ELSEVIER

Decision Support Systems 24 (1998) 3–16

Decision Support Systems

An economic analysis of electronic secondary markets: installed base, technology, durability and firm profitability

Ravi Arunkundram *, Arun Sundararajan [1]

Department of Information Systems, Stern School of Business, 44 West 4th Street, New York, NY 10012-1126, USA

Abstract

The Internet has spawned a number of partially structured electronic secondary markets, which enable the trading of secondary goods between consumers. Many of these, such as Usenet groups, or WWW sites for niche products, tend to be self-administering; however, there has been significant recent growth in the number of more general web-based markets of this kind. These electronic secondary markets, while facilitating reliable and liquid trade of used goods, could also have an impact on the desirability of new products, as well as products that are complementary/compatible to those traded. We present an economic framework for analyzing how these markets affect the demand for a primary product. We examine when it is optimal for a firm to operate a market of this kind, and when its 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. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Electronic markets; Electronic commerce; Secondary markets; Price formation; Web-based trading; Buyer welfare; Market structure; Mixed market model; Information economics

1. Introduction

Commerce on the Internet has grown considerably over the last few years, and is projected to increase by many multiples from 1998 to 2002, both in terms of sales revenues and number of participants (see Refs. [1] or [2] for some recent Internet commerce forecasts). 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. There are numerous articles in the trade press and in research literature that focus on the immense commercial potential of Internet-based markets (see, for instance [3–16]).

An interesting part of Internet-based commerce that has not received much attention from researchers is the profusion of sites that enable buyers and sellers to trade durable products. Certain Usenet newsgroups and electronic bulletin boards that are run by academic institutions constitute examples of these sites, which we call *Electronic Secondary Markets*. We define an electronic secondary market

* Corresponding author. Tel.: +1-212-998-0834; Fax: +1-212-998-0833; E-mail: rarunkun@stern.nyu.edu

[1] E-mail: asundara@stern.nyu.edu.

0167-9236/98/$ - see front matter © 1998 Elsevier Science B.V. All rights reserved.
PII: S0167-9236(98)00059-1

as *Internet-based forum* that allows buyers and sellers to *trade used products* by placing bids and offers *on a channel that is commonly accessed* by all participants in the market. It is a *secondary* market, since the products that are bought are not sold by the original maker of the product.

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 nonprofit 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. Some Web-based services such as OnSale and CarPoint combine primary and secondary electronic markets. Further, we have observed that the participant volume in certain Usenet secondary markets has 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 significant benefit for buyers and sellers.

Forrester Research [15] calls the Internet the fourth channel for exchanging information between parties to a transaction, such as suppliers, buyers, sellers and intermediaries (the other three channels being face-to-face communication, telephone communication and mailings). The three factors Maney et al. cite as having driven the growth in commerce on the Net are all applicable to ESMs:

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.

In addition, 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*. In Section 2, we provide an overview of ESMs and their characteristics.

2. Overview of electronic secondary markets

There are three additional features that characterize electronic secondary marketplaces and distinguish them from most physical marketplaces:

1. Electronic markets 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.
2. Electronic secondary marketplaces allow for immediate offer revision and negotiation.
3. 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.

The first feature requires no further discussion; it is obvious and well established. We discuss the other two features below.

2.1. Offer revision and negotiation

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 enabled faster and smoother matching of supply and demand, and consequently, efficient price setting for a particular product.

2.2. Availability of the trading histories of buyers and sellers

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. In secondary markets for used goods (electronic or otherwise), buyers and sellers are exposed to the risk of opportunistic behavior induced by uncertainty and lack of verifiability of product and price claims. Many buyers and sellers on these electronic secondary markets acquire reputations for accuracy, verifiability and reliability of their price and product quality descriptions and their payment behavior. A trader's reputation acts as a signal that reduces the measure of uncertainty associated with his trading behavior, and allows all parties to a transaction to assess the risk of opportunistic behavior more accurately, which 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 three key features that will fuel the growth of electronic commerce [16]. The advantages of an electronic market relative to a campus or community bulletin board 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 note 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, in addition to the remarkable success of sites such as eBay, several market makers for primary market goods such as OnSale and Microwarehouse now have exclusive sites that act as secondary markets.

This motivates our model of an electronic secondary market, and our analysis of its impact on demand and price setting in the primary market. Since electronic secondary markets are influenced by the simultaneous existence of 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, the conditions under which these effects prevail.

