Pricing Information Goods: A Strategic Analysis of the Selling and On-demand Pricing Mechanisms

Sridhar Balasubramanian[1]
Associate Professor of Marketing
University of North Carolina at Chapel Hill
Kenan-Flagler Business School, CB#3490
Chapel Hill, NC 27599-3490
Email Address: Sridhar_Balasubramanian@unc.edu
Phone: (919) 962-3194 Fax: (919) 962-7186

Shantanu Bhattacharya
Associate Professor of Technology and Operations Management
INSEAD, 1 Ayer Rajah Avenue
Singapore 138676

Viswanathan Krishnan
Sheryl and Harvey White Endowed Chair in Management Leadership
Rady School of Management
Pepper Canyon Hall, Room 316
9500 Gilman Dr., MC 0093
La Jolla, CA 92093-0093

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[1] Corresponding Author

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Abstract

We analyze two pricing mechanisms for information goods – selling, where an up-front payment allows unrestricted use by the consumer, and on-demand (pay per-use) pricing where the payments are tailored to the consumer's usage patterns. We analytically model these pricing mechanisms in a market where consumers differ in terms of the frequency of information good usage and utility per-use. When a monopolist employs each mechanism independently, we demonstrate that on-demand pricing generally yields higher profits than selling, provided the transaction cost associated with the former is not too high. We then analyze a competitive scenario where one duopolist employs selling and the other employs on-demand pricing. Here, the findings from the monopoly case are reversed and selling always yields higher profits than on-demand pricing. Further, we demonstrate that as the transaction cost associated with on-demand pricing increases, surprisingly, the profits of both duopolists can increase. We then extend the models in two directions. First, we show that if a monopolist intends to introduce an upgrade to the information good at some point in the future, then on-demand pricing is preferable. In contrast, in a competitive setting, upgrades further enhance the attractiveness of selling. Second, we consider the case where competing, vertically differentiated firms can choose endogenously between the two pricing mechanisms. Here, we show that the profits to each firm derive primarily from selling, but that the firm that offers high quality adopts both pricing mechanisms and the firm that offers lower quality adopts only selling. We conclude by highlighting the implications of the analysis.

1 Introduction

Numerous products and services, including music, books, games, movies, and personal and enterprise software, are now available in purely virtual incarnations. Such "information goods" can be sold in the conventional sense, with consumers receiving the rights to unlimited usage. However, the networked environment also offers the possibility of metered transactions, where the good is paid for on a per-use basis. Advances in network technology and adaptations to product architecture have enhanced the popularity of such "on-demand pricing" (Altinkemer and Tomak 2001). In this paper, we analyze the performance of the selling and on-demand pricing mechanisms in monopoly and duopoly contexts.

Initiatives to implement on-demand pricing are already in place in a range of markets (Economist 2004). First, on-demand pricing is increasingly common in consumer markets for communication, music, gaming, and movies (Altinkemer and Bandyopadhyay 2000, Machrone 2006). For example, cellular telephone service providers often charge for electronic texting on a per-use basis. Yahoo! and Google have designed on-demand plans to distribute music and other digital content online (Dreir 2005). Microsoft and Oracle have used on-demand pricing to distribute mass market applications software (eserver.com). Next, on the enterprise side, firms such as Sun Microsystems and SAP now charge for software applications on a per-use basis (Bradbury 2005, Chen 2004). Similarly, firms now offer online conferencing facilities (e.g., Webex.com) and "off-the-shelf" customer relationship management (CRM) applications on-demand (Booker 2000, Tynan 2004). Finally, on-demand pricing has also been adopted for technical software such as Computer Aided Design (CAD) suites, where demand is linked to available projects and is therefore uncertain across time (Machine Design 2000). The annual growth of the on-demand market is in the range of 20%, compared to single-digit growth rates for outright sales (Lacy 2006). Gartner Inc. predicts that by 2008, more than 50% of software purchases from application service providers (ASPs) would be on an on-demand basis (D'Agostino 2005).

On-demand pricing is consistent with the software-as-a-service (SAAS) concept and offers some advantages over outright sale (Orr 2006). A key advantage is that consumers can pay an intermittent "pay-as-you-go" fee that is a function of usage rather than a high up-front price – this makes on-demand pricing appealing to consumers with low usage frequencies (Nicolle 2002). Despite these benefits, there is an ongoing debate about the benefits of on-demand pricing compared to selling (Bonasia 2007). We compare the two pricing mechanisms in this paper, and demonstrate how the strength of each mechanism varies as a function of consumers' usage utility and frequency of usage, and across monopoly and duopoly contexts. Specifically, our analysis advances the theory related to the pricing of information goods by addressing the following issues:

- How do the selling and on-demand pricing mechanisms perform in markets where consumers differ in terms of (a) utility per-use of the good and (b) usage frequency?
- How do conventional sellers and on-demand providers compete for a common market?
- How does the possibility of future upgrades affect the attractiveness of selling and on-demand pricing?
- When both mechanisms are available, how do competing firms that offer vertically differentiated information goods endogenously choose a pricing strategy?

Our results are briefly summarized as follows. First, consider a monopolist who chooses between selling and on-demand pricing. Here, on-demand pricing yields higher profits than selling, provided the transaction cost associated with on-demand pricing is not too high. This superiority of on-demand pricing derives from its ability to perfectly discriminate among consumers in terms of usage frequency. In contrast, in setting the up-front sale price, the seller has to accommodate consumer heterogeneity along both the usage utility and usage frequency dimensions. Consequently, selling is less efficient at extracting consumer surplus.

Second, consider a duopoly where one firm engages in selling and the other offers on-demand pricing. Here, in contrast to the monopoly case, we show that selling outperforms on-demand pricing in a variety of situations. A particularly striking finding in the duopoly case is that the profits of the competitor that adopts on-demand pricing is inverted-U shaped with respect to the transaction costs associated with on-demand pricing. We demonstrate that a higher transaction cost can reduce competitive pressure and allow the profits of both the on-demand provider and the seller to increase. However, as the transaction cost increases even further, on-demand pricing becomes less attractive from the consumer's perspective compared to outright purchase, and the profits of the on-demand provider drop.

We also present two extensions: First, we show that when a monopolist intends to offer an upgrade to an existing information good later in the adoption time horizon, then on-demand pricing is the superior choice. However, in a duopoly, the presence of an upgrade enhances the profitability of selling to a greater extent. Second, we consider the case where duopolists with vertically differentiated information goods can adopt selling, or on-demand pricing, or both mechanisms. Here, we show that when each firm is required to adopt both mechanisms, then on-demand pricing makes a minor contribution to the profits of each firm but plays an important role in enhancing the profits from selling. When each firm can freely choose the mechanism it adopts, the low quality firm adopts only selling whereas the high quality firm adopts both mechanisms. Overall, a key theme that emerges from the analysis is that the attractiveness of on-demand pricing and selling can vary significantly across market scenarios.

1.1 Extant Literature

Numerous technically-oriented papers have discussed the challenges involved in turning software into a service, including the complexity and costs of software licensing (Banker et al. 1993) and architectural modifications required to support this transition (e.g., Turner et al. 2003). Economic models related to the pricing of information goods have been introduced more recently. Bakos and Brynjolfsson (1997) analyze how pricing strategies for information goods under bundling, site licensing, and subscription pricing can vary as a function of how consumer utility is aggregated across different goods, consumers, or time. Bakos (1998) further conceptually discusses how software and other types of information content can be disaggregated and sold on-demand. Choudhary et al. (1998) model a scenario where a monopolist first rents out a beta-version of an information good at low prices to build up network externality effects, and then introduces a refined version that capitalizes on those effects. Varian (2000) studies a monopolist who employs selling and renting in a situation where offerings can be mutually shared within a consumer pool and derives conditions under which markets for sharing can lead to increased producer profits. Bhargava and Sundaresan (2004) examine how contingent auctions can be employed to price on-demand computing services, and describe how capacity commitments under demand uncertainty can influence the outcome. Elfatatry and Layzell (2004) conclude that one of the advantages of the software rental model is the ability of the consumer to negotiate with the firm to arrive at a mutually beneficial contract.

In the literature on usage-based pricing for information goods, Altman and Chu (2001) study flexible pricing schemes for network services and compare flat-rate and usage-based pricing policies. Gundepudi et al. (2001) examine how spot and forward pricing schemes differentially accommodate uncertainty in the reservation prices of consumers. Jain and Kannan (2002) examine how the variation in consumer expertise and valuation of information affects the choice of usage-based and flat-rate pricing for database access. Mackie-Mason and Varian (1995) and McKnight and Boroumand (2000) examine how a menu of pricing schemes can be constructed for network-based services. In a competitive context, Mason (2001) compares two-part (fixed subscription plus usage) and flat rate pricing (subscription) in a duopolistic setting and finds that the best response to a flat rate pricing scheme is a two-part tariff. Other issues examined in the context of pricing information goods include the dynamic pricing of online databases (West 2000), the implications of customization for competition in markets for information goods (Dewan et al. 2003), and the pricing of open source software with the dual-licensing model and the support model (Kim et al. 2006).

Services driven through technology-intensive interfaces can enhance the value of offerings and change the nature of competition in the marketplace (Nault and Dexter 1995). On balance however, much remains to be studied about how such services ultimately create a strategic advantage (Ba and Johansson 2006). Our work takes a step in this direction. To our knowledge, this paper is the first to consider the net utility derived by consumers to be a function of two different constructs: the utility derived per-use and the frequency of usage, and to examine how this construction of utility impacts the effectiveness of selling and on-demand pricing.

The base model is introduced in Section 2. In Section 3, the selling and on-demand pricing mechanisms are compared under a variety of conditions, including where they are used independently by a monopolist or in competition with each other. We present two extensions – one pertaining to upgrades in Section 4, and the other to the endogenous choice of selling and/or on-demand pricing by duopolists in Section 5. The findings are summarized and their implications are discussed in Section 6.

2 The model

2.1 Assumptions and notation

We first detail the assumptions made and notation used. Some assumptions will later be simplified to analyze the endogenous model of competition – these revised assumptions are described in Section 5.

Assumption 1 Consumers decide to purchase the information good, use it on-demand, or abstain from the market after considering the benefits that flow over a N-period horizon.

This horizon could be set, for example, by a credible pre-announcement of the launch date of an advanced version of an existing information good. We assume that consumers have a certain expected pattern of information good usage across the decision horizon.

