An Economic Analysis of Electronic Secondary Markets: Installed Base, Technology, Durability and Firm Profitability

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Abstract

A number of unstructured or partially structured electronic secondary markets exist to enable the sale and trading of goods between consumers. Many tend to be self-administering UseNet groups, or WWW sites for niche products; however, there has been significant recent growth in the number of more general web-based markets of this kind. Apart from facilitating reliable and liquid trade of used goods, the existence of these markets can alter the desirability of new product, as well as products that are complementary/compatible, and one expects to see a proliferation of such trading forums as Internet technology continues to become more widespread and reliable, and less expensive. We present a economic framework for analyzing how these electronic secondary markets affect the demand for a primary product. We then examine when it is optimal for a firm to operate a market of this kind, and when their presence is socially optimal. Surprisingly, we find that in a number of cases, the presence of these markets has a primary positive effect on the profitability of a new good; this leads us to conjecture that there will soon be a number of such trading forums operated by manufacturers of primary goods. We also find that in a majority of cases, it is feasible for a third-party intermediary to profitably operate such a market. Key parameters that affect the desirability of the market are the existing installed customer base, the cost of information technology, the durability of the products in question, their rate of technological obsolescence and the nature of customer preferences.

1 Introduction

Commerce on the Internet has grown considerably over the last 4 years. Forrester Research (Maney, et. al, 1996) calls the Internet the fourth channel for exchanging information between suppliers, buyers, sellers and intermediaries, to a transaction (the other three channels being face-to-face communication, telephone communication and mailings). They also list their three reasons for the steep growth in business on the Internet:

1. It removes telephonic time constraints, thereby making it possible for buyers and sellers to exchange information at any time.

2. It enables media that exceed the richness of catalogs and other printed material.

3. It provides individualized attention, much like a sales force.

The term electronic commerce has become a catch-all phrase to describe all buying and selling activities based either on the Internet, or EDI transactions between businesses. However, an aspect of Internet based commerce that has not been studied much is the profusion of Usenet newsgroups that allow buyers and sellers to post their bids for products that are on sale. Usenet based newsgroups are only one of the many fora that bring together buyers and sellers. Many educational institutions have their own electronic bulletin boards, as do many regional non-profit organizations. In addition to the newsgroup-based facilities, there are also an increasing number of Web based services, including Barter Net and netTrader . These resellers are often product-focused. One of our hypotheses is that such markets will continue to grow rapidly, sometimes with the active support of the producers of primary goods.

In addition to the reasons cited by Forrester, these electronic marketplaces offer three benefits that most physical marketplaces cannot provide. For one, they can bring together geographically dispersed buyers and sellers, allowing them to transact either synchronously or asynchronously.. This increases the potential size of the market significantly.

Secondly, electronic marketplaces allow for immediate offer revision and negotiation. In the period from December 1995 to July 1996, as many as a fifth of the transactions that took place on a newsgroup that brought together the buyers and sellers of used photographic equipment (*rec.photo.marketplace*) were characterized by revision of bids and negotiations between buyers and sellers that was instantaneously broadcast to all buyers and sellers on that forum. In addition, there were numerous e-mail messages exchanged privately between buyers and sellers prior to the conclusion of transactions (which by their very nature were not available to us for analysis). There is little doubt, however, that this forum featured extensive bid-ask price revisions and negotiations. This allows for faster and smoother matching of supply and demand, and consequently, efficient price setting for a particular product.

Finally electronic markets facilitate the storage and recall of the trading histories of buyers and sellers. These can often be used as a quality signal by one or both parties to the transaction. For instance, most newsgroups archive versions of earlier messages, which can be searched by specialized search engines like Dejanews (*http://www.dejanews.com*). These search engines can also provide a profile of the buyer or seller based on their past postings to a particular forum or fora. Many frequent buyers and sellers on these fora acquire reputations for accuracy, verifiability and reliability of their price and product quality descriptions and their payment behavior, which act as signals that reduce the measure of uncertainty associated with their trading behavior. In secondary markets for used goods (electronic or otherwise) in which buyers and sellers are exposed to the risk of opportunistic behavior induced by uncertainty and lack of verifiability of product and price claims, this is of considerable value.

It has also been argued that *authenticity* (identity of the buyer/seller) *integrity* (verifiability and completeness of product/price information) and *non-repudiation* (the ability to hold a buyer or seller to the terms of the transaction that they are committed to) are the three key features that will fuel the growth of electronic commerce (Umbach, 1996). The advantages of an electronic market are that it allows for greater authenticity and integrity of buyer-seller interaction than, say, a (physical) bulletin board on which an individual may leave a scribbled not of a buy/sell offer. It is precisely these factors, along with the ability to produce a richer context of information at a very low cost (the marginal cost of an e-mail or web newsgroup posting is negligible) that has made buying and selling in secondary electronic markets a commercially viable and popular activity. In recognition of the above trends, several market makers for primary market goods such as electronic auctioneers like On-Sale and Microwarehouse now have exclusive sites that act as secondary markets.

Further, we have observed that the participant volume in certain Usenet secondary markets have nearly doubled between December 1995 and December 1996. Driving this growth has been the rapid increase in the penetration of PC's and the ease of transacting on the web (made possible in part by popular software suites that integrate browsing, conferencing and creation of real time synchronous, shared contexts, like Netscape's Collabra software, which allow rich information specification and negotiation possibilities). Forrester Research claims that the Internet provides a highly effective trading mechanism by giving buyers the ability to both determine their needs, and costlessly seek suppliers. Since search on an electronic medium is intrinsically less costly than physical search, this a considerable benefit for buyers and sellers.

We therefore believe that electronic secondary markets offer advantages that distinguish them to a very significant extent from physical secondary markets; this difference is more than one of *degree.* When viewed against the backdrop of rapid technological advances, it becomes a difference of *kind.* This motivates our model of an electronic secondary market, and our analysis of its impact on prices of a new good in the primary market. Since electronic secondary markets do not preclude, and are influenced by, the simultaneous existence of used goods and new goods, we will also examine the impact of the price of new goods on the price of used goods and the resulting behavior of buyers and sellers at equilibrium.

In the models that follow, we analyze whether the presence of an electronic secondary market can have a positive impact on a firm's sales, and a positive impact on consumer welfare, and if so, when this effect is present. Since an electronic secondary market for a particular product enables costless search for a used product, and, if operated effectively, ensures that the product purchased is not a 'lemon' (as discussed above), it increases consumer confidence levels in used-good purchase. It also makes the trade of a used good liquid. That any secondary market has these features is crucial; only electronic markets can simultaneously ensure quality, liquidity and costless search, and this is precisely the distinction between market kind and degree of efficiency that we alluded to earlier.

