switch to picking up used goods free (in region G, $p_S = 0$).

The question of increasing second period quality only is more interesting. Mathematically, this corresponds to differentiating the monopolist's optimal profit with respect to v along the locus v+k = constant. The results differ between regions. In region K, consumers are clearly better off and monopoly profits rise. In region L (where there are only consumers buying new once or twice) monopoly profits fall. Since goods are more attractive in the second period, more consumers buy. At the same time, some individuals who previously bought new and scrapped will instead keep the good; the second effect dominates and overall demand for new products falls.

In region G all markets exist but $p_S = 0$. Second period goods become more attractive, inducing some consumers who were buying new twice to keep their good. At the same time some consumers who were buying new only once will now prefer to buy

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[10] For example, when $v = 0.5$, $k = 1$ (the parameter values of Figure 5) and n=3, there can be no second-hand market with p_S positive.

used; both of these shifts are bad for the monopolist, and its profit decreases. Note also that some consumers who were not buying at all will now "buy" used goods; supply decreases and demand increaseson the second-hand market, but this does not affect the monopolist's profit, and since we assume no change of regime, p_S remains equal to zero.

In region F, finally, all markets exist, p_S is positive and

$$\frac{\partial \Pi^F}{\partial v} \bigg|_{k+v=const} = \frac{(2v+k-\tau)(2v-k+3\tau)}{2(4v+k)^2} . \tag{14}$$

Obviously, $2v+k-\tau$ is positive in this regime, as this is equal to $2p_N^F > 0$ (see (7)). Hence, the sign of the derivative is given by sgn $(2v-k+3\tau)$, which is ambiguous. For example, when $\tau = 0$, $k = 1$ and $v = 1/2$, this derivative is zero and we are in region F (see Figure 5); by continuity, $(2v-k+3\tau)$ can thus take either sign. The reason for this is as follows. The "first round" effects are the same as in region G above; but here the resale price p_S will increase. This positively feeds back ("second round" effect) and increases the number of consumers who buy new twice; this results in an ambiguous total effect.

The analysis in region F is clarified if we define first period quality as $q_1 = v+k$ and second period quality as $q_2 = v$. Then, the sign of (14) is

$$\text{sgn} \frac{\partial \Pi^F}{\partial v} \bigg|_{q_1=const} = \text{sgn} \ (3q_2 - q_1 + 3\tau).$$

Hence, profit is decreasing in q_2 for $q_2 < (q_1-3\tau)/3$, whereas the reverse is true for $q_2 > (q_1-3\tau)/3$. This shows that the monopolist would always move out of region F, if it could costlessly adjust second-period quality. The arguments developed above, concerning regions G, K and L show that it would end up in either region K or L. In region K, the optimal q_2 quality is $q_2 = q_1$ (we assume that q_2 is bounded by q_1); in region L, the optimal $q_2 = 0$. In both cases, the optimal profit is $q_1/2$ and a monopolist which can costlessly control q_2 whilst leaving q_1 unchanged will always choose q_2 so as to close down second-hand trading. Thus we have:

Proposition 6. The monopolist is indifferent between (a) $q_2 = q_1$ (region L), with each consumer buying new twice and paying a price $q_1/2$; and (b) $q_2 = 0$ (region K), with the same mass of consumers buying new at a price q_1 and keeping.

The fact that $q_2 = q_1$ gives the same profit as $q_2 = 0$ does not hinge on Assumption U. Indeed, $q_2 = q_1$ entails $k = 0$; there is no benefit to newness per se and all

active consumers will keep. If $q_2 = 0$, $v = 0$, and the good is worthless in the second period; all active consumers buy new in every period and the willingness to pay of any individual is exactly half that for the same quality goods that last two periods. Hence, the two-period demand curve - and the equilibrium profit - is the same in both situations.

Two polar assumptions on costs give some intuition on what happens if one removes the simplifying assumption that production and quality adjustment costs are zero. First suppose it costs $c > 0$ to produce one unit of quality q_1, but q_2 can still be adjusted freely. Then, obviously, the monopolist will prefer to be in region K, where consumers buy and keep. On the other hand, if $c = 0$ but higher q_2 entailed higher cost, then the solution $q_2 = 0$ would be preferred and the monopolist would choose to be in region L, where consumers buy new twice.[11]

The monopolist may not have enough control over q_2 to close down the second-hand market completely. However, if it has some control over q_2, the analysis of region F shows that the monopolist may wish either to increase or decrease it. For our earlier example of warranties, an extended time period may increase its profits (if the warranty is transferable), because of the positive impact on the resale price which feeds back into increased demand for new durables.