Assumption 2 The market is heterogenous along two dimensions. Each consumer is characterized by a per-period usage frequency and a utility per-use (or usage utility).

Specifically, consumer i is characterized by the coordinate pair (θ_i,ϕ_i), where θ_i is the usage frequency with which the consumer i expects to use the information good in any period and ϕ_i captures the associated utility per-use.

Assumption 3 The usage utility ϕ is uniformly distributed between 0 and ϕ_H, and the usage frequency θ is uniformly distributed between 0 and θ_H.

This specification accommodates a wide variety of market structures and consumer behaviors. For example, if θ_H is greater than 1, then consumers can use the information good multiple times in a single period. Note that the scenario where θ is uniformly distributed over $[0, 1]$ is a special case of the proposed model – here, θ_i represents the probability of using the product in a given period. The upper limits of the uniform distributions are elastic – this will help us capture a range of market preferences.

Assumption 4 Consumers using on-demand pricing incur a transaction cost T per usage occasion.

The transaction cost reflects the disutility from the repeated administrative and transaction costs associated with on-demand pricing (Varian 2000, Cheng et al. 2003). For example, to play a music album from an online music site, the consumer has to first log into the site. The transaction cost could also capture other disutility from linking payment tightly to consumption, including the "ticking meter" effect (Train 1991). When usage experiences in the on-demand and selling mechanisms converge, the transaction cost reduces to zero.

Assumption 5 The discount factor for future utility, δ, is the same for the firm and consumers.

For tractability, we assume that we have a perfect capital market, where the firm and consumers discount profits and utilities, respectively, at the same rate.

Assumption 6 The marginal costs of production are zero.

Similar to Varian (2000), we assume that the information good can be reproduced and delivered at negligible marginal cost. Further, whereas fixed costs are relevant to entry and equilibrium market structure, they do not directly impinge on optimal pricing decisions. Therefore, we ignore fixed costs as well.

We consider a horizon of N periods. The total utility to a consumer over this horizon is obtained by multiplying the expected utility accrued per period and D, the NPV factor over N periods. The NPV factor is defined as follows:

$$D = 1 + \delta + \delta^2 + \delta^3 + ... + \delta^{N-1} = \frac{1-\delta^N}{1-\delta}$$

The notation used is summarized in Table 1.

Variable	Description	Variable	Description
θ_i	Usage frequency of consumer i	p_O	On-demand payment per-use
ϕ_i	Per-use utility to consumer i	p_S	Selling price
T	Transaction cost from on-demand usage	MS_O	On-demand market share
U_{iO}	Surplus of consumer i from on-demand	MS_S	Selling market share
U_{iS}	Surplus of consumer i from buying	Π_O	Profits from on-demand pricing
δ, D	Discount factor and NPV factor	Π_S	Profits from selling

Table 1: Notation used in paper

2.2 Model setup

We first analyze the performance of selling and on-demand pricing in a monopoly. Whereas we derive some results of interest here, the primary objective is to set a baseline for the competitive case. Consider consumer i with a per-use utility of ϕ_i and a usage frequency of θ_i. Given p_O, this consumer will find on-demand pricing feasible only when:

$$\phi_i - T \geq p_O.$$

Similarly, consumer i would find buying a feasible proposition only when:

$$\theta_i \phi_i D \geq p_S$$

The participation constraint for on-demand pricing requires that the per-use utility (net of the transaction cost) must be greater than the payment per-use p_O for on-demand pricing to be feasible for consumer i. In the participation constraint for selling, the left hand side represents the (expected) discounted utility consumer i gains from using the good through the time horizon N. This utility must be greater than the up-front purchase price for buying to be feasible. The cumulative surplus gained by consumer i under each pricing mechanism is:

$$\text{On-demand: } U_{iO}(p_O) = \theta_i(\phi_i - T - p_O)D \quad (1)$$

$$\text{Selling: } U_{iS}(p_S) = \theta_i \phi_i D - p_S \quad (2)$$

In both equations (1) and (2) above, the usage frequency parameter θ multiplies the discount factor D. Consequently, specifying heterogeneity in θ or in D yields equivalent outcomes in the model solution. Note that in computing the surplus under selling, the price p_S is directly subtracted from the consumer's utility with no discounting. This is because purchasing the good involves a cash outflow only at the outset. In contrast, under on-demand pricing, payments are made only with a usage frequency of θ_i in each period because per-use payments are perfectly coordinated with realized usage across time. Therefore, on-demand pricing tightly links payments to usage. The model captures this important insight in a transparent way.

Figure 1 displays the market shares of the on-demand and selling mechanisms, when each is independently used by the monopolist. If the monopolist only offers on-demand pricing, all consumers with $\phi_i > p_O + T$ potentially to use the information good. Accordingly, the market share is $\frac{\phi_H - (p_O + T)}{\phi_H}$. Note that the average frequency of on-demand usage in each period is $\frac{\theta_H}{2}$. Therefore, the expected profits under on-demand pricing are:

$$\Pi_O(p_O) = \frac{\phi_H - (p_O + T)}{\phi_H} \frac{\theta_H}{2} p_O D \quad (3)$$

If the firm sells the information good, all consumers with usage frequencies in the range $\theta \in [\frac{p_S}{\phi D}, \theta_H]$ derive (weakly) positive utility from their purchase. The fraction of the market purchasing the good, and the resulting profit expressions are, respectively:

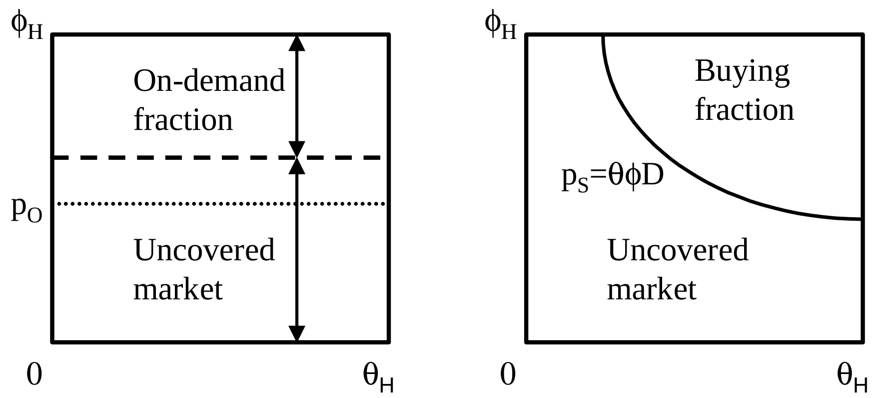

Figure 1: Market shares for on-demand pricing and selling

$$MS_S(p_S) = \frac{1}{\phi_H\theta_H}\int_{\phi=\frac{p_S}{\theta_H D}}^{\phi_H}[\theta_H - \frac{p_S}{\phi D}]d\phi = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log(\frac{p_S}{\theta_H\phi_H D})]$$
$$\Pi_S(p_S) = MS_S(p_S)p_S = \frac{p_S}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log(\frac{p_S}{\theta_H\phi_H D})] \quad (4)$$

The model provides a parsimonious and flexible representation of the selling and on-demand pricing mechanisms. The key dimensions of usage frequency and usage utility can capture a range of real-life usage patterns. For example, an independent graphics designer may adopt on-demand pricing when using a complex graphics software suite for the occasional major contract. In contrast, a large design firm may buy the software suite to service a regular stream of such jobs.

3 Selling and on-demand pricing in monopoly and duopoly contexts

3.1 Monopoly

We now derive analytical expressions for the optimal price, the optimal on-demand payment per-use, and other outcomes when the monopolist uses either of these mechanisms (see Appendix A1 for proof). The results are tabulated in Table 1.

	On-demand	**Selling**
Payment per use/Selling price	$p_O = \frac{\phi_H - T}{2}$	$p_S = 0.285\ \theta_H\ \phi_H\ D$
Market share	$MS_O = \frac{\phi_H - T}{2\phi_H}$	$MS_S = 0.358$
Profits	$\frac{1}{8}\frac{\theta_H(\phi_H - T)^2}{\phi_H}D$	$0.1018\ \theta_H\ \phi_H\ D$

Table 1: Optimal outcomes in a monopoly

Proposition 1 *If the monopolist uses only on-demand pricing or selling, the profits from on-demand pricing are higher than the profits from selling if* $T < 0.0976\phi_H$.

For a monopolist, on-demand pricing is the preferred mechanism unless transaction costs are high. The interesting insight here is that, because the per-use payment is set to maximize revenues on a period-by-period basis, the optimal per-use payment and market coverage are independent of the distribution of usage frequency and the NPV factor D. Stated differently, on-demand pricing is capable of efficient discrimination along the usage frequency dimension because a consumer pays for the good contingent on usage. However, overall profits under on-demand pricing increase linearly with the average usage frequency and with D. In contrast, the monopolist cannot discriminate efficiently based on the frequency of usage under selling. Under selling, the consumer has to make an early decision about buying the good and this decision depends on both expected usage utility and usage frequency. Selling generally yields lower profits on account of this loss of a dimension for perfect discrimination across consumers. Note that the profits under selling increase when either the average frequency of usage or the utility per-use increases. The optimal market share for the seller is 35.8%. Reducing the selling price further would decrease margin to an extent that would not be compensated for by the higher market share.

The monopoly results can be extended in two directions. First, if the monopolist jointly offers selling and on-demand pricing, only consumers with a frequency of usage that is higher than a certain critical frequency given by $\theta_c = \frac{p_S}{(p_O+T)D}$ will buy the product, whereas consumers with a lower frequency of usage will prefer on-demand pricing (see Electronic Appendix 1 for proof). Further, we find that, depending on the transaction cost T, the monopolist adjusts the role of the selling and on-demand pricing mechanisms in generating profits. The monopolist employs only on-demand pricing when T=0. As T approaches ϕ_H, the monopolist employs only selling. For intermediate levels of T, the monopolist employs both mechanisms. As expected, the share of the profits generated by on-demand pricing decreases as T increases.

Second, consider the case where the information good has some positive marginal costs (e.g., as with CDs and DVDs). Such costs decrease profits from both mechanisms, but more sharply reduce profits from selling (see Electronic Appendix 2 for proof). Intuitively, under selling there is a dedicated unit variable cost allocated to each consumer who buys the good. In contrast, the allocation of supply to demand is more finely controlled under on-demand pricing. For example, in a video store, the same DVD can be rented out to different consumers at different points of time – therefore, the variable costs can be allocated across a wider consumer base.