Intuitively, therefore, there are at least two significant effects that a market of this kind can have on the sales of a primary good:

1. It can reduce a firm's sales by causing potential buyers of a new good to buy a used good instead — since a reliable, liquid source of these products now exists

2. They can increase a firm's sales by allowing existing owners (who would otherwise be stuck with an old good) to sell their old good at a fair price, and buy

a new good.

Though it may appear that these two effects balance, this is almost never true. Even if the net demand effect balances out, there can be a price effect on the new good, thereby changing firm profits. Also, some of the buyers of a used good may not have been potential buyers of the new good, and hence it can also have a net demand effect on the sales of the new good. Evidently, a key driver here is the nature of consumer preferences for new and used goods. Other factors of consequence are the amount of value that the product loses with use (subsequently referred to as the durability of the product), the rate at which the firm introduces new products (which, ceteris paribus, is directly related to the previous factor), and the size of the market — both existing owners, and potential buyers.

2 A Model of Electronic Secondary Markets

Our model examines a monopolist who produces a single durable product, and sells it in a market whose size we normalize to 1. The consumer valuations of a new product in any period are uniformly distributed from 0 to 1 (this is a widely used model of consumer preferences, and in the absence of a used product, generates a downward sloping linear demand curve). The valuation that the consumers place on a used good are uniformly distributed from 0 to δ, where δ measures (inversely) the degradation in performance of the good. We refer to δ as the *durability* of the product. As briefly mentioned earlier, the durability δ has many possible drivers. It is affected by the intrinsic durability or reliability of the product (for instance, a television is more durable than a toothbrush), and is increasing in this factor. It is also affected by the rate at which new products are introduced. If a firm produces a new product every month, then the previous month's product is almost as good as this month's product, and hence a high rate of product turnover pushes δ up. On the other hand, if a new product is introduced every few years, then δ is likely to be lower. Finally, it is also affected by the rate of related technological progress (which is why, for instance, a PC would have a low value of δ, despite its relatively high reliability, and rapid product turnover.

We assume that if a consumer has a valuation of v for a new good, then that consumer values a used good at δv. This is in agreement with the distributional assumptions made earlier, and ensures that consumer valuations of new and used goods are consistent. The firm has a constant marginal cost, which we normalize to zero. [1] It decides on a price for the new good with perfect knowledge of the

[1]This is a standard assumption in linear models of this kind; one can justify this easily by interpreting the valuations of consumers as their valuations net of marginal cost; since the firm is never going to price below marginal cost, considering those consumers for which this valuation is 0 or positive and rescaling the distribution so that the upper limit is 1 will reduce the problem back to the one we currently are analyzing. It does, however, restrict the price of the used good to being above marginal cost; hence, modifying this to incorporate positive costs will only strengthen results

percentage of the market that already owns an old good. Evidently, a consumer who does not own the product buys it only if her valuation $v > p$, where p is the price of the new product. Also, in the absence of a secondary market for old products, an existing customer buys the new good only if the value derived from the new good is greater than the value derived from the used good, or if:

$$v - p > \delta v \Rightarrow v > \frac{p}{1-\delta}$$

We first examine a single period model with an existing base of owners of an old good. At this point, the percentage of the market which owns an old product is exogenously specified. This can occur in a number of different situations; some factors that can contribute to this are a short-lived product, or a product for which it is expected that manufacturing may not be sustained beyond a single period. It is also a partial model of entry by a new firm into a market where there is an existing good similar to its new good (though we do not consider competitive effects at this point).

Another reason for examining this model is that it forms the basic building block for a dynamic model. Even if the firm makes the product in many periods, and one models this in a multi-period setting, one would need to use some form of backward induction to determine the sequence of prices that the firm would charge The price that the firm charges in any period is a function of the durability δ, the distribution

indicating the desirability of an electronic secondary market.

of customer preferences, and the current market situation i.e. the percentage of consumers who own used goods; precisely the model we are constructing. We represent the installed base of customers by those who have valuations greater than or equal to $h, 0 < h < 1$.

2.1 Absence of an electronic secondary market

We first consider the base case, where there is no secondary market, electronic or otherwise. The firm sets a price p for the new good to maximize its single period profits. This induces a demand $q(p)$ and corresponding profits $pq(p)$. The demand is not smooth — it depends on the relative values of p, h and $h(1-\delta)$. There are three possible cases:

$(i)\quad p \geq h$

$(ii)\quad h(1-\delta) \leq p \leq h$

$(iii)\quad p \leq h(1-\delta)$

We derive the demand and profit functions for each of these cases, and then analyze what the optimal choice of p is for different values of h and δ. Recall that a buyer who does not own an old good will purchase the new one if her valuation is higher than p, and an existing owner will discard the old product and buy the new one if her valuation is higher than $\frac{p}{1-\delta}$.

The first case ($p \geq h$) induces no new buyers, since all the potential buyers who do not own the good have valuations less than h, which is less than p. Hence,

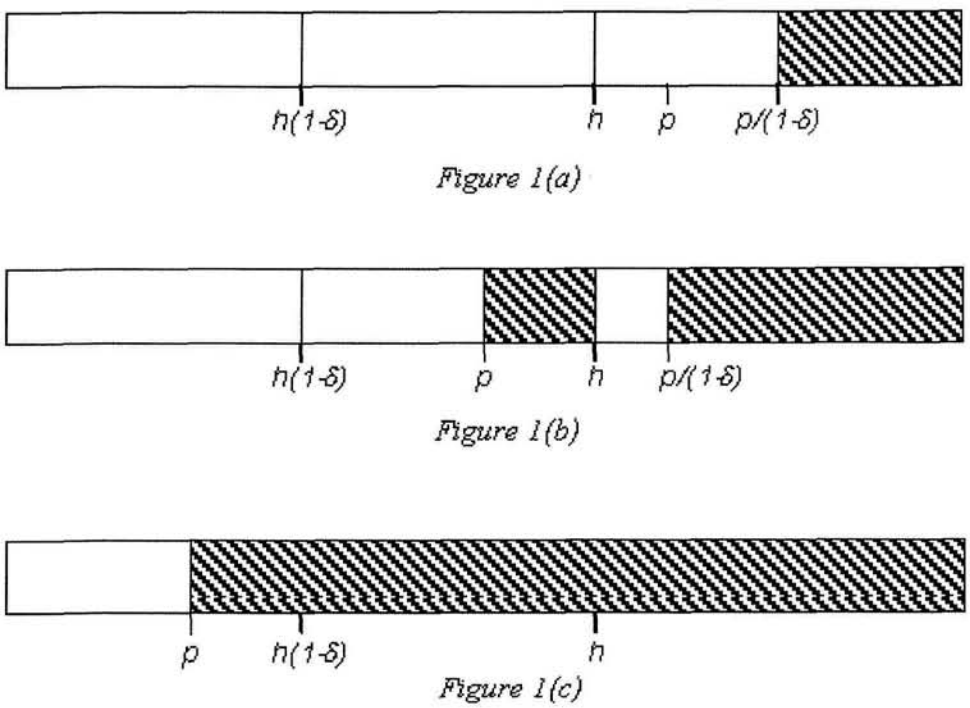

Figure 1: Demand in the absence of a secondary market

as shown in Figure 1, the entire demand will come from existing owners who have valuations higher than $\frac{p}{1-\delta}$, and this will induce a demand of $q(p) = (1 - \frac{p}{1-\delta})$, and corresponding profits of $p(1 - \frac{p}{1-\delta})$.