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 can increase consumer confidence levels in used-good purchase. It also makes the trade of a used good liquid. These features are crucial to the effective functioning of any secondary market. Only electronic markets can simultaneously ensure quality, liquidity and costless search, and this is precisely why the distinction between an electronic secondary market and a nonelectronic market represents a difference of kind rather than degree, as mentioned 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. An ESM can:

1. 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. 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 extent to which the product loses value 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—consisting of both existing owners, and potential buyers. One of our hypotheses is that such markets will continue to grow rapidly, sometimes with the active support of the producers of primary goods.

3. Outline of model

This section provides an overview of the model and a discussion of the modeling primitives that reflect the issues discussed in Section 2.

(1) Our model examines a monopolist who produces a single durable product, and sells it in a market whose size we normalize to 1.

(2) The consumer valuations of a new product in any period are uniformly distributed from 0 to 1. [2] 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. 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 results in a higher durability coefficient (increases δ). 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).

(3) We assume that a consumer's valuation of a good is directly proportional to its durability. If the 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.

(4) The firm has a constant marginal cost, which we normalize to zero. [3] The firm sets the price of a new good with perfect knowledge of the exaction proportion 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).

[2] This is a widely used model of consumer preferences, and in the absence of a used product, generates a downward sloping linear demand curve.

[3] 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 indicating the desirability of an electronic secondary market.

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 of customer preferences, and the current market situation i.e., the proportion of consumers who own used goods; precisely the model that drive the analysis in this paper. We represent the *installed base of customers* by those who have valuations greater than or equal to h, where $0 < h < 1$.

4. 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) $p \geq h$,
(ii) $h(1-\delta) \leq p \leq h$,
(iii) $p \leq h(1-\delta)$.

We derive the demand and profit functions for each of these cases, and then analyze optimal price p for different values of installed base h and durability 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 $p/(1-\delta)$.

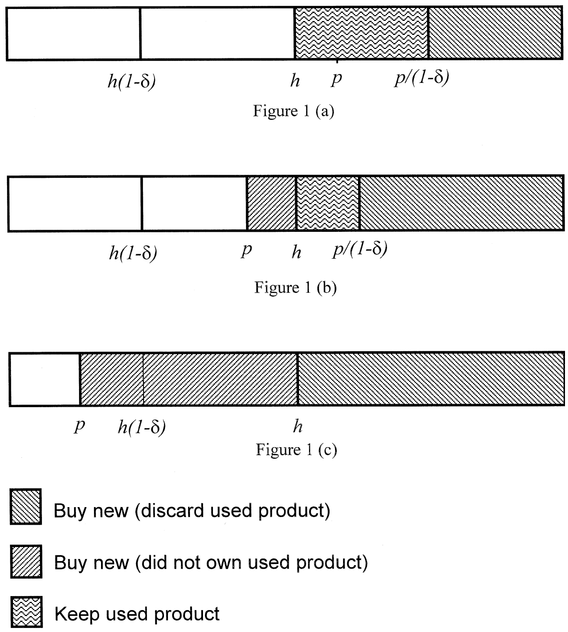

Fig. 1. Consumer buying patterns without a secondary market.

4.1. Case 1: $p \geq h$

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

4.2. Case 2: $h(1-\delta) \leq p \leq h$

The second case $[h(1-\delta) \leq p \leq h]$ induces both new buyers and existing owners to buy the good, as shown in Fig. 1(b). Since $p > h(1-\delta)$, which implies that $p/(1-\delta) > h$, 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, $q(p) = [1 - p/(1-\delta)] + (h - p)$.

4.3. Case 3: $p \leq h(1-\delta)$

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

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 $pq(p)$.

$$q(p;h) = \begin{cases} \left(1-\dfrac{p}{1-\delta}\right) \text{ if } p \geq h & \text{PriceRegime1,} \\ \left(1-\dfrac{p}{1-\delta}\right) + (h-p) & \text{PriceRegime2,} \\ \text{if } h(1-\delta) \leq p \leq h & \\ (1-p) \text{ if } p \leq h(1-\delta) & \text{PriceRegime3.} \end{cases}$$

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 in Table 1.

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 in Table 1 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 Appendix A.