We have considered the case where a monopolist either sells the information good or adopts on-demand pricing – henceforth, this is referred to as the "base" case. We now examine the competitive context.

3.2 Duopoly

We assume that one firm employs selling and that the competitor employs on-demand pricing for the same information good. This allows us to focus on how the pricing mechanisms can serve as vehicles for differentiation in themselves. Note that if the firms employed the same pricing mechanism, perfect competition and zero profits would result.

Consumers select the mechanism that maximizes their utility surplus (or abstain from the market). Recall that the utility surpluses related to on-demand pricing and buying are described in eqns (1) and (2) respectively. Consumer i chooses on-demand pricing only if $U_{iO}(p_O) > U_{iS}(p_S)$. Therefore, consumers will buy only if they have a usage frequency that is higher than a certain critical frequency denoted by $\theta_c = \frac{p_S}{(p_O+T)D}$. Consumers with a lower frequency of usage than this would either use on-demand pricing or abstain from the market. Figure 2 illustrates the resulting

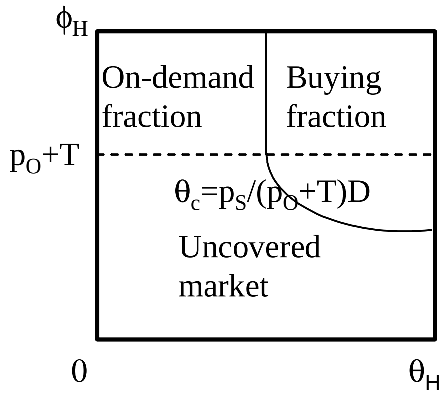

Figure 2: Market shares for on-demand pricing and selling in duopoly

market shares of the pricing mechanisms.

From Figure 2, the expressions for the market shares of the selling and on-demand mechanisms are:

$$MS_S(p_S, p_O) = \frac{1}{\phi_H\theta_H}\left[\int_{\frac{p_S}{\phi_H D}}^{\theta_H} (\phi_H - \frac{p_S}{\theta D})d\theta - \int_{\frac{p_S}{\phi_H D}}^{\frac{p_S}{(p_O+T)D}} (\phi_H - \frac{p_S}{\theta D})d\theta\right]$$

$$= \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S\phi_H}{(p_O+T)D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H(p_O+T)D}\}] \quad (5)$$

$$MS_O(p_S, p_O) = \frac{1}{\phi_H\theta_H}[\phi_H - (p_O+T)]\frac{p_S}{(p_O+T)D} \quad (6)$$

The competing firms maximize their individual profits:

$$\text{Seller: } \underset{p_S}{Max}\ \Pi_S(p_S, p_O) = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S\phi_H}{(p_O+T)D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H(p_O+T)D}\}]p_S \quad (7)$$

$$\text{On-demand: } \underset{p_O}{Max}\ \Pi_O(p_S, p_O) = \frac{1}{2\phi_H\theta_H}[\phi_H - (p_O+T)][\frac{p_S}{(p_O+T)D}]^2 p_O D \quad (8)$$

In the corresponding Nash equilibrium, the optimal per-use payment under on-demand pricing is $p_O = \frac{T(\phi_H - T)}{\phi_H + T}$, and the optimal selling price satisfies the following implicit equation: $\theta_H\phi_H - \frac{2p_S\phi_H}{(p_O+T)D} + \frac{2p_S}{D}\log[\frac{p_S}{(p_O+T)\theta_H D}] + \frac{p_S}{D} = 0$ (Proofs are in Electronic Appendix 3). Propositions 2 and 3 summarize our findings (Proofs are in Electronic Appendices 4 and 5, respectively).

Proposition 2 *The optimal per-use payment and selling price in the duopoly are lower than the corresponding optimal per-use payment and selling price when a monopolist uses the mech-*

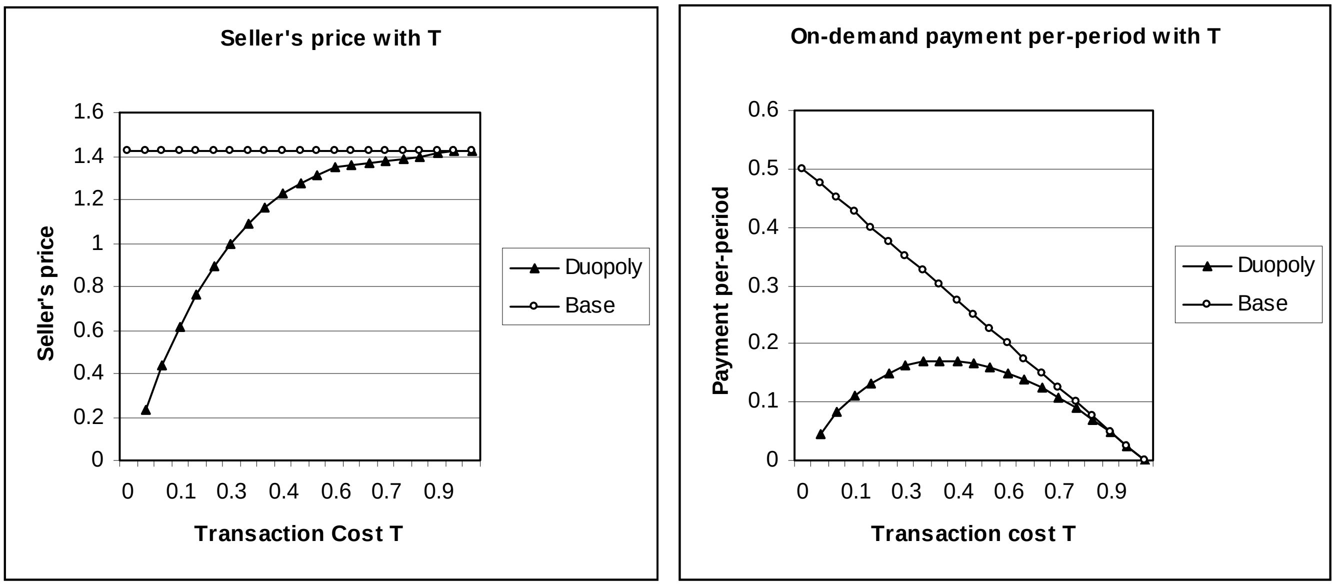

Figure 3: Selling price and on-demand payment per-period in base case and duopoly

anisms independently. However, the optimal payment per-period payment of the on-demand provider in the competitive case first increases, and then decreases with transaction cost (T).

Proposition 2 captures the price suppressing effect of competition. However, in addition, there are some subtle and interesting forces at work here (see Figures 3, 4 and 5 for a comparison of prices, profits, and market shares across the base case and the duopoly; for illustrative purposes, these graphs are plotted assuming $\theta_H = \phi_H = 1$, $D = 5$). Specifically, in the competitive scenario, one would expect that per-use payment and profits of the firm that adopts on-demand pricing should be high when transaction costs associated with that mechanism are low. Surprisingly though, when the transaction costs are very low, both the per-use payment and the profits of the firm that offers on-demand pricing are low. In fact, the per-use payment and profits initially increase as the transaction costs increase (leading to the increasing part of the inverted U-shaped profit function). The intuition is that, when transaction costs are very low, the firm that adopts selling has to lower prices sharply to attract consumers – this lowers profits across the board. As the transaction costs increase, the competitive pressure in the market decreases and the profits of both competitors increase. However,

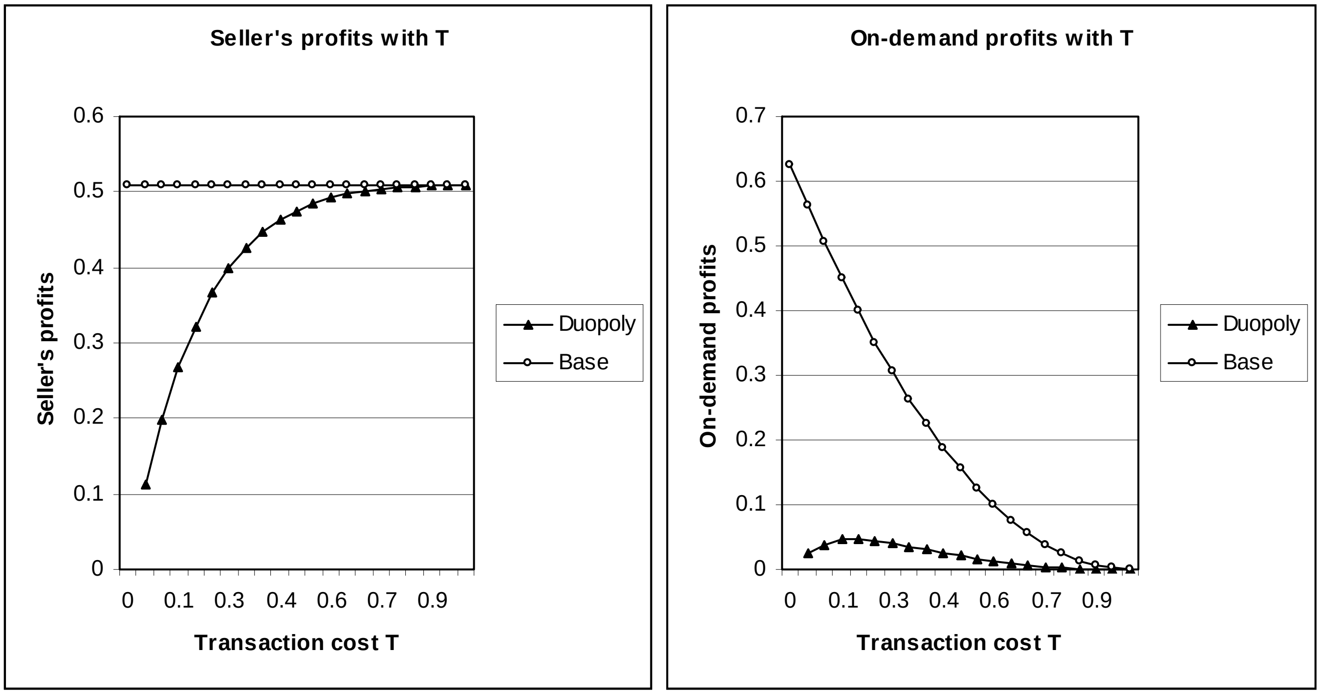

Figure 4: Profits from selling and on-demand pricing in base case and duopoly

as the transaction cost associated with on-demand pricing continues to increase further, the profits of the firm that offers on-demand pricing begin to decrease (leading to the decreasing part of the inverted U-shaped profit function) because that mechanism is ultimately less attractive from the consumer's viewpoint.