The second case $[h(1-\delta) \leq p \leq h)]$ induces both new buyers and existing owners to buy the good, as shown in figure 1(b). Since $p > h(1-\delta)$, which implies that $\frac{p}{1-\delta} > h$, there are existing owners who choose not to buy the new product. However, since $p < h$, there is positive demand from new buyers. The magnitude of this demand is $(h-p)$. Hence, in this case, $q(p) = (1 - \frac{p}{1-\delta}) + (h-p)$.

In the third case $[p \leq h(1-\delta)]$,all existing owners discard their old product and buy a new one (since $\frac{p}{1-\delta} \leq h$). Also, all other consumers with valuations greater than p will buy the product. The demand is therefore $q(p) = (1-h)+(h-p) = (1-p)$.

We refer to these three cases as the three *price regimes* the firm can choose.

The demand function $q(p)$ in the absence of a secondary market is summarized below. The profit function in each case is simply $pq(p)$.

$$q(p;h) = \begin{cases} (1 - \frac{p}{1-\delta}) \text{ if } p \geq h & \text{(Price Regime1)} \\ (1 - \frac{p}{1-\delta}) + (h-p) \text{ if } h(1-\delta) \leq p \leq h & \text{(Price Regime 2)} \\ (1-p) \text{ if } p \leq h(1-\delta) & \text{(Price Regime 3)} \end{cases}$$

The firm will choose the value of p which maximizes this profit function. We now determine the profit maximizing price. The problem is one of simple quadratic constrained maximization in each of the three cases. We summarize the results of this optimization below.

	Price p^*	Profits $\pi(p^*)$
Case 1 (i)	$\frac{1-\delta}{2}$ if $h \leq \frac{1-\delta}{2}$	$\frac{1-\delta}{4}$
Case 1 (ii)	h if $h \geq \frac{1-\delta}{2}$	$h - \frac{h^2}{(1-\delta)}$
Case 2 (i)	$\frac{(1+h)(1-\delta)}{2(2-\delta)}$ if $\frac{(1-\delta)}{(3-\delta)} \leq h \leq \frac{1}{(3-2\delta)}$	$\frac{(1+h)^2(1-\delta)}{4(2-\delta)}$
Case 2 (ii)	$h(1-\delta)$ if $h \geq \frac{1}{(3-2\delta)}$	$h(1-\delta) - h^2(1-\delta)^2$
Case 2 (iii)	h if $h \leq \frac{(1-\delta)}{(3-\delta)}$	$h - \frac{h^2}{(1-\delta)}$
Case 3 (i)	$\frac{1}{2}$ if $h \geq \frac{1}{2(1-\delta)}$	$\frac{1}{4}$
Case 3 (ii)	$h(1-\delta)$ if $h \leq \frac{1}{2(1-\delta)}$	$h(1-\delta) - h^2(1-\delta)^2$

The reader can easily verify that these are accurate. The analysis proceeded as follows. For each of the cases, the first order conditions were determined; the inequalities in the Price column above represent the condition that separate the situations in which the unconstrained optimum satisfies the constraints, and the situations in which it does not.

In the absence of the electronic secondary market, the optimal profit is therefore crucially dependent on the relative values of the installed base, and the product durability. To determine which of the cases is optimal, we first consider the case where the durability is not very low. Proofs of this result, and of subsequent lemmas and propositions are in an appendix at the end of the paper.

Lemma 1 *If* $1 \geq \delta \geq 0.22$, *then* $\frac{(1-\delta)}{(3-\delta)} \leq \frac{1-\delta}{2} \leq \frac{1}{(3-2\delta)} \leq \frac{1}{2(1-\delta)}$

This ordering allows us to examine sequentially which of the three price regimes is optimal for different values of h. The following result shows which of these is optimal for different values of h.

Proposition 1 *(i) If* $h \leq (\sqrt{2-\delta}-1)$, *then* $p^* = \frac{1-\delta}{2}, \pi(p^*) = \frac{1-\delta}{4}$

(ii) If $(\sqrt{2-\delta}-1) \leq h \leq \frac{1}{(3-2\delta)}$, *then* $p^* = \frac{(1+h)(1-\delta)}{2(2-\delta)}, \pi(p^*) = \frac{(1+h)^2(1-\delta)}{4(2-\delta)}$

(iii) If $\frac{1}{(3-2\delta)} \leq h \leq \frac{1}{2(1-\delta)}$, *then* $p^* = h(1-\delta), \pi(p^*) = h(1-\delta) - h^2(1-\delta)^2$

(iv) If $h \geq \frac{1}{2(1-\delta)}$, *then* $p^* = \frac{1}{2}, \pi(p^*) = \frac{1}{4}$

The regions of (h, δ) for which each of the prices are optimal are depicted graphically in Figure 2.

2.2 Presence of an electronic secondary market

Now consider the case where there is an efficient electronic secondary market (henceforth referred to as an ESM). This market may be either run by the firm, or by a third party intermediary. As in the earlier case, we consider an existing base of owners. The percentage of the market that owns an old product is still exogenously specified.