Lemma 1. *If $1 \geq \delta \geq 0.22$, then $(1-\delta)/(3-\delta)/ \leq (1-\delta)/2 \leq 1/(3-2\delta) \leq 1/2(1-\delta)$.*

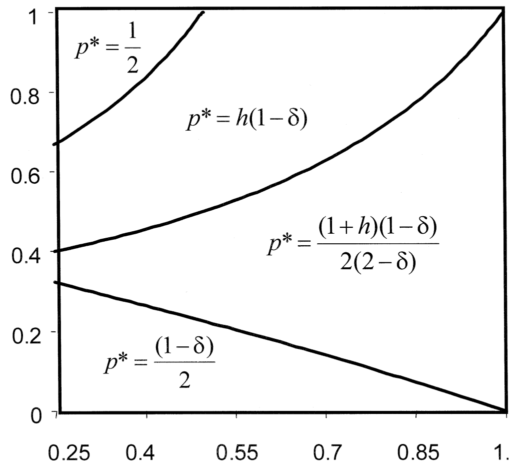

Fig. 2. Optimal price for different durability and installed base.

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 2. *(i) If $\leq (h \leq \sqrt{2-\delta} - 1)$, then $p* = (1-\delta)/2$, $\pi(p*) = (1-\delta)/4$. (ii) If $(\sqrt{2-\delta} - 1) \leq h \leq 1/(3-2\delta)$, then $p* = [(1+h)(1-\delta)]/2(2-\delta)$, $\pi(p*) = [(1+h)^2(1-\delta)]/4(2-\delta)$. (iii) If $1/(3-2\delta) \leq h \leq 1/2(1-\delta)$, then $p* = h(1-\delta)$, $\pi(p*) = h(1-\delta) - h^2(1-\delta)^2$. (iv) If $h \geq (1)/2(1-\delta)$, then $p* = 1/2$, $\pi(p*) = 1/4$.*

Fig. 2 provides a graphical summary of the relationship between installed base, durability and optimal price. The regions where the four different prices above are each optimal are determined by the relative values of customer valuation (on the horizontal axis), and durability (on the vertical axis).

Table 1

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

5. Presence of an electronic secondary market

In this section, we analyze the impact of an electronic secondary market (henceforth referred to as an ESM). We employ a model similar to one discussed in the earlier section and investigate how installed base and durability affect the optimal price and firm profits in the presence of an ESM.

We now consider the case where there is an efficient 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 proportion of the market that owns an old product is still exogenously specified. 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 secondary market. Existing owners of the product from prior purchase (we will refer to this as the used good from here onwards) can now sell the product 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 is not a direct choice of the firm, is non-negative, and clears the market (i.e., the price at which supply and demand for the used good 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 $p \times q(p, p_0)$ 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 the four entities; p, h, $(p - p_0)/(1 - \delta)$ and p_0/δ. The following lemma establishes a simple result that narrows the number of relevant cases significantly.**Lemma 3.** *If $p > (p - p_0)/(1 - \delta)$, then $p_0/\delta > p$.*

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

(i) $p < (p\text{-}p_0)/(1\text{-}\delta) < h$,
(ii) $p < h < (p\text{-}p_0)/(1\text{-}\delta)$,
(iii) $h < p < (p\text{-}p_0)/(1\text{-}\delta)$.

It is not necessary to consider other cases since they preclude the existence of trade in the ESM.

If $p > (p - p_0)/(1 - \delta)$, then, by Lemma 2, $p_0/\delta > p > (p - p_0)/(1 - \delta)$ and the used good would have no sales, since all buyers who would wish to buy the used good $(v > p_0/\delta)$ would prefer to buy the new good (since $v \not< (p - p_0)/(1 - \delta)$).

Also, if $p < (p - p_0)/(1 - \delta)$, then, by Lemma 2, $p_0/\delta < p$, which implies that $p_0/\delta < h$, $p_0/\delta < (p - p_0)/(1 - \delta)$ in cases (i) and (ii); we will now show that case (iii) cannot support an ESM, so the position of p_0/δ is irrelevant.