Proposition 3 *In a duopoly, the profits of the seller are always higher than those of the firm that offers on-demand pricing.*

Proposition 3 is interesting in several respects. Recall that when transaction costs associated with on-demand pricing are low, a monopolist who has to choose between selling and on-demand pricing will prefer the latter. However, from Proposition 3, we see that in a competitive situation, the seller's profits are higher even for low transaction costs. To obtain the intuition, note that when the firm that offers on-demand pricing increases its per-use payment, it loses substantial revenues because all consumers with a utility per-use that is lower than the per-use payment drop out, taking the entire temporal stream of revenue associated with them. In contrast, under selling, the frequency of usage contributes to the total projected utility of the consumer and performs the role of tying the consumer to the selling mechanism. Further, the consumers who generate the most profits under on-demand pricing in a monopoly – those with a high frequency of usage – are precisely those who are captured by the seller in a duopoly (see the division of market shares in Figure 2). The ability of on-demand pricing to allow consumers to flexibly choose to use the information good contingent on need is a strength in the monopoly context. The reverse side of the coin, though, is the inability of on-demand pricing to lock in consumers at an early stage. This inability, which has no adverse consequences in a monopoly, constitutes the weakness of on-demand pricing in a duopoly. In contrast, when competing against the on-demand mechanism, selling captures the "best" consumers – those whose utility per-use and usage frequency are both relatively high.

Propositions 1 and 3 jointly offer some interesting insights into the choice of the mechanism to go to market. If a firm wants to adopt one of the two mechanisms and transaction costs are relatively low, it will choose on-demand pricing if it does not expect competition. However, if the firm expects competition, it will choose to sell the information good instead. This result is analogous to a "defensive" positioning strategy, where a firm chooses to accept lower profits which are more robust in the face of competition, rather than pursue higher profits that are susceptible to significant erosion on competitive entry.

We next examine the case where the information good can be upgraded at some point in the future.

4 Selling and on-demand pricing with upgrades

We now consider the impact of a future upgrade to the information good in a monopoly (where the monopolist can choose either selling or on-demand pricing) and in a duopoly (where one firm chooses selling and the other chooses on-demand pricing). We separately consider the cases where consumers are myopic or strategic. Myopic consumers have no foresight regarding the introduction

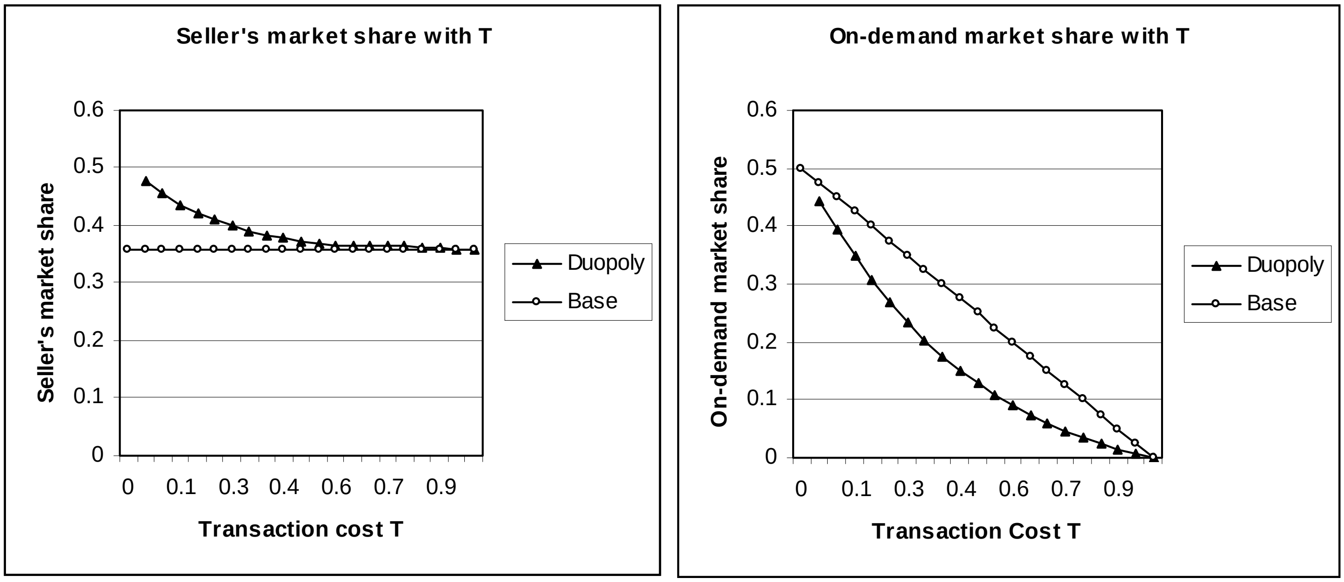

Figure 5: Selling and on-demand market shares in base case and duopoly

of the upgrade. Therefore, the upgrade will introduce no competitive effect because these consumers will initially choose between selling and on-demand pricing solely based on the base information good. Later on, these consumers will simply decide whether or not to purchase the upgrade. In contrast, strategic consumers expect the upgrade to be introduced and will evaluate the base good and the upgrade as a bundle. Therefore, the upgrade will exert a competitive effect even at the time of initial choice.

Let the upgrade be introduced in period k, where $k < N$. The consumer obtains a higher per-use utility of $a\phi$ $(a > 1)$ from the upgrade. Therefore, post-upgrade, the per-use utility is uniformly distributed between 0 and $a\phi_H$. Let D_{k-1} denote the NPV factor over $k-1$ periods ($D_{k-1} = \frac{1-\delta^{k-1}}{1-\delta}$), and D denote the NPV factor over N periods (as before).

4.1 Upgrades in a monopoly

First, consider a monopolist who adopts on-demand pricing. Here, whether consumers are myopic or strategic makes no difference because all payments are made on a per-use basis. Therefore, the strategic consumer's knowledge about the forthcoming upgrade does not impact the pricing decision. The profits from the base good and the upgrade are denoted by, respectively:

$$\Pi_{O1}(p_{O1}) = \frac{\phi_H-(p_{O1}+T)}{\phi_H}\frac{\theta_H}{2}p_{O1}D_{k-1}\,;\Pi_{O2}(p_{O2}) = \frac{a\phi_H-(p_{O2}+T)}{a\phi_H}\frac{\theta_H}{2}p_{O2}(D-D_{k-1}) \tag{9}$$

The total profits are $\Pi_O = \Pi_{O1}+\Pi_{O2}$ (from eqn 9). Because the upgrade delivers a higher utility, the firm charges a higher per-use payment after the upgrade has been introduced (the optimal per-period payments are derived in the Electronic Appendix 6).

Second, consider the case where the monopolist employs selling in a market where consumers are myopic. Here, the base good will be priced exactly as in the monopoly without upgrades and profits are identical to that case as well (see eqn. (4) for the profit expression). Consumers only pay for the additional utility derived from the upgrade. If the upgrade is introduced in period k, this additional surplus is: $(a-1)\phi\theta(D-D_{k-1})-\delta^{k-1}p_U$. This additional surplus is set to zero to find the fraction of consumers who will buy the upgrade. This condition is structurally identical to that which applies when consumers decide whether or not to buy the base good. Therefore, all consumers who purchase the base good will also choose to upgrade. The profits from the upgrade alone (Π_{S2}) are denoted by:

$$\Pi_{S2}(p_U) = \delta^{k-1}p_U MS_{S2} = \frac{\delta^{k-1}p_U}{\phi_H\theta_H}[\theta_H\phi_H - \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})} + \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})}log(\frac{\delta^{k-1}p_U}{(a-1)\theta_H\phi_H(D-D_{k-1})})] \tag{10}$$

When consumers are myopic, the monopolist first solves for the optimal price of the base good (see eqn. 4). Given the optimal price p_{S1} for the base good, the firm then solves for the optimal upgrade price that maximizes the profits denoted in eqn. (10) above. In doing so, the monopolist must ensure that $MS_{S2} \leq MS_{S1}$,so that only a subset of consumers who purchased the base good will purchase the upgrade. This condition is satisfied because all consumers who purchased the base good will also buy the upgrade.

Third, consider the case where the monopolist sells the information good to strategic consumers who anticipate the upgrade. Here, a consumer's decision to adopt the base good could depend on the expected price of the upgrade as well. Therefore, the monopolist will jointly decide on the two prices to maximize total profits:

$$\underset{p_{S1},p_U}{Max}\ \Pi_{S1}(p_{S1},p_U) = \frac{p_S+\delta^{k-1}p_U}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S+\delta^{k-1}p_U}{\widetilde{D}} + \frac{p_S+\delta^{k-1}p_U}{\widetilde{D}} log(\frac{p_S+\delta^{k-1}p_U}{\theta_H\phi_H\widetilde{D}})] \quad (11)$$

where $\widetilde{D} = D + (a-1)(D - D_{k-1})$.

The findings are summarized in the following proposition (see Electronic Appendix 6 for derivations and proofs):

Proposition 4a *If a monopolist offers the information good with a future upgrade, then the cut-off transaction cost below which on-demand pricing yields higher profits than selling is higher compared to the case where the firm only offers the basic information good. This holds true for both myopic and strategic consumers. Therefore, the presence of the future upgrade increases the relative attractiveness of on-demand pricing compared to selling.*

In a monopoly, the cut-off transaction cost below which on-demand pricing is superior to selling is $T_C = 0.0976\phi_H$ (see Proposition 1). According to Proposition 4a, the cut-off transaction cost is higher than $0.0976\phi_H$ if the monopolist offers a future upgrade. The intuition is as follows. Under on-demand pricing, the per-use payment can easily be shifted upward to recapture a substantial fraction of the surplus generated by the increase in per-use utility delivered by the upgrade. In contrast, the selling mechanism cannot separately deal with this increase in per-use utility because here consumers consider the total utility derived from a combination of usage utility and usage frequency. Therefore, selling is less efficient at recapturing the surplus generated by the upgrade.