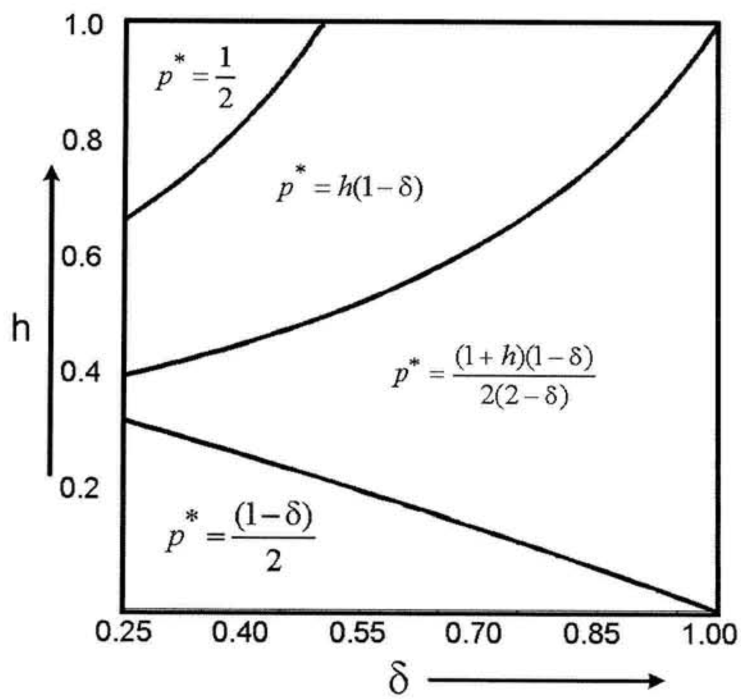

Figure 2: Optimal price for different durability and installed base

In addition to the features discussed in the earlier case, in the current model, an additional type of transaction is enabled due to the existence of the electronic market. Existing owners of the product from prior purchase (we will refer to this as the *used good* from here onwards) can now sell it as a used good if they can find buyers for it in the ESM that are willing to pay them their desired price. Therefore, a buyer has two different buying options open to her in this period. She can buy a new good from the firm, or buy a used good from a first period buyer though the ESM. Further, a buyer who owns a used good will not buy another used good; we will also show that if she sells it at all, it will be to buy a new good. Any buyer who buys a new good will do so only if her valuation of the good $v > p$ where p is the price of the new good. However, not all buyers whose valuations of the new good are greater than this price will buy the product, as some may derive higher value by buying the used good at the ESM price p_0. It is easy to show that the maximum price that the old good will fetch in a market is limited by the price of the new good (since no buyer would buy a used good at a price greater than that of the new good). A buyer who prefers the new good to buying the old good has a valuation that is characterized by:

$$v - p > \delta v - p_0 \Rightarrow v > \frac{p - p_0}{1 - \delta}$$

Also, an existing owner who wishes to sell the old good in the ESM and then buy a new one, has a valuation that is characterized by:

$$v - p + p_0 > \delta v \Rightarrow v > \frac{p - p_0}{1 - \delta}$$

We continue to use h to indicate the installed base of customers whose valuations of the product in the earlier period was greater than or equal to h, $0 < h < 1$. The firm sets the price p of the new good to maximize its profits, taking into account the expected activity in the electronic secondary market. This choice of p by the firm induces a price p_0 for the used good. The price p_0 (which is not a direct choice of the firm) is non-negative, and clears the market (i.e. the supply and demand for the used good at p_0 are equal). If no positive market clearing price exists, then trade does not occur on the ESM. The values of p and p_0 induce a demand $q(p, p_0)$ for the new good, and corresponding profits $pq(p, p_0)$ for the firm.

A buyer who buys the used good, has a valuation that is given by:

$$\delta v - p_0 > 0 \Rightarrow v > \frac{p_0}{\delta}$$

The demand for the new good therefore depends on the relative values of p, h, $\frac{p - p_0}{1 - \delta}$ and $\frac{p_0}{\delta}$. The following lemma establishes a simple result that narrows the number of relevant cases significantly.

Lemma 2 *If* $p > \frac{p - p_0}{1 - \delta}$, *then* $\frac{p_0}{\delta} > p$

Now, we show that there are just three relevant situations:

$(i) \quad p < \frac{p - p_0}{1 - \delta} < h$

$(ii) \quad p < h < \frac{p - p_0}{1 - \delta}$

$(iii) \quad h < p < \frac{p - p_0}{1 - \delta}$

It is not necessary to consider other cases since they preclude the existence of trade in the ESM. If $p > \frac{p - p_0}{1 - \delta}$, then, by Lemma 2, $\frac{p_0}{\delta} > p > \frac{p - p_0}{1 - \delta}$ and the used good would have no sales, since all buyers who would wish to buy the used good $(v > \frac{p_0}{\delta})$ would prefer to buy the new good (since $v \not< \frac{p - p_0}{1 - \delta}$). Also, if $p < \frac{p - p_0}{1 - \delta}$, then, by Lemma 2, $\frac{p_0}{\delta} < p$, which implies that $\frac{p_0}{\delta} < h$, $\frac{p_0}{\delta} < \frac{p - p_0}{1 - \delta}$ in cases (i) and (ii); we shall subsequently show that (iii) cannot support an ESM, so the position of $\frac{p_0}{\delta}$ is irrelevant.

Consider case (iii), $h < p < \frac{p - p_0}{1 - \delta}$ results in the following demand:

$$q(p) = 1 - (\frac{p - p_0}{1 - \delta})$$

To determine the market clearing price of the used good, we equate the demand for the used good to its supply:

$$\begin{aligned} h - \frac{p_0}{\delta} &= 1 - (\frac{p - p_0}{1 - \delta}) \\ &\Rightarrow p_0 = \delta p - (1 - h)(1 - \delta)\delta \\ &\Rightarrow q(p) = 1 - (p + \delta(1 - h)), \end{aligned}$$

so long as $\frac{p_0}{\delta} < h$, and $p_0 > 0$.

The firm's profits from this price are:

$$p(1-(p+\delta(1-h))$$

Therefore, the profit maximizing price $p^*$is

$$p^* = \frac{1-\delta(1-h)}{2}$$

Now, for $p^*$to be a feasible price in the range, it must support a positive p_0. However, p_0 is positive only if $\delta p - (1-h)(1-\delta)\delta \geq 0$, which reduces to $h \geq \frac{1-\delta}{2-\delta}$. Also, case (iii) requires that $h \leq p^*$, or $h \leq \frac{1-\delta(1-h)}{2}$, which reduces to $h \leq \frac{1-\delta}{2-\delta}$. Hence, this case is irrelevant (note that even if one set $p = h$, and looked for a solution, one gets the same contradiction, and hence even a boundary solution cannot be supported).

The following proposition establishes when each of the other two cases occurs. The consumer behavior for these cases is summarized in Figure 3.