4. Conclusions

We have constructed a model of second-hand markets where market segmentation is endogenously determined and where a monopolist in the primary market, faced with perfect competition in the used goods market, will not necessarily have an incentive to kill off the second-hand market. One explanantion for this is that the existence of the second-hand market enables the monopolist to achieve a form of indirect price discrimination. This is done via the segmentation of the market into different types of consumers, even though the monopolist cannot directly charge different prices to different consumers. Using the second-hand market, the monopolist can effectively extract high surplus from consumers with high willingness to pay for high quality (i.e. new) products, while at the

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[11] Swan (1972) uses the representative consumer model with zero transaction costs to analyze monopoly provision of durability. The assumption of homothetic preferences provides enough structure on the inverse demand functions to show that monopoly and competitive choice of durability are the same, so that a monopolist has no special incentive to shut down the second-hand market (planned obsolescence). In our model, as long as producing a durable which is perfectly good for two periods costs less than producing two units which last only one period (and assuming costs are such that intermediate durabilities are not optimal), the monopolist will provide full durability. At this solution, all active consumers keep for $\tau > 0$; for $\tau = 0$, as in Swan, there is no difference between keeping and trading second-hand (with oneself!), so like in Swan, a monopolist does not close down the second-hand market.

same time also benefitting from those with lower willingness to pay via the channel of the second-hand price which increases demand of those buying new. The smaller the transaction cost on the used products market, the greater the surplus extraction possibilities and the higher the monopolist can set its price, at least when second-hand prices are positive.

There are however also situations in which it will be optimal for the monopolist to price the second-hand market out of existence. This may be done either via a low price (when the optimal price is in region G) which floods the second-hand market driving the price there to zero but still allows some individuals to consume used goods by picking them up free, or else, a very low price (region L) which induces all those wishing to consume the durable to buy new. Alternatively, the monopolist may wish to choose a high price to wipe out the second-hand market, with all those who buy choosing to hang on to the durable because of high replacement cost. It is the explicit consideration of transactions costs in our model which allows for this rich set of possibilities.

We also looked at the effect of transactions costs on monopoly profits. These have an ambiguous impact. Assuming that we start in a regime in which all markets do exist (region F), the monopolist locally prefers lower transaction costs, e.g. taxes on used cars; however, it may be that even better than this, the monopolist would prefer a large increase in transaction costs, so that it can strangle the secondary market.

Finally, we considered the question whether a monopolist prefers a more or less durable product by treating durability as the quality of the product in second period use. When there exists a full set of markets (region F), both answers are possible, since profits may be locally increasing or decreasing. The reason for which a firm may purposely wish to deteriorate its product by reducing second-hand quality, even if it does not gain from reduced costs by doing so, is that this may shift demand from the second-hand toward the new-new and new-and-keep segments.[12] Of course, this will also decrease the second-hand price which is a countervailing force and the reason for the ambiguous result. It is only once we allow for endogenous segmentation (via the assumption that consumer tastes are heterogeneous) that we can provide an explanation of these forces. As indicated throughout the paper, the results hold for more than just the uniform density of consumer tastes, which was used for illustration. However a fully general treatment might only obscure the basic points.

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[12] A similarity is to be found in the literature on vertical product differentiation (see Mussa and Rosen (1978)), where a monopoly seller may purposely wish to also provide a low quality version of its product to segment the market.

Second-hand markets are important in several major industries (cars, for instance) and there are many questions that can be raised when we explicitly account for them. When do firms find it profitable to extend warranty coverage to second-hand buyers?[13] Should tax rates be lower on second-hand purchases than on new goods? What are the effects of government controls on second-hand quality? The framework also lends itself to study "overlapping generations" models of new and second-hand goods and could be used to (numerically) study the transition from one steady-state to another, induced by changes of parameters representing the warranty system, tax rates, government controls, etc. Finally, we have (implicitly) assumed that the costs associated with renting the product are prohibitively high for the monopolist (due to moral hazard problems for example - see the discussion in Rust (1986)). A full treatment of the problem in the context of the present model would tell us more about when the monopolist prefers to sell rather than to rent. Given that in our model consumers are heterogeneous, it might be possible that in equilibrium the monopolist will rent to some consumers and sell to others.

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[13] See Ireland (1988) for an analysis of the incentives for firms to actually create defective products and then segment the market with warranties.

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