4.2 Upgrades in a duopoly

First, consider the case where consumers are strategic. We assume that one firm sells the information good and the competitor adopts on-demand pricing. Strategic consumers compute and compare the total utility surplus derived from using the good (and its forthcoming upgrade) on-demand and from buying them. These utility surpluses are respectively denoted by:

$$U_{iO}(p_{O1}, p_{O2}) = \theta_i[(\phi_i - T - p_{O1})D_{k-1} + (a\phi_i - T - p_{O2})(D - D_{k-1})] \quad (12)$$

$$U_{iS}(p_S, p_U) = \theta_i\phi_i[D + (a-1)(D - D_{k-1})] - (p_S + \delta^{k-1}p_U) \quad (13)$$

Here, p_{O2} is the per-use payment for the upgraded information good, and p_U is the (selling) price of the upgrade. Consumer i will prefer to purchase the information good only if $U_{iS}(p_S, p_U) > U_{iO}(p_{O1}, p_{O2})$. That is, consumers will adopt on-demand pricing only if their expected frequency of usage is lower than the critical frequency denoted by:

$$\theta_c = \frac{p_S + \delta^{k-1} p_U}{(p_{O1}+T)D_{k-1} + (p_{O2}+T)(D - D_{k-1})} \tag{14}$$

To find the threshold per-use utility above which consumers are willing to use the product on an on-demand basis, we set $U_{iO}(p_{O1}, p_{O2}) = 0$.This yields:

$$\phi_c = \frac{(p_{O1}+T)D_{k-1} + (p_{O2}+T)(D - D_{k-1})}{D_{k-1} + a(D - D_{k-1})} \tag{15}$$

All consumers with usage frequencies below θ_c and per-use utility above ϕ_c (from eqns (14) and (15) above) use the good on-demand. Using these cut-off thresholds, the market shares and profit expressions corresponding to the selling and on-demand pricing mechanisms can be derived. Using standard maximization techniques, the optimal prices and on-demand payments for the base and upgraded good can be derived (see Electronic Appendix 7).

Second, consider the case where consumers are myopic. Here, the profits of the competitors are the sums of the profits from the base good and the upgrade – but as in the monopoly case, the difference here is that each firm maximizes the profits from these two sources sequentially rather than jointly. Because consumers do not expect the upgrade, competition in the context of the base good is identical to competition in the case without the upgrade. However, once the consumers are locked into either mechanism for the base good, the competitors simply price the upgrade when it is introduced as if they were monopolists with captive customers. The following proposition describes how the upgrades affects the attractiveness of the two pricing mechanisms (the proof is provided in the Electronic Appendix 7):

Proposition 4b *Consider a duopoly where one firm sells the information good and the other adopts on-demand pricing. If the competitors offer a future upgrade, the profits of firm that sells the good increases to a greater extent than those of the firm that adopts on-demand pricing. This holds true for both myopic and strategic consumers. Therefore, the presence of the future* *upgrade increases the relative attractiveness of selling compared to on-demand pricing in a duopoly.*

The intuition is as follows. In a duopoly, if the firm that offers on-demand pricing increases its per-use payment for the base information good and the upgrade, it loses substantial revenues. This is because all consumers with a utility per-use that is lower than the revised per-use payment drop out, taking the entire temporal stream of revenue associated with them. In contrast, under selling, the frequency of usage contributes to the total projected utility of the consumer and performs the role of tying the consumer more tightly to the selling mechanism. Therefore, even with the upgrade, selling can address the market more efficiently in a competitive setting by jointly using the utility per-use and the usage frequency dimensions.

The findings from this section can be summarized as follows. When there is no upgrade, the attractiveness of on-demand pricing and selling reverse across a monopoly and a duopoly. On-demand pricing is more profitable in a monopoly provided the transaction cost associated with it is not too high. In contrast, selling is more profitable in a duopoly. The presence of the upgrade strengthens the attractiveness of the favored mechanism in the monopoly and duopoly contexts.

5 Duopoly with endogenous choice of pricing mechanisms

We now consider the case where two competing firms can each offer both the selling and on-demand pricing mechanisms. For analytical tractability, we assume that the frequency of usage (θ_i) is uniformly distributed between 0 and 1 ($\theta_H = 1$). Further, we assume that there are two segments of consumers: those in segment 1 have a per-use utility of 1, whereas those in segment 2 have a lower per-use utility of $\phi(\phi < 1)$.[2] To maintain consistency with the earlier analysis, we assume that each segment comprises the same number of consumers. The firms are vertically differentiated – we

[2] We prove in the Electronic Appendix that both firms cannot provide on-demand pricing to consumers with the same per period utility at a given level of frequency of usage - there is no equilibrium in this case. Therefore, this assumption does not detract from the key insights of the model.

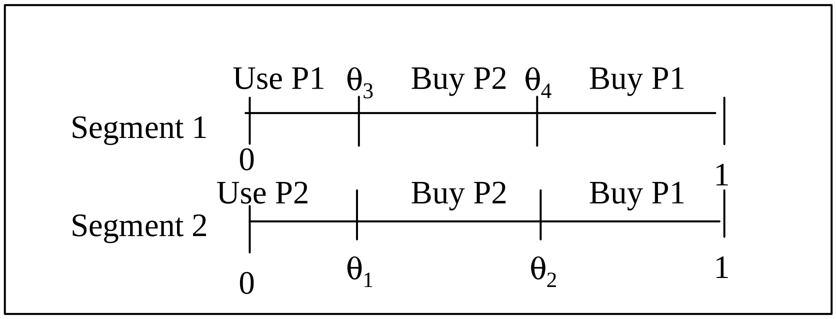

Figure 6: Market shares for selling and on-demand pricing under endogenous competition

assume that firm 1's offering is superior to that of firm 2. Specifically, the good offered by firm 2 has a quality level of λ times that of good 1 ($\lambda < 1$).[3]. Accordingly, consumer i in segment 1 derives the following utility surpluses from adopting on-demand pricing and from buying the information good from firms 1 and 2 respectively:

$$\text{On-demand: } U_1(p_{O1}) = \theta_i(1 - T - p_{O1})D; U_1(p_{O2}) = \theta_i(\lambda - T - p_{O2})D$$
$$\text{Buying: } U_1(p_{S1}) = \theta_i D - p_{S1}; U_1(p_{S2}) = \theta_i \lambda D - p_{S2}$$

Correspondingly, consumer i in segment 2 derives the following utility surpluses:

$$\text{On-demand: } U_2(p_{O1}) = \theta_i(\phi - T - p_{O1})D; U_2(p_{O2}) = \theta_i(\lambda\phi - T - p_{O2})D$$
$$\text{Buying: } U_2(p_{S1}) = \theta_i \phi D - p_{S1}; U_2(p_{S2}) = \theta_i \lambda\phi D - p_{S2}$$

We assume at the outset that, on account of established precedence or other reasons, each firm is "forced" to employ both the pricing mechanisms. Accordingly, the market sub-segments that adopt on-demand pricing and buy each good are described in Figure 6 (see Electronic Appendix 8 for proofs).

As demonstrated in Figure 6, consumers with a lower frequency of usage than the critical frequency will prefer on-demand pricing. In addition, only consumers with a non-negative utility surplus from either buying or adopting on-demand pricing will participate in the market. However, each

[3]If both IIOs have the same per-period utility, there is no equilibrium possible.

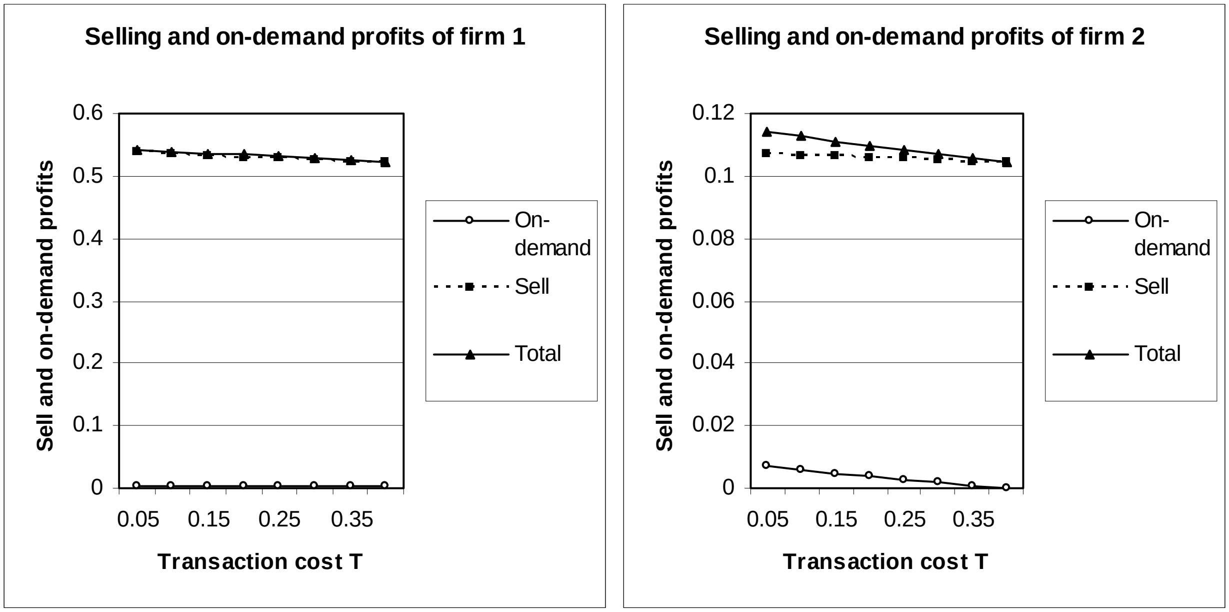

Figure 7: Profits from selling and on-demand pricing under endogenous competition

segment has a homogenous utility per-use across consumers. Therefore, the per-use payments are set so that both segments participate in the 0n-demand market (this is the case provided $\lambda\phi > T$). The expressions for the profits of firm 1 and firm 2 are, respectively:

$$\Pi_1(p_{O1}, p_{S1}) = \underset{p_{O1},p_{S1}}{Max}\ \frac{1}{2}\left[\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}\right]^2 p_{O1}D + \left[1-\frac{p_{S1}-p_{S2}}{(1-\lambda)D}+1-\frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}\right]p_{S1} \quad (16)$$

$$\Pi_2(p_{O2}, p_{S2}) = \underset{p_{O2},p_{S2}}{Max}\ \frac{1}{2}\left[\frac{p_{S2}}{(p_{O2}+T)D}\right]^2 p_{O2}D + \left[\frac{p_{S1}-p_{S2}}{(1-\lambda)D}-\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}+\frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}-\frac{p_{S2}}{(p_{O2}+T)D}\right]p_{S2} \quad (17)$$

We compute the Nash equilibrium to find the optimal per-use payments and selling prices of the duopolists from eqns (16) and (17). The corresponding equilibrium profits of the two firms from each mechanisms are described in Figure 7 (for expository purposes, the following values have been used: $\lambda = 0.8, \phi = 0.5, D = 5$).