Proposition 2 *(a) If the firm wishes to have trade in the ESM, the optimal price* p^* *satisfies* $p^* \leq h$, $p^* \leq \frac{p-p_0}{1-\delta}$, *and results in the following prices and profits:* $p^* = \frac{1-\delta(1-h)}{2}$, $p_0 = \frac{\delta[h(2-\delta)-(1-\delta)]}{2}$ *and* $\pi(p^*) = \frac{[1-\delta(1-h)]^2}{4}$

(b) If $h \leq \frac{1-\delta}{2-\delta}$ *, then it is optimal for the firm if no trade to occur in the ESM.*

(c) If $\frac{1-\delta}{2-\delta} \leq h \leq \frac{1+\delta}{2+\delta}$ *, then the ESM price* p_0 *induced is such that* $p \leq h \leq \frac{p-p_0}{1-\delta}$

(d) If $h \geq \frac{1+\delta}{2+\delta}$*, then the ESM price* p_0 *induces is such that* $p \leq \frac{p-p_0}{1-\delta} \leq h$

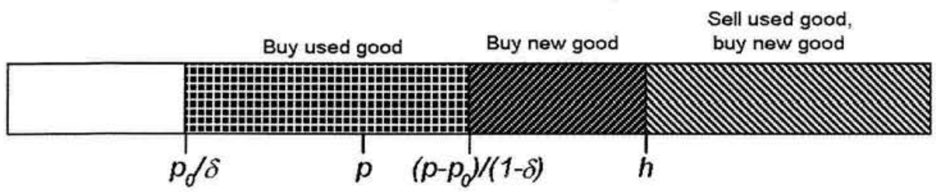

Figure 3(a)

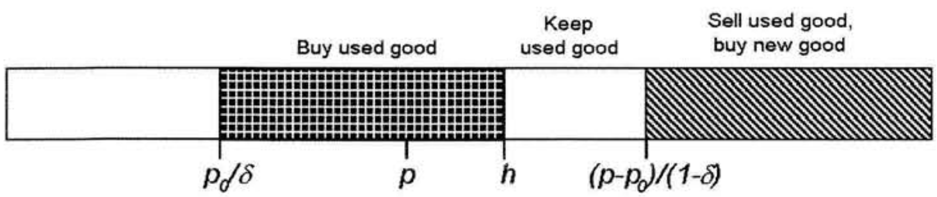

Figure 3(b)

Figure 3: Consumer buying patterns with an electronic secondary market

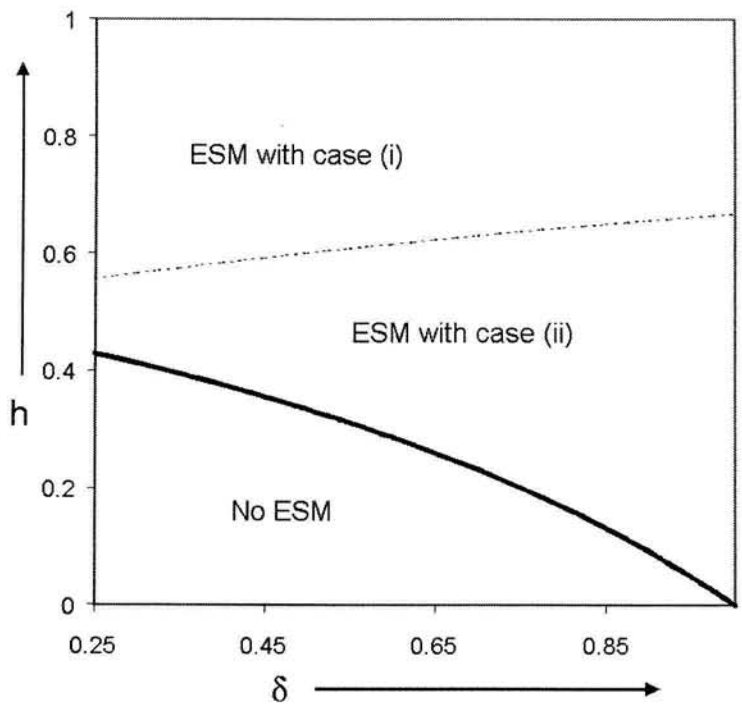

Figure 4: When an ESM is feasible

The results are summarized below, and in Figure 4.

Range of h	Relevant Case	Optimal Price p^*	Profits $\pi(p^*)$
$h < \frac{1-\delta}{2-\delta}$	Non Relevant	–	–
$\frac{1-\delta}{2-\delta} \leq h \leq \frac{1+\delta}{2+\delta}$	Case (ii)	$\frac{1-\delta(1-h)}{2}$	$\frac{[1-\delta(1-h)]^2}{4}$
$h \geq \frac{1+\delta}{2+\delta}$	Case (i)	$\frac{1-\delta(1-h)}{2}$	$\frac{[1-\delta(1-h)]^2}{4}$

3 When are electronic markets optimal ?

Having characterized the nature of firm profits as a function of the relative positions of h and δ, it is now possible to compare when the base case is dominated by the ESM case. We first examine when a firm should introduce an electronic secondary trading forum. Subsequently, we look at the welfare implications of ESMs. Finally, we discuss other costs, benefits and issues involved in the introduction of markets of this kind.

3.1 Profit maximizing (when should a firm operate its own ESM)

We now investigate when it is optimal for a firm to introduce an electronic market. Now, it is evident from Proposition 2 that $\pi(p^*)$ is always strictly less than $\frac{1}{4}$ (the profits without an ESM $h \geq \frac{1}{2(1-\delta)}$) when a secondary market exists, and that an electronic secondary market is not feasible if h is less than $\frac{1-\delta}{2-\delta}$. This immediately leads to our first result:

Proposition 3 *If* $h \geq \frac{1}{2(1-\delta)}$, *or* $h \leq \frac{1-\delta}{2-\delta}$ *then it is strictly sub-optimal for a firm to introduce an electronic secondary market.*

This leaves us with just two regions: $\frac{1-\delta}{2-\delta} \leq h \leq \frac{1}{(3-2\delta)}$, and $\frac{1}{(3-2\delta)} \leq h \leq \frac{1}{2(1-\delta)}$ for which we need to compare the results of Propositions 1 and 2 (since $\sqrt{2-\delta}-1 < \frac{1-\delta}{2-\delta}$ for all $1 \geq \delta \geq 0$). The comparison is straightforward, but analytically messy — we equate profit functions, and look for the (h, δ) combinations that form the boundary between the regions where the presence of an ESM dominates, and the region where the absence of an ESM dominates. However, the equations by themselves are highly non-linear, and it is not possible to get any intuition from them, or perform any meaningful comparative statics analysis. Therefore, we plot boundaries in (h, δ) space, and examine when each situation is optimal. Interestingly, the (h, δ) values for which the ESM starts to dominate are remarkably close for both the cases (the curves almost coincide). Of course, one is relevant only for $h \leq \frac{1}{(3-2\delta)}$ while the other is relevant for $h \leq \frac{1}{(3-2\delta)}$; nevertheless, this virtual coinciding of boundaries is something that we plan to investigate more closely in the future.

Our analysis is summarized in Figure 5, and interpreted below.