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

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

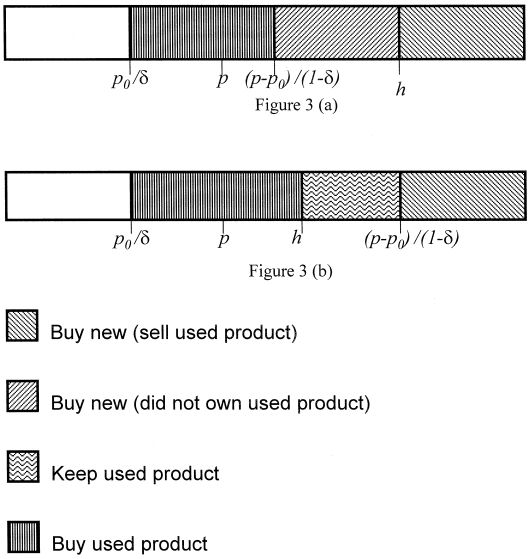

Fig. 3. Consumer buying patterns with an ESM.

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

$$h-\frac{p_0}{\delta} \quad = \quad 1-\left(\frac{p-p_0}{1-\delta}\right)$$

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

$$\Rightarrow \quad q(p)=1-(p+\delta(1-h)),$$

so long as $p_0/\delta<h$, 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.

The condition for a positive p_0 is:

$$\delta p-(1-h)(1-\delta)\delta\geq 0,$$

which reduces to:

$$h\geq\frac{1-\delta}{2-\delta}. \tag{1}$$

Also, case (iii) requires that:

$$h\leq p*, \Rightarrow h\leq\frac{1-\delta(1-h)}{2},$$

which reduces to:

$$h\leq\frac{1-\delta}{2-\delta}. \tag{2}$$

Since Eqs. (1) and (2) cannot both be true, a contradiction results and hence, this case is irrelevant (note that even if the limiting value of p is to be set at $p=h$, the same contradiction results, and hence even a boundary solution cannot be supported).

The proposition that follows establishes when each of the other two cases occurs. The consumer behavior in each situation is summarized in Fig. 3.

Proposition 4. *(a) If the firm wishes to have trade in the ESM, the optimal price* $p*$ *satisfies* $p*\leq h$, $p*\leq(p-p_0)/(1-\delta)$, *and results in the following prices and profits:* $p^*=[1-\delta(1-h)]/2$, $p_0=(\delta[h(2-\delta)-(1-\delta)])/2$ *and* $\pi(p*)=[1-\delta(1-h)]^2/4$. *(b) If* $h\leq(1-\delta)/(2-\delta)$, *then it is optimal for the firm if no trade to occur in the ESM. (c) If* $(1-\delta)/(2-\delta)\leq h\leq(1+\delta)/(2+\delta)$, *then the ESM price* p_0 *induced is such that* $p\leq h\leq(p-p_0)/(1-\delta)$. *(d) If* $h\geq(1+\delta)/(2+\delta)$, *then the ESM price* p_0 *induces is such that* $p\leq(p-p_0)/(1-\delta)\leq h$.

The results are summarized in Table 2 and in Fig. 4.

Table 2

Range of h	Relevant case	Optimal price $p*$	Profits $\pi(p*)$
$h<(1-\delta)/(2-\delta)$	Non-relevant	–	–
$(1-\delta)/(2-\delta)$ $\leq h\leq(1+\delta)/(2+\delta)$	Case (ii)	$[1-\delta(1-h)]/2$	$[1-\delta(1-h)]^2/4$
$h\geq(1+\delta)/(2+\delta)$	Case (i)	$[1-\delta(1-h)]/2$	$[1-\delta(1-h)]^2/4$

6. When are electronic markets optimal?

In this section, we examine the conditions under which electronic markets are optimal and the resulting price(s) of the new and used good, the induced demand for the two goods and the firm profits that result. 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.

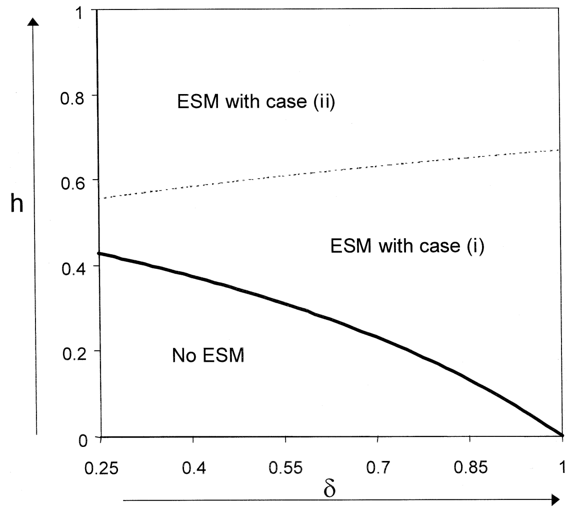

Fig. 4. When an ESM is feasible.