The key findings are captured in the following result (see Electronic Appendix 8 for proof):

Result 1 *If each firm employs both selling and on-demand pricing, then each firm sets the per-use payment so that the utility from the segment it serves with this mechanism is completely extracted. That is, firms 1 and 2 serve segments 1 and 2 and charge per-use payments of* $1-T$

and $\lambda\phi - T$ respectively. Both firms 1 and 2 have a higher contribution to their profits from selling than from on-demand pricing.

The market shares of the firms are as described in Figure 6. Note that, in equilibrium, selling dominates on-demand pricing in terms of delivered profits. This is consistent with the findings from the earlier competitive analysis where a seller competed with an on-demand provider. When the firms use selling and on-demand pricing together, we find that both firms charge high per-use payments in equilibrium. In fact, firm 1 and firm 2 extract all the surplus from consumers in segments 1 and 2 who adopt on-demand pricing by setting the per-use payment at $1-T$ and $\lambda\phi-T$ respectively. This is surprising because it appears at first sight that the firms could do better by decreasing per-use payments. Specifically, in Figure 6, note that the consumers in segment 1 who buy from firm 2 are located between those who use the information good from firm 1 on-demand, and those who buy the good from firm 1. Therefore, firm 1 could ostensibly compete more strongly with firm 2 by lowering its per-use payment. This would move threshold θ_3 to the right, capturing more of the consumers in segment 1 who buy firm 2's product. Contrary to this reasoning, firm 1 chooses a high per-use payment. The intuition is that high on-demand prices help prop up the selling prices of both firms. When firm 1 maintains a high on-demand per-use payment, this encourages firm 2 to increase its selling price as well. This, in turn, increases the selling price charged by firm 1 which competes with firm 2 at boundary θ_4. To summarize, firm 1 ameliorates competition at boundary θ_3 with the objective of simultaneously ameliorating competition at boundary θ_4. We term this the "competitive straddle" effect.

Next, consider the case where each firm makes an unconstrained choice of pricing mechanisms. Here, the key finding is as follows:

Result 2 *If each firm can choose whether or not to employ selling and/or on-demand pricing, then firm 1 employs both selling and on-demand pricing whereas firm 2 employs solely selling. The profits to firm 1 from selling are higher than those from on-demand pricing.*

We demonstrate that the profits of both competitors are higher if firm 2 discards on-demand pricing and employs solely selling (see Electronic Appendix 8 for proof). The intuition partially derives from the fact that firm 2 has to balance the profits from on-demand pricing and selling because the market shares of these mechanisms are adjacent to each other in segment 2 (see Figure 6). On-demand pricing attracts consumers with a low frequency of usage. Consequently, on-demand pricing does not necessarily generate substantial profits for firm 2 itself, and can simultaneously lower the potential profits that would otherwise accrue to the selling mechanism in segment 2. In addition, an increase in the selling price of firm 2 moderates competition in segment 1 and increases the profits it derives from that segment. Therefore, on balance, firm 2 prefers to use only the selling mechanism. To summarize, firm 2 discards one pricing mechanism and accepts marginally lower profits from one segment but simultaneously reduces the competitive intensity and increases the profits it derives from the other segment. We term this the “cross-segment balancing” effect.

Overall, our findings in the endogenous competition case highlight the importance of thinking about how the on-demand pricing and selling mechanisms can work in cooperation with each other to enhance profits, and competitively against each other to reduce profits. The optimal go-to-market strategy should balance these forces across segments with the objective of maximizing firm-level profits.

6 Conclusion

We analyzed two pricing mechanisms for information goods – selling, where an up-front payment bestows unrestricted usage rights to the consumer, and on-demand pricing, where payments are closely tailored to the consumer’s usage patterns. Consumer utility was modeled as a function of both the frequency of usage and the utility per-use of the good. This contrasts with the traditional consideration of utility as a bundled variable which incorporates the effects of both these components. This deconstruction of utility yielded new insights into the performance of selling and on-demand pricing in a variety of market contexts.

To set a baseline for the analysis, we first considered a monopolist who could either adopt on-demand pricing or sell the good. Here, we first showed that when transaction costs associated with on-demand pricing are zero, profits from on-demand pricing are higher than those from selling irrespective of the configuration of the market. Intuitively, on-demand pricing achieves perfect discrimination in terms of usage frequency by allowing consumers to use the information good only when it is needed. Selling is hard pressed to counter this ability. Therefore, when using only one pricing mechanism, the monopolist prefers on-demand pricing when transaction costs are low, and selling if transaction costs are high. We then showed that the presence of a positive unit marginal cost – which applies primarily to information goods with some material content such as CDs and DVDs – lowers absolute profits from both pricing mechanisms but hurts selling more than on-demand pricing. This is because, under selling, each consumer has to be allocated one unit of the good. In contrast, under on-demand pricing, a smaller quantity of goods can satisfy demand (as is the case with DVD renters such as Blockbuster, Inc.).

Our key contributions pertain to the competitive context. We first examined competition in a duopoly where one firm sold the information good and the other offered on-demand pricing. Here, in contrast to the monopoly case, the seller's profits generally dominated the on-demand provider's profits. A counterintuitive finding was that the profits of both competitors were low when the transaction cost associated with on-demand pricing was low, and both profits initially increased as the transaction cost increased. The intuition was traced back to the role of the transaction cost in moderating the level of competition in the market. A higher transaction cost for on-demand pricing reduced the competitive pressure in the market. Consequently, both the selling price and the per-use payment increased, yielding higher profits for both competitors.

These insights can be summarized as follows. Whereas on-demand pricing yields higher profits than selling for low transaction costs when each mechanism is used alone by a monopolist, the seller has a competitive advantage in a duopoly. The key managerial implication is that a monopolist who wants to employ just one pricing mechanism is better off with on-demand pricing provided the associated transaction costs are not too high. In contrast, a monopolist who expects future competition is better off pursuing a "defensive" positioning strategy by choosing instead to sell the information good.

Extending the analysis further, we showed that when the monopolist expected to introduce a future upgrade, the attractiveness of on-demand pricing increased. Under on-demand pricing, the additional benefits from the upgrade could be smoothly transferred to the consumers and the post-upgrade per-period payments could be increased. On the other hand, the selling mechanism struggled with simultaneously balancing the usage utility and usage frequency dimensions towards extracting consumer surplus. The reverse held in a competitive scenario. Selling generally yielded higher profits that on-demand pricing under competition, and this relative profitability of selling was strengthened in the presence of the upgrade.

Finally, we analyzed the case where each duopolist could choose to sell the information good, employ on-demand pricing, or adopt both mechanisms. When the duopolists were compelled to adopt both mechanisms, the on-demand payments were set at the per-use reservation utilities of the two segments. The on-demand mechanism's direct contribution to profits was weak compared to the selling mechanism – instead, the high on-demand payments played a role in propping up the selling prices and increasing profits from selling. We further demonstrated that when the duopolists could freely choose to adopt either or both of the pricing mechanisms, the firm offering the inferior information good dispensed with on-demand pricing and adopted only selling, whereas the firm offering the superior product adopted both mechanisms. In the absence of on-demand pricing by the firm offering the inferior product, the competitiveness of the market was lowered and the equilibrium profits of each competitor increased.

Our analysis has implications for both researchers and managers. For researchers, our analysis opens up new perspectives related to pricing and market segmentation in the context of information goods. Our initiative to decompose consumer utility into the usage utility and usage frequency components appears to be a simple step, but as evidenced in the paper, it opens up a wealth of issues for analysis and delivers a range of counterintuitive insights.

For managers, our findings provide insights into how they can analyze their markets along the dimensions of usage utility and usage frequency, possibly segment the market into consumer groups along these dimensions, and then consider offering either a single pricing mechanism, or a menu of pricing mechanisms to maximize profits. In addition, our analysis provides insights into how these mechanisms can be managed in a competitive context. From the perspective of both researchers and managers, an interesting finding in the competitive context is that higher transaction costs associated with on-demand pricing can reduce competition and enhance profits of both the seller and the on-demand provider.

Our analysis has the following limitations that can be addressed by future research. First, we did not consider the possibility of price discrimination. The ability to further enhance profits by offering usage frequency-based discounts and other price discrimination mechanisms, can be analyzed in both the monopoly and competitive contexts. Second, we assumed that the frequency of usage and the utility per-use were distributed uniformly across consumers. Future work could relax this assumption and verify the robustness of our results to other specifications. Third, for the purposes of tractability, we have primarily focused on the case where consumers are differentiated in terms of usage utility and usage frequency. Future work could incorporate the notion of horizontal differentiation where consumers have varying preferences for the offerings. This is an emerging area of research and much remains to be done. We hope our work catalyzes further interest and work in the area.

References

Altinkemer, K. and S. Bandyopadhyay. 2000. Bundling and distribution of digitized music over the Internet. *Journal of Organizational Computing and Electronic Commerce*, 10, 209-224.

Altinkemer, K. and K. Tomak. 2001. A distributed allocation mechanism for network resources using software agents. *Information Technology and Management*, 2, 165-173.

Altman, J. and K. Chu. 2001. How to charge for network services – Flat-Rate or Usage-Based. *Computer Networks*, 36, 519-531.

Ba, S. and W.C. Johansson. 2006. An exploratory study of the impact of e-service process on online customer satisfaction. *Production and Operations Management*. In press.

Bakos, Y. 1998. The emerging role of electronic marketplaces on the Internet. *Communications of the ACM*, August, 41, 35-42.

Bakos, Y. and E. Brynjolfsson. 1997. Aggregation and disaggregation of information goods: Implications for bundling, site licensing and micropayment systems. *Conference on Internet Publishing and Beyond: The Economics of Digital Information and Intellectual Property*, Kennedy School of Government, Harvard University, Cambridge, Massachusetts, June.

Banker, R.D., S.M. Datar, C.F. Kemerer and D. Zweig. 1993. Software complexity and maintenance costs. *Communications of the ACM*, November, 36, 81-94.