An electronic secondary market is optimal from a *firm's* perspective if the durability of the product is not low, or the rate of new product introduction is not low, and if the installed base of the product is fairly low.

The dotted lines in Figure 5 represent the boundaries of the regions from Proposition 1 and 2. As one can see, both $h \geq \frac{1}{2(1-\delta)}$ (top left corner) and $h \leq \frac{1-\delta}{2-\delta}$ (bottom, decreasing from left to right) are well outside the region of interest. This result is even more interesting if one examines Figure 6, which replicates Figure 5 in a somewhat realistic area of the space; for reasonable values of h and δ (i.e. when the product is not almost completely perishable, and when the firm's installed base

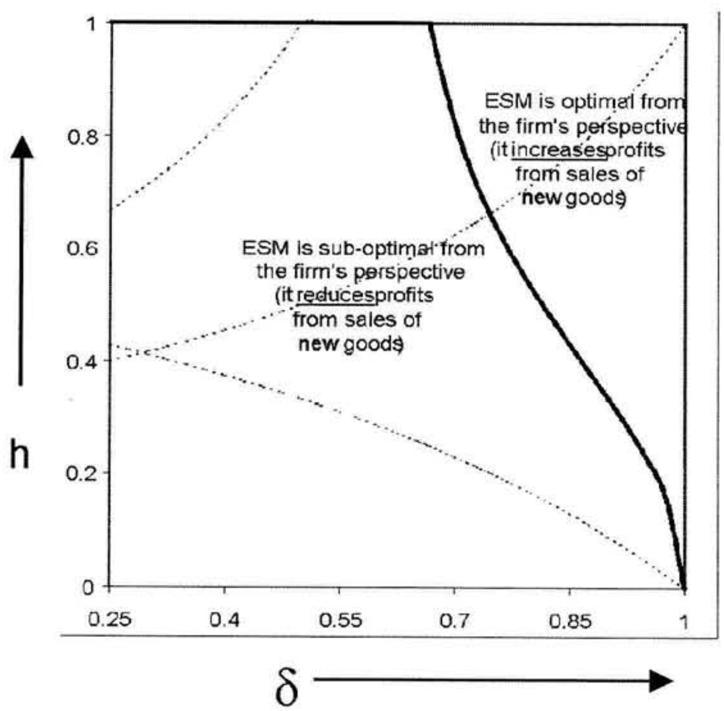

Figure 5: When an ESM is optimal

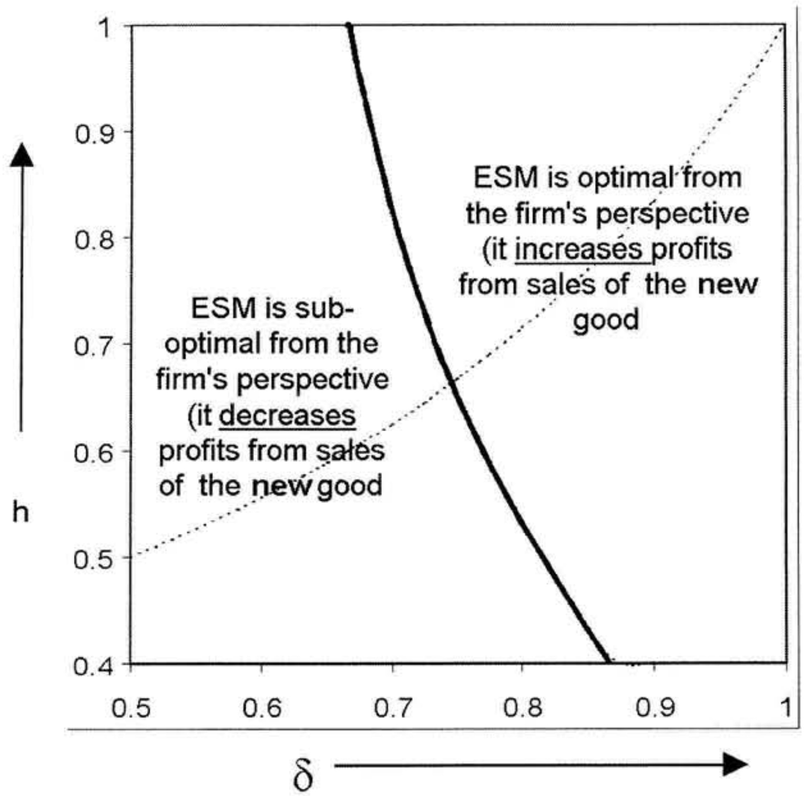

Figure 6: When an ESM increases profits in the primary market – a closer look.

is 60% or less of the entire potential market) Here, we see that in almost half the possible cases, the presence of an electronic *secondary* market increases the profits of the firm from sales in the *primary* market (i.e. from sales of the new good). This ignores any commissions that the operator of the market (i.e. the firm in this case) could charge — it is simply from the price-demand effects the increased liquidity of the second-hand good has on the primary good's sales.]

Also, as the durability of the good increases, or as the rate of product turnover increases, the firm gets more value from the ESM — this is fairly intuitive. However, more interestingly, as the installed base decreases, the firm has a better chance of profiting from an ESM. One could argue that if the installed base is low then the lack of supply of the used good would drive the electronic secondary market price out of business. However, as one can see, this is not the case; the firm ends up reaping additional rents from sales of the primary good by simultaneously enabling sales in the ESM by causing a higher percentage of consumers to hold on to their used good); evidently, the price effect on profitability dominates the demand effect.

3.2 Welfare maximizing (when can an intermediary operate an ESM)

Our next task was to analyze when an interested *third-party intermediary* can operate an electronic secondary market profitably. We examined consumer surplus (the net excess value all consumers get after purchase) under the presence of an ESM, and then under the absence of an ESM. The rationale for this is that if the consumers were collectively strictly better off with an ESM, then they would be collectively willing to pay to get an intermediary to operate this market, by giving up a fraction of their surplus towards the operation of the market.

This question was answered fairly easily. Whenever an electronic market is *feasible*, then it turns out that it is *strictly optimal* from the consumers' perspective, and hence an intermediary could operate the market profitably. This seems intuitively plausible, since (a) high-value consumers who repurchase now get some positive payment for their old good, instead of throwing it away, and (b) low-value consumers who could not afford the new good can now afford the used good, thereby increasing their surplus from zero.

One may wonder how this market can cause both the consumers and the firm to be simultaneously strictly better off in a fraction of the cases. Logically,if the firm's share of the pie (profits) go up, one may ask, then shouldn't the consumer's share of the pie (consumer surplus) go down. The reason is simple; here, when an ESM is operated, *total surplus* increases — hence the size of the pie increases, which enables both parties to be better off, even when their relative fractions change.