6.1. When should a firm operate its own ESM?

We now investigate when it is optimal for a firm to introduce an electronic market. Two results are evident from Proposition 2:

1. $\pi(p*)$ is always strictly less than $1/4$ (the profits without an ESM and $h \geq 1/2(1-\delta)$) when a electronic market exists, and
2. An ESM is not feasible if h is less than $(1-\delta)/(2-\delta)$.

The above two observations immediately lead to our first result:**Proposition 5.** *If $h \geq 1/2(1-\delta)$, or $h \leq (1-\delta)/(2-\delta)$, then it is strictly suboptimal for a firm to introduce an electronic secondary market.*

This leaves us with just two regions: $(1-\delta)/(2-\delta) \leq h \leq 1/(3-2\delta)$, and $1/(3-2\delta) \leq h \leq 1/2(1-\delta)$ for which we need to compare the results of Propositions 1 and 2 (since $\sqrt{2-\delta}-1 < (1-\delta)/(2-\delta)$ 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 nonlinear, 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 $h \leq 1/(3-2\delta)$ while the other is relevant for $h \leq 1/(3-2\delta)$; nevertheless, this virtual coinciding of boundaries is something that we plan to investigate more closely in the future.

Our analysis is summarized in Fig. 5 and the interpretation follows.

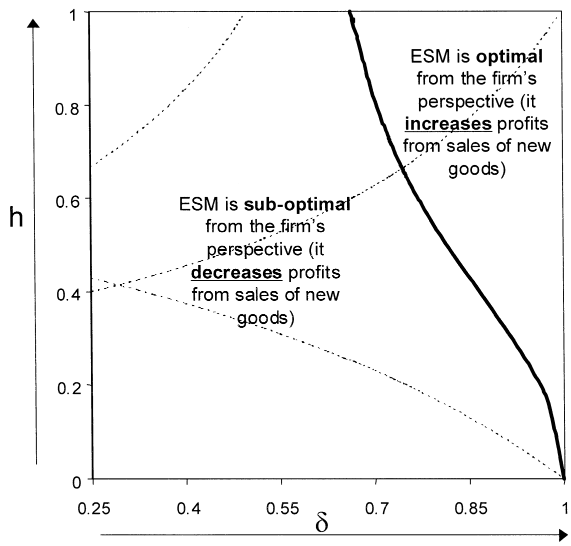

Fig. 5. When an ESM is optimal.

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 Fig. 5 represent the boundaries of the regions from Proposition 1 and 2. As one can see, both $h \geq 1/2(1-\delta)$ (top left corner) and $h \leq (1-\delta)/(2-\delta)$ (bottom, decreasing from left to right) are well outside the region of interest. This result is even more interesting if one examines Fig. 6, which replicates Fig. 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 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.

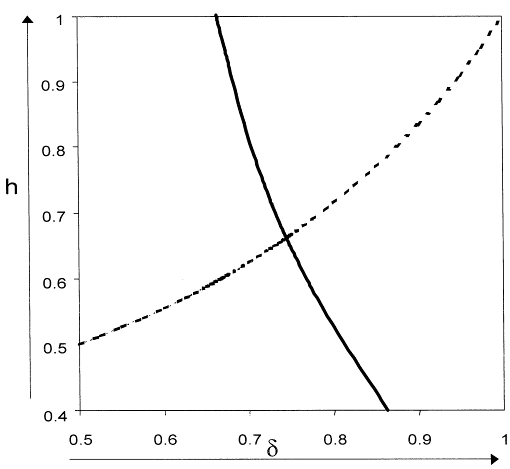

Fig. 6. When an ESM is optimal-a closer look.

6.2. 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*, 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. It may seem that as the firm's share of the pie (profits) increases, the consumer's share of the pie (consumer surplus) go down. However, this is not in consonance with the theoretical predictions of our model. The explanation for the divergence of 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 examines 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.