Bhargava, H.K. and S. Sundaresan. 2004. Computing as utility: Managing availability, commitment and pricing through contingent bid auctions. *Journal of Management Information Systems*, Fall, 21, 201-227.

Bonasia, J. 2007. Lawson wary of hype in on-demand software. *Investors Business Daily*, Thursday, August 9.

Booker, E. 2000. ABCs of ASPs. *B to B*, 85, 29-30.

Bradbury, D. 2005. Financing the future. *Computer Weekly*, February 18, 22-23.

Chen, J. 2004. A new model of customer support and service at SAP. *INSEAD Project Report*.

Cheng, H.K., H. Demirkan and G.J. Koehler. 2003. Price and capacity competition of application services duopoly. *Information Systems and E-Business Management*, 1, 305-329.

Choudhary, V., K. Tomak and A. Chaturvedi. 1998. Economic benefits of renting software. *Journal of Organizational Computing and Electronic Commerce*, 8(4), 277-305.

D'Agostino, D. 2005. Rent or buy? *CIO Insight, Technology*, May, 75-78.

Dewan, R., B. Jing and A. Seidmann. 2003. Product customization and price competition on the Internet. *Management Science*, 49, 1055-1070.

Dreir, T. 2005. Yahoo! gets music right on its first try. *PC Magazine*, 24, 37-37.

Elfatatry, A. and P. Layzell. Negotiating in service-oriented environments. *Communications of the ACM*, 47, 103-108.

Gundepudi, N. Rudi and A. Seidmann. 2001. Forward versus spot buying of information goods. *Journal of Management Information Systems*, 18, 107-131.

Jain, S. and P. Kannan. 2002. Pricing of information products on online servers: Issues, models and analysis. *Management Science*, 48, 1123-1142.

Kim, B.C., P. Chen and T. Mukhopadhyay. 2006. Pricing Open Source Software. *Working Paper, Tepper School of Business, Carnegie-Mellon University.*

Lacy, S. 2006. The on-demand software scrum. *Business Week Online*, September 8, 21-25.

Machine Design. 2000. Renting CAD over the Internet. *Machine Design*, 72, 70-73.

Machrone, B. 2006. What's in your wallet? *PC Magazine*, June 6, 68-69.

Mackie-Mason, J. and H.R. Varian. 1995. Pricing the Internet. *Public Access to the Internet, ed. B.K. Keller, MIT Press, Cambridge, MA.*

Mason, R. 2001. Flat rate versus usage pricing under congestion. Manuscript.

McKnight, L. and J. Boroumand. 2000. Pricing Internet services: After flat rate. *Telecommunications Policy*, 24, 565-590.

Nault, B. R. and A. S. Dexter. 1995. Added value and pricing with information technology. *MIS Quarterly*, 19 (4), 449-463.

Nicolle, L. 2002. At your service. *Enterprise*, April/May 17-18.

Orr, B. 2006. SAAS just may be the end of software as we know it. ABA Banking Journal, August, 98, 51-52.

Train, K. 1991. Optimal regulation. *MIT Press*, Cambridge, MA.

Turner, M. and D. Budgen. 2003. Turning software into a service. *Computer*, October, 36, 38-44.

Tynan, D. 2004. CRM: Buy or rent? *Sales and Marketing Management*, 156, 41-45.

Varian, H. R. 2000. Buying, sharing and renting information goods. *The Journal of Industrial*

Economics, XLVIII 4, 473-488..

West, L. 2000. Private markets for public good: Pricing strategies of online database vendors. *Journal of Management Information Systems*, 17, 59-85.

APPENDIX

APPENDIX A1: **Proof of Proposition 1**:

If the firm charges a per-use payment of p_O, all consumers with $\phi_i \geq p_O + T$ use the information good. The market fraction using the good is, therefore: $\frac{\phi_H - (p_O+T)}{\phi_H}$. The average frequency of using the good for consumers in this fraction in any given period is $\frac{\theta_H}{2}$. The expected profits for the firm are:

$$\Pi_O = \frac{\phi_H - (p_O+T)}{\phi_H}\frac{\theta_H}{2}p_O D$$

The first order condition (FOC, henceforth) with respect to p_O yields $p_O = \frac{\phi_H - T}{2}$. The second order condition (SOC, henceforth) for Π_O to be concave can easily be seen to be satisfied because Π_O is quadratic in p_O with a negative sign on the square term (the second derivative of Π_O with respect to p_O is -1). Substituting the optimal value for p_O in the expression for the market fraction and profits yields the results in the proposition.

In the pure selling case, if the firm charges a selling price of p_S, then in Figure 2, at any given usage utility ϕ,consumers with usage probability in the range $\theta \in [\frac{p_S}{\phi D}, \theta_H]$ derive (weakly) positive utility from the purchase. From Figure 1, the market fraction purchasing and the selling profits, respectively, are denoted by:

$$MS_S = \frac{1}{\phi_H\theta_H}\int_{\frac{p_S}{\phi_H D}}^{\theta_H}[\phi_H - \frac{p_S}{\theta D}]d\theta = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H\phi_H D}\}]$$
$$\Pi_S = \frac{p_S}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H\phi_H D}\}]$$

The FOC with respect to p_S yields $\frac{2p_S}{\theta_H\phi_H D}log\{\frac{p_S}{\theta_H\phi_H D}\} - \frac{p_S}{\theta_H\phi_H D} + 1 = 0$. If $\frac{p_S}{\theta_H\phi_H D} = d$, then $d = 0.285$, and therefore $p_S = 0.285\theta_H\phi_H D$. The SOC evaluated at $p_S = 0.285\theta_H\phi_H D$ reveals that the second derivative with respect to p_S is negative. Note that for all conditions of p_O and p_S in all the sections in this paper, the FOCs are sufficient because the optimal solutions have to be interior point solutions (except for the monopoly case, where the firm may prefer one mechanism to the other). This is because the profits go to zero if p_O and p_S are priced at the extremities (if either p_O or p_S is zero, then the margins are zero, and if they are equal to the upper bounds, then the market shares are zero). Substituting the optimal value for p_S in the expression for the market fraction and profits yields the results in the proposition. Equating the profits from on-demand pricing and selling yields the cut-off transaction cost. ■

ELECTRONIC APPENDIX

ELECTRONIC APPENDIX 1: Joint use of on-demand and selling mechanisms in a monopoly:

Recall that the utilities related to on-demand pricing and buying are $U_{iO}(p_O) = \theta_i(\phi_i - T - p_O)D$ and $U_{iS}(p_S) = \theta_i\phi_i D - p_S$ respectively. Consumer i uses on-demand pricing only if $U_{iO}(p_O) > U_{iS}(p_S)$. Thus, consumers will buy only if they have a frequency of usage that is higher than a certain critical frequency given by $\theta_c = \frac{p_S}{(p_O+T)D}$. Consumers with a lower frequency of usage than this critical frequency will prefer on-demand pricing. In addition, only consumers with a nonnegative utility from either pricing mechanism will participate in the market. From Figure 2, the analytical expressions for the market shares of the selling and on-demand mechanisms are the same as in the duopoly and are given by:

$$MS_S(p_S, p_O) = \frac{1}{\phi_H\theta_H}\Big[\int_{\frac{p_S}{\phi_H D}}^{\theta_H} [\phi_H - \tfrac{p_S}{\theta D}]d\theta - \int_{\frac{p_S}{\phi_H D}}^{\frac{p_S}{(p_O+T)D}} [\phi_H - \tfrac{p_S}{\theta D}]d\theta\Big]$$

$$= \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S\phi_H}{(p_O+T)D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H(p_O+T)D}\}]$$

$$MS_O(p_S, p_O) = \frac{1}{\phi_H\theta_H}[\phi_H - (p_O+T)]\frac{p_S}{(p_O+T)D}$$

The profits from the selling and on-demand mechanisms, and total profits are, respectively:

$$\Pi_S(p_S, p_O) = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S\phi_H}{(p_O+T)D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H(p_O+T)D}\}]p_S$$

$$\Pi_O(p_S, p_O) = \frac{1}{2\phi_H\theta_H}[\phi_H - (p_O + T)][\frac{p_S}{(p_O+T)D}]^2 p_O D$$

$$\Pi(p_S, p_O) = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S\phi_H}{(p_O+T)D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H(p_O+T)D}\}]p_S + \frac{1}{2\phi_H\theta_H}[\phi_H - (p_O + T)][\frac{p_S}{(p_O+T)D}]^2 p_O D$$

Note that the profits corresponding to on-demand pricing are computed by multiplying the market share for the on-demand pricing and the total payments discounted over time with the average frequency of usage, given by $\frac{p_S}{2(p_O+T)D}$. The analytical expressions for the optimal selling price and the per-use payment under on-demand pricing are derived from the FOCs of $\Pi(p_S, p_O)$ with respect to the selling price and per-period payment charged by the monopolist. The optimal per-period payment derived from the FOCs is: $p_O = \frac{1}{4}[\phi_H - T + \sqrt{(\phi_H - T)^2 + 16\phi_H T}] - T$. Further, from the FOCs, we can see that the optimal selling price to be charged by the monopolist satisfies the following implicit equation: $\theta_H\phi_H - \frac{p_S(\phi_H - T)}{(p_O+T)D} + \frac{2p_S}{D}log[\frac{p_S}{(p_O+T)\theta_H D}] - \frac{p_S\phi_H T}{(p_O+T)^2 D} = 0$. After substituting the closed form expression for p_O, this implicit equation can be solved to yield the optimal price for any given set of parameters θ_H and ϕ_H.