However, it is not sufficient that one simply examine when consumer surplus is higher; in order for a third-party intermediary to operate the market, the surplus has to be higher even when the consumers pay a commission or brokerage fee; hence, one needs to estimate the relative magnitudes of the surplus. We are currently in the process of performing this analysis, and will have these results available shortly.

3.3 Other issues – components, competition and repeated trade

The model we have presented can be extended to analyze other economic settings that may alter the desirability of an ESM. For instance, an ESM need not be restricted to just selling used products; it could (and is) be a forum for trading allied components of a product. For instance, a liquid second-hand electronic market for Brand X computer monitors would increase the desirability of the complementary product (i.e. Brand X personal computers), and if the firm that manufactured the computers established a reliable, liquid, Web-based market of this kind, it could potentially increase consumer valuations of its primary good. Our preliminary analysis shows that this effect enhances the desirability of an electronic secondary market; we use our basic model, but with two complementary goods instead of a single product.

Another key factor is that of competition. A firm facing a perfectly competitive market can compete more effectively by using an ESM as a quality factor; in the absence of similar moves by competitors, this could be a successful market-share capturing strategy. The effect is compounded if one considers the case of complementary goods as well; if there are many products of many types in the market, and a firm enables secondary trading in these goods exclusively for its customers, it could potentially increase profits. However, there are some liquidity/profit margin trade-offs here, which are not immediately resolvable.

Finally, our model seamlessly becomes a period model in a multi-period setting. This is an important line of research, since one can relax the implicit assumption of uniform quality, and explicitly model the observed phenomenon of consumers' trading histories enhancing their reliability. Also, we have not considered the fact that a consumer's valuation of a good is positively affected by the possibility of being able to easily sell it for a fair price *in the future* — a dynamic model will enable the analysis of this effect as well. There is also the issue of used goods of *different ages* that can be captured in such a model; however, at this stage, our analysis of this is research-in-progress.

4 Conclusions and Future Work

We have explicitly modeled the economic effects of an electronic secondary market on firm profits and consumer surplus. Our key insights are summarized below:

1. When a firm has a very share of the potential consumer market, and faces a high rate of technological obsolescence, the existence of an electronic secondary market will tend to have a negative impact on the profitability of the firm's sales of new goods.

2. However, in a significant fraction of situations, it is optimal for the *manufacturer* of a product or set of products to operate an electronic market which enables the trade of their used goods or components. Rather than cannibalizing sales of new goods, this can actually have a positive effect on the profits from new goods. This effect is positive even when the customers ignore the benefits from easier future sales — simply the *existence* of the market to sell current used products can benefit the firm.

3. The desirability of these markets from the firm's perspective is enhanced when:
   - the durability of their product is high, or
   - the rate at which they introduce new versions of their product is high, and
   - the share they have of the product market is higher.
4. The presence of these electronic forums are almost always optimal from the perspective of the consumer; hence, in cases where the firm does not have enough of an incentive to establish the market, we expect a third-party intermediary to run such a market. The emergence of a number of such electronic channels for used goods indicates that this has been recognized to some extent.
5. The establishing of an ESM can improve a firm's competitive position in an oligopoly; hence, we expect that this will emerge as a new way that a firm can use information technology for competitive advantage in the near future; however, it is likely that only the first few movers will gain any competitive rents from this move.

Our current research includes *explicitly* modeling the effects of *trading histories* on the operation of the market, using a game-theoretic model. There is also the issue of imperfect correlation between the valuations of new and used goods, which can be captured by imposing a noise factor on our current model. This could also proxy for quality variance in the used goods. Finally, we also will be investigating the relative merits of different trading mechanisms in ESM's; though determining a market clearing price is the only logical static solution, it appears that a dynamic model could involve interpersonal exchanges of information, and other market divisions, that could affect firm profitability and welfare in very interesting ways.

5 Appendix

Proof of Lemma 1: *The two outer inequalities are true for all* δ *in* $[0,1)$. *The middle inequality is satisfied at equality for two values of* δ, *of which the only fractional value is* $\delta = \frac{5-\sqrt{17}}{4} \approx 0.22$. *The result follows immediately from the fact that* $\dfrac{1-\delta}{2}$ *is decreasing in* δ, *while* $\dfrac{1}{(3-2\delta)}$ *is increasing in* δ.

Proof of Proposition 1: *In each interval for h, the firm chooses one of the three price regimes – the one which gives it the highest profits. We consider each of the intervals:*

(A) $h \leq \dfrac{(1-\delta)}{(3-\delta)}$ *: The profits under each of the price regimes are summarized below:*

Price Regime	Optimal Price	Optimal Profit Level
(i) $p \geq h$	$p^* = \frac{1-\delta}{2}$	$\pi^* = \frac{1-\delta}{4}$
(ii) $h(1-\delta) \leq p \leq h$	$p^* = h$	$\pi^* = h - \frac{h^2}{(1-\delta)}$
(iii) $p \leq h(1-\delta)$	$p^* = h(1-\delta)$	$\pi^* = h(1-\delta) - h^2(1-\delta)^2$

These figures are obtained by referring to the table of prices and profits, and using the corresponding values. Comparing profit levels, one sees that (i) is always superior to (ii), since (i) represents the optimal value of the profit equation in (ii). Comparing (i) and (iii), we see that (iii) dominates (i) only if $\frac{1}{2+2\sqrt{\delta}} < h < \frac{1}{2-2\sqrt{\delta}}$. *However, since* $\frac{(1-\delta)}{(3-\delta)} < \frac{1}{2+2\sqrt{\delta}}$*, (i) is dominant.*

(B) $\frac{(1-\delta)}{(3-\delta)} \leq h \leq \frac{1-\delta}{2}$ *: The profits under each of the price regimes are summarized below:*

Price Regime	Optimal Price	Optimal Profit Level
(i) $p \geq h$	$p^* = \frac{1-\delta}{2}$	$\pi^* = \frac{1-\delta}{4}$
(ii) $h(1-\delta) \leq p \leq h$	$p^* = \frac{(1+h)(1-\delta)}{2(2-\delta)}$	$\pi^* = \frac{(1+h)^2(1-\delta)}{4(2-\delta)}$
(iii) $p \leq h(1-\delta)$	$p^* = h(1-\delta)$	$\pi^* = h(1-\delta) - h^2(1-\delta)^2$

(ii) always dominates (iii), since (ii) represents the optimum in this interval, and is hence at least as good as the values of the objective at the boundaries. Now, (ii) is better than (i) if $h \geq (\sqrt{2-\delta}-1)$ *(this is obtained by solving for the h that equates the profits in (ii) and (i)). Also, one can easily verify that* $\frac{(1-\delta)}{(3-\delta)} \leq (\sqrt{2-\delta}-1) \leq \frac{1-\delta}{2}$

for $0 \leq \delta \leq 1$ *(for instance, by a plot in Mathematica). Hence, (i) is better if* $h \leq (\sqrt{2-\delta} - 1)$, *and (ii) is the dominant solution, at least upto* $h = \frac{1-\delta}{2}$.