6.3. 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 be (and is) a forum for trading allied components of a product. For instance, a liquid second-hand electronic market for Brand × DVD players would increase the desirability of a complementary product (i.e., Brand × TVs or display devices), and if the firm that manufactured the DVD players 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; when there are many products of many types in the market, and a firm that enables secondary trading in these goods exclusively for its customers, could potentially increase profits. However, there are some liquidity/profit margin trade-offs here, which are not immediately resolvable.

Finally, our model can be seamlessly transformed into 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.

7. 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 high 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 remarkably high corporate valuations of sites such as eBay 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 act as a proxy for quality variance in the used goods.

Finally, we will also investigate 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.

Appendix A

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 $\delta = (5 - \sqrt{17})/4 \approx 0.22$. The result follows immediately from the fact that $(1-\delta)/2$ is decreasing in δ, while $1/(3-2\delta)$ 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 following intervals.*

(A) $h \le (1-\delta)/(3-\delta)$: The profits under each of the price regimes are summarized in Table 3.

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 $1/(2+2\sqrt{\delta}) < h < 1/(2-2\sqrt{\delta})$. However, since $(1-\delta)/(3-\delta) < 1/(2+2\sqrt{\delta})$, (i) is dominant.

(B) $(1-\delta)/(3-\delta) \le h \le (1-\delta)/2$: The profits under each of the price regimes are summarized in Table 4.

(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 $h \ge (\sqrt{2-\delta} - 1)$ (this is obtained by solving for the h that equates the profits in (ii) and (i)). Also, one can easily verify that $(1-\delta)/(3-\delta) \le (\sqrt{2-\delta} - 1) \le (1-\delta)/2$ for $0 \le \delta \le 1$ (for instance, by a plot in Mathematica). Hence, (i) is better if $h \le (\sqrt{2-\delta} - 1)$, and (ii) is the dominant solution, at least up to $h = (1-\delta)/2$.

(C) $(1-\delta)/2 \le h \le 1/(3-2\delta)$: The profits under each of the price regimes are summarized in Table 5.

The proof here is trivial. (ii) represents the optimal solution to maximizing $p[(1-p/(1-\delta)) + (h-p)]$, 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) $1/(3-2\delta) \le h \le 1/2(1-\delta)$: The profits under each of the price regimes are summarized in Table 6.

Table 3

Price regime	Optimal price	Optimal profit level
(i) $p \ge h$	$p* = (1-\delta)/2$	$\pi * = (1-\delta)/4$
(ii) $h(1-\delta) \le p \le h$	$p* = h$	$\pi * = h - h^2/(1-\delta)$
(iii) $p \le h(1-\delta)$	$p* = h(1-\delta)$	$\pi * = h(1-\delta) - h^2(1-\delta)^2$

Table 4

Price regime	Optimal price	Optimal profit level
(i) $p \ge h$	$p* = (1-\delta)/2$	$\pi * = (1-\delta)/4$
(ii) $h(1-\delta) \le p \le h$	$p* = [(1+h) \times (1-\delta)]/2(2-\delta)$	$\pi * = [(1+h)^2 \times (1-\delta)]/2(2-\delta)$
(iii) $p \le h(1-\delta)$	$p* = h(1-\delta)$	$\pi * = h(1-\delta) - h^2(1-\delta)^2$

Table 5

Price regime	Optimal price	Optimal profit level
(i) $p \ge h$	$p* = h$	$\pi * = h - h^2/(1-\delta)$
(ii) $h(1-\delta) \le p \le h$	$p* = [(1+h) \times (1-\delta)]/2(2-\delta)$	$\pi * = [(1+h)^2 \times (1-\delta)]/4(2-\delta)$
(iii) $p \le h(1-\delta)$	$p* = h(1-\delta)$	$\pi * = h(1-\delta) - h^2(1-\delta)^2$

Table 6

Price regime	Optimal price	Optimal profit level
(i) $p \geq h$	$p* = h$	$\pi* = h - h^2/(1-\delta)$
(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 $h < (1-\delta)/(3-3\delta+\delta^2)$, which is less than $1/(3-2\delta)$. Hence, (ii)/(iii) (which are identical in this case) dominates in the specified region.(E) $h \geq 1/2(1-\delta)$: The profits under each of the price regimes are summarized in Table 7.