(C) $\frac{1-\delta}{2} \leq h \leq \frac{1}{(3-2\delta)}$: *The profits under each of the price regimes are summarized below:*

Price Regime	*Optimal Price*	*Optimal Profit Level*
(i) $p \geq h$	$p^* = h$	$\pi^* = h - \frac{h^2}{(1-\delta)}$
(ii) $h(1-\delta) \leq p \leq h$	$p^* = \frac{(1+h)(1-\delta)}{2(2-\delta)}$	$\pi^* = \frac{(1+h)^2(1-\delta)}{4(2-\delta)}$
(iii) $p \leq h(1-\delta)$	$p^* = h(1-\delta)$	$\pi^* = h(1-\delta) - h^2(1-\delta)^2$

The proof here is trivial. (ii) represents the optimal solution to maximizing $p[(1 - \frac{p}{1-\delta}) + (h-p)]$, *the profit function under price regime 2. (i) and (iii) represent the values of this function at* $p = h$ *and* $p = h(1-\delta)$ *respectively; evidently, (ii) is at least as good as (i) and (iii)*

(D) $\frac{1}{(3-2\delta)} \leq h \leq \frac{1}{2(1-\delta)}$: *The profits under each of the price regimes are summarized below:*

Price Regime	*Optimal Price*	*Optimal Profit Level*
(i) $p \geq h$	$p^* = h$	$\pi^* = h - \frac{h^2}{(1-\delta)}$
(ii) $h(1-\delta) \leq p \leq h$	$p^* = h(1-\delta)$	$\pi^* = h(1-\delta) - h^2(1-\delta)^2$
(iii) $p \leq h(1-\delta)$	$p^* = h(1-\delta)$	$\pi^* = h(1-\delta) - h^2(1-\delta)^2$

There are only two distinct cases here. Equating the profit functions and solving for h, one sees that (i) dominates if $h < \frac{1-\delta}{(3-3\delta+\delta^2)}$, *which is less than* $\frac{1}{(3-2\delta)}$.

Hence, (ii)/(iii) (which are identical in this case) dominates in the specified region.

(E) $h \geq \frac{1}{2(1-\delta)}$ *: The profits under each of the price regimes are summarized below:*

Price Regime	*Optimal Price*	*Optimal Profit Level*
(i) $p \geq h$	$p^* = h$	$\pi^* = h - \frac{h^2}{(1-\delta)}$
(ii) $h(1-\delta) \leq p \leq h$	$p^* = h(1-\delta)$	$\pi^* = h(1-\delta) - h^2(1-\delta)^2$
(iii) $p \leq h(1-\delta)$	$p^* = \frac{1}{2}$	$\pi^* = \frac{1}{4}$

(iii) is evidently dominant, as it represents the global optimum of $p(1-p)$, *which is the highest possible profits the firm can make for any value of* h. *This completes the proof.*

Proof of Lemma 2 $p > \frac{p - p_0}{1-\delta} \Rightarrow p(1-\delta) > p - p_0$

$\Rightarrow -p\delta > -p_0 \Rightarrow p_0 > p\delta$

and the result follows immediately.

Proof of Lemma 3 $\frac{1+\delta}{2+\delta}$ *is always greater than* $\frac{1-\delta}{2-\delta}$ $\forall \delta \in [0,1]$. *Also,* $\frac{1-\delta}{2-3\delta} - \frac{1+\delta}{2+\delta} \geq 0$ *if* $\delta > \frac{2}{3}$ *or if* $\delta < -2$. *The result follows.*

Proof of Proposition 2 *We have eliminated case (i); hence the only option we have is that* $p^* \leq h$, $p^* \leq \frac{p - p_0}{1-\delta}$ *(cases (ii) and (iii)). Consider case (ii). The demand for the new good is still*

$$q(p) = 1 - (\frac{p - p_0}{1 - \delta})$$

and therefore the analysis proceeds as in case (i), yielding the secondary market price:

$$p_0 = \delta p - (1 - h)(1 - \delta)\delta,$$

and the optimal price level for the new good,

$$p^* = \frac{1 - \delta(1 - h)}{2}.$$

The optimal profit level is obtained by computing $p^* q(p^*)$*, and works out to be*

$$\pi(p^*) = \frac{[1 - \delta(1 - h)]^2}{4}$$

Now, $p_0 \geq 0 \Rightarrow \delta p - (1 - h)(1 - \delta)\delta \geq 0$*, which reduces to* $h \geq \frac{1 - \delta}{2 - \delta}$*. Hence Now, for* p^* *to be in the required region, we require that* $h \geq p^*$*, or* $h \geq \frac{1 - \delta}{2 - \delta}$*, which is consistent with* $p_0 > 0$*. The condition* $p^* \leq \frac{p^* - p_0}{1 - \delta}$ *reduces to* $h \leq \frac{1 + \delta}{2 + \delta}$

Now consider case (i). The demand from repeat buyers is $1 - h$*, and the demand for the new good from new buyers is* $h - \frac{p - p_0}{1 - \delta}$*, yielding a total demand of*

$$q(p) = 1 - (\frac{p - p_0}{1 - \delta})$$

The demand for the used good is $\frac{p - p_0}{1 - \delta} - \frac{p_0}{\delta}$*. To determine the market clearing price, we equate supply to demand. Supply of the used good is* $(1 - h)$*; hence, the market clearing condition is*

$$\frac{p - p_0}{1 - \delta} - \frac{p_0}{\delta} = 1 - h$$

which again reduces to

$$p_0 = \delta p - (1 - h)(1 - \delta)\delta$$

As is evident, the demand equations are identical to case (ii); hence the optimal prices and profits are the same. The only difference here is that $p^* \geq \frac{p^* - p_0}{1 - \delta}$*, which reduces to* $h \geq \frac{1 + \delta}{2 + \delta}$.

Therefore, the firm will set a price $p^* \leq h$*, and depending on the value of* h*, the market clearing price* p_0 *will correspond either to case (i) or case (ii). Since the firm can achieve its optimal profit level* $\frac{[1 - \delta(1 - h)]^2}{4}$ *for all* $h \geq \frac{1 - \delta}{2 - \delta}$*, there is no need to examine boundary solutions, as they are bound to be inferior. This completes the proof.*

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