(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. *$p > (p-p_0)/(1-\delta) \Rightarrow p(1-\delta) > p - p_0 \Rightarrow -p\delta > -p_0 \Rightarrow p_0 > p\delta$ and the result follows immediately.*

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

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

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

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

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

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

The demand for the used good is $(p-p_0)/(1-\delta) - p_0/\delta$. 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 $p^* \geq (p^* - p_0)/(1-\delta)$, which reduces to $h \geq (1+\delta)/(2+\delta)$.

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 $[1-\delta(1-h)]^2/4$ for all $h \geq (1-\delta)/(2-\delta)$, there is no need to examine boundary solutions, as they are bound to be inferior. This completes the proof.

Table 7

Price regime	Optimal price	Optimal profit level
(i) $p \geq h$	$p* = h$	$\pi* = h - h^2/(1-\delta)$
(ii) $h(1-\delta) \leq p \leq h$	$p* = h(1-\delta)$	$\pi* = h(1-\delta) - h^2(1-\delta)^2$
(iii) $p \leq h \times (1-\delta)$	$p* = 1/2$	$\pi* = 1/4$

References

[1] M. Krantz, The CyberSpace Marketplace, Time, July 20, 1998.
[2] H. Greene, G. DeGeorge, A. Barrett, The Virtual Mall Gets Real, Business Week, January 26, 1998.
[3] J.B. Baty, R.M. Lee, InterShop: enhancing the vendor/customer dialectic in electronic shopping, Journal of Management Information Systems 11 (4) (1995) 9–31.
[4] R. Benjamin, R. Wigand, Electronic markets and virtual value chains on the information superhighway, Sloan Management Review 37 (1995) 62–72.
[5] R. Burke, Do you see what I see? The future of virtual shopping, Journal of the Academy of Marketing Science 25 (4) (1997) 352–360.
[6] B.H. Clark, Welcome to my parlor, Marketing Management 5 (4) (1997) 10–25.
[7] Forrester Research, Assessing the Internet's impact on your business, WWW site at http://204.179.229.10/images/sep96lsr/v103.gif, 1996.
[8] A. Gupta, D. Stahl, A. Whinston, An economic approach to network computing with priority classes, Journal of Organizational Computing and Electronic Commerce 6 (1996) 71–95.
[9] A. Gupta, D. Stahl, A. Whinston, A stochastic equilibrium model of Internet pricing, Journal of Economic Dynamics and Control 21 (5) (1997) 697–722.
[10] A. Kambil, Electronic commerce: implications of the Internet for business practice and strategy, Business Economics 30 (4) (1995) 27–33.
[11] D. Leebaert, Transaction interoperability: the key to electronic commerce, Telecommunications (Americas Edition) 30 (6) (1996) 58–62.
[12] J. Sviokla, Marketspace markets: factors for success and failure, in: C.K. Kemerer (Ed.), Information Technology and Industrial Competitiveness: How I.T. Shapes Competition, Kluwer Academic Publishers, 1997.
[13] B. Weber, Elements of market structure for online commerce, in: C.K. Kemerer (Ed.), Information Technology and Industrial Competitiveness: How I.T. Shapes Competition, Kluwer Academic Publishers, 1997.
[14] R. Maney, B. Chatham, J. Meringer, M. Wallace, Vision: The Fourth Channel, The Forrester Report, WWW site at http://204.179.229.10/reports/sep96lsr.htm, 1996.
[15] K. Umbach, The Internet: A California Policy Perspective, http://www.unlimited.net/~kumbach/internet/ch2.html, 1996.
[16] J. Alba, J. Lynch, B. Weitz, C. Janiszewski, Interactive home shopping: consumer, retailer, and manufacturer incentives to participate in electronic marketplaces, Journal of Marketing 61 (3) (1997) 38–53.

Ravi Arunkundram is a Doctoral student in the Department of Information Systems at the Leonard N. Stern School of Business, New York University. He received a MPhil in Information Systems from New York Universtiy, and a MBA (PGDIM) in Finance from the Indian Institute of Management, Bangalore. His current research studies the impact of IT on electronic markets and the role of Information Technology in knowledge intensive firms.

Arun Sundararajan is an Assistant Professor of Information Systems at the Leonard N. Stern School of Business, New York University. He recieved a PhD in Business Administration and MSc in Management Science from the University of Rochester, and a BTech in Electrical Engineering from the Indian Institute of Technology, Madras. His current research studies the role of information technology in determining the structure and scope of organizations and markets.