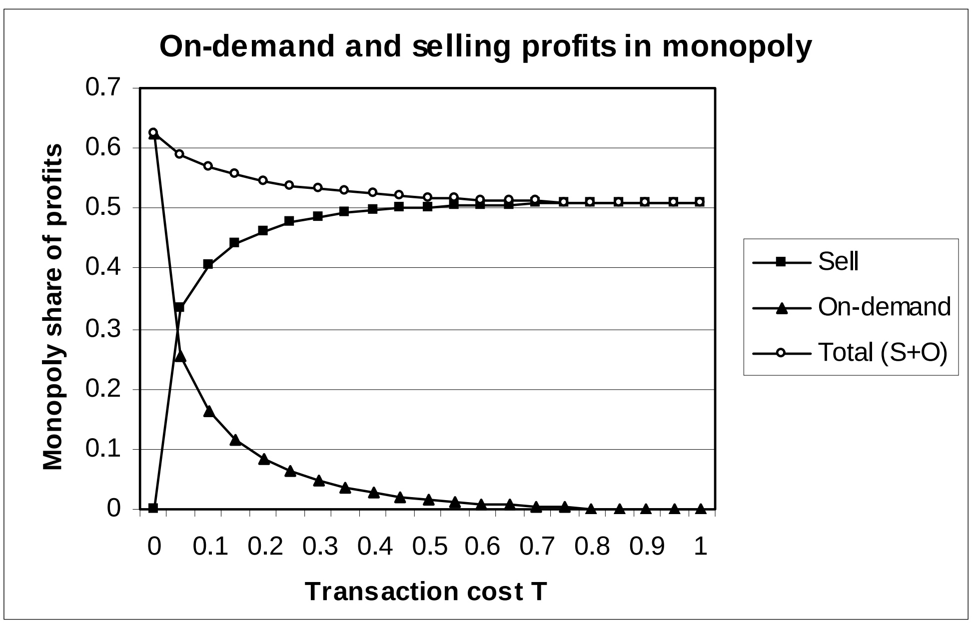

Figure E1: Profits from joint use of selling and on-demand pricing in monopoly

Figure E1 describes the profits from the selling and on-demand pricing mechanisms when they are used together (assuming $\theta_H = \phi_H = 1$, $D = 5$). The optimal per-period payment and the optimal price increase from the base case where the monopolist uses each pricing mechanism alone. It can be verified that the monopolist obtains lower market shares from each mechanism compared to when each is used independently. However, the total market share is higher when the mechanisms are used jointly than when each is used independently. Further, even when both mechanisms are available, the monopolist uses on-demand pricing alone when transaction cost T=0, both mechanisms when T is at a moderate level (with a substantial fraction of the total profit accruing from on-demand pricing), and the selling mechanism alone when T is high. ■

ELECTRONIC APPENDIX 2: Analysis with positive unit variable cost:

As before, the market fraction (or volume of consumers) that participates under on-demand pricing is $\frac{\phi_H-(p_O+T)}{\phi_H}$. The average frequency with which consumers use on-demand pricing in any given period is $\frac{\theta_H}{2}$. The expected profits for the firm are $\Pi_O = \frac{\phi_H-(p_O+T)}{\phi_H}\frac{\theta_H}{2}(p_O D - c)$. To explain this profit function, note that the market share is multiplied by the average frequency of usage of $\frac{\theta_H}{2}$ to yield the total number of times the good is used in any given period. The resulting quantity is then multiplied by p_O to yield the total revenue per period. Finally multiplying the revenue by the NPV discount factor D yields the discounted value of total revenues. On the cost side, the firm needs to produce at the outset the quantity of goods that will be used during each period – this is denoted by $\frac{\phi_H-(p_O+T)}{\phi_H}\frac{\theta_H}{2}$ – at the cost of c per unit. For example, at a video store, a fixed number of DVDs are procured, which can be used over multiple months. This cost is subtracted from the revenues to yield the net profits in the expression above. Alternatively, if the firm sells the good outright, then from eqn (4), the profits are:

$$\Pi_S = \frac{(p_S-c)}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log(\frac{p_S}{\theta_H\phi_H D})]$$

The optimal payments per period and the optimal selling price are derived from the corresponding FOCs. The optimal per-period payment is $p_O = \frac{(\phi_H-T)D+c}{2}$ and the corresponding profits are $\Pi_O = \frac{[(\phi_H-T)D-c]^2\theta_H}{8\phi_H D}$. The optimal price is characterized by the implicit equation $\theta_H\phi_H - \frac{p_S}{D} +$

$\frac{2p_S}{D} log(\frac{p_S}{\theta_H \phi_H D}) - \frac{c}{D} log(\frac{p_S}{\theta_H \phi_H D}) = 0.$

Both the optimal per-period payment and the optimal price increase if there is a positive unit variable cost. This is intuitive. The cut-off transaction cost below which on-demand pricing yields higher profits than selling is described in the figure below in Figure E2 (for $D = 5$).

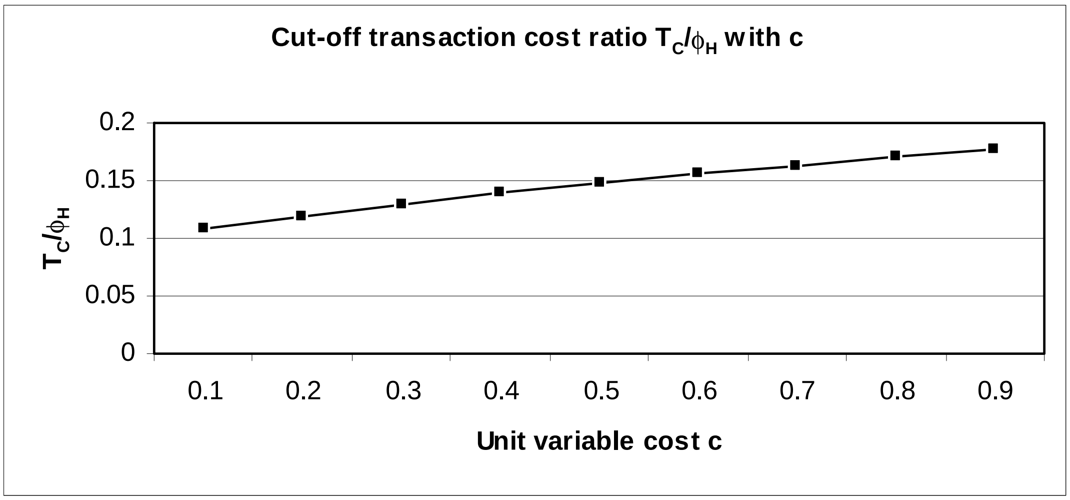

Figure E2: Cut-off transaction cost ratio $\frac{T_C}{\phi_H}$ with unit variable cost c

As observed in Figure E2, the cut-off transaction cost (T_C) increases in the unit variable cost. That is, the presence of a positive unit variable cost increases the attractiveness of on-demand pricing compared to selling. ■

ELECTRONIC APPENDIX 3: Derivation of equilibrium payment per-use and price in a duopoly

Consider a duopoly where one firm offers on-demand pricing and the competitor sells the information good. The profits of the firm that offers on-demand pricing are:

$$\Pi_O = \frac{1}{2\phi_H \theta_H}[\phi_H - (p_O + T)][\frac{p_S}{(p_O+T)D}]^2 p_O D$$

The first order condition with respect to p_O yields:

$$(p_O + T)^2[\phi_H - 2p_O - T] = 2p_O[\phi_H - (p_O + T)](p_O + T)$$

which on simplification yields $p_O = \frac{T(\phi_H - T)}{\phi_H + T}$. Next, the seller's profits in the duopoly are:

$$\Pi_S = \frac{1}{\phi_H \theta_H}[\theta_H \phi_H - \frac{p_S \phi_H}{(p_O+T)D} + \frac{p_S}{D} log\{\frac{p_S}{\theta_H(p_O+T)D}\}] p_S$$

The FOC for the seller yields:

$$\theta_H \phi_H - \frac{2p_S \phi_H}{(p_O+T)D} + \frac{p_S}{D} log\{\frac{p_S}{\theta_H(p_O+T)D}\} + \frac{p_S}{D}[1 + log\{\frac{p_S}{\theta_H(p_O+T)D}\}] = 0$$

which on simplification yields the implicit equation:

$$\theta_H \phi_H - \frac{2p_S \phi_H}{(p_O+T)D} + \frac{2p_S}{D} log\{\frac{p_S}{\theta_H(p_O+T)D}\} + \frac{p_S}{D} = 0 \qquad \blacksquare$$

ELECTRONIC APPENDIX 4: Proof of relationships between prices and per-period payments across the monopoly and the duopoly

To prove that the per-period payment in the duopoly is lower than that under independent on-demand pricing by a monopolist, we have to prove that $\frac{T(\phi_H - T)}{\phi_H + T} \leq \frac{\phi_H - T}{2}$, which simplifies to $\phi_H \geq T$. This is true by assumption. Next consider the selling price. We have to show that the selling price in a duopoly (referred to in this proof as p_{DS}) as characterized by the implicit equation $\theta_H \phi_H - \frac{2p_{DS}\phi_H}{(p_{DO}+T)D} + \frac{2p_{DS}}{D} log\{\frac{p_{DS}}{\theta_H(p_{DO}+T)D}\} + \frac{p_{DS}}{D} = 0$ (where $p_{DO} = \frac{T(\phi_H - T)}{\phi_H + T}$) is lower than the selling price in a monopoly (referred to in this proof as p_{PS}) as characterized by the implicit equation $\theta_H \phi_H + \frac{2p_{PS}}{D} \log p_{PS} - \frac{p_{PS}}{D}[2\log(D\phi_H\theta_H) + 1] = 0$ (where $p_{PS} = 0.285\theta_H\phi_H D$).

We rewrite the implicit equations for the selling price in a duopoly and monopoly cases as, respectively

$$\theta_H \phi_H + \frac{2p_{DS}}{D} \log p_{DS} - \frac{p_{DS}}{D}[2\log(D\theta_H) + 2\log(p_{DO}+T) + \frac{2\phi_H}{p_{DO}+T} - 1] = 0$$
$$\theta_H \phi_H + \frac{2p_{PS}}{D} \log p_{PS} - \frac{p_{PS}}{D}[2\log(D\phi_H\theta_H) + 1] = 0$$

Comparing the two implicit equations, we can easily see that if the part of the third term multiplying $\frac{p_{DS}}{D}$ is greater than the one multiplying $\frac{p_{PS}}{D}$, then the corresponding p_{DS} must be smaller for the equations to equal zero. Therefore, to show that $p_{DS} < p_{PS}$, we need to show that:

$$2\log(D\theta_H) + 2\log(p_{DO} + T) + \frac{2\phi_H}{p_{DO}+T} - 1 > 2\log(D\phi_H\theta_H) + 1$$

which reduces to showing that $\frac{2\phi_H}{p_{DO}+T} - 1 > 2\log\frac{\phi_H}{p_{DO}+T} + 1$

which reduces to showing that $\frac{\phi_H}{p_{DO}+T} > \log\frac{\phi_H}{p_{DO}+T} + 1$.

Now this is always true because, if $x > 1$, then $x > 1 + \log(x)$, as evident from the power series expansion of $\log(x)$.

Finally, one can directly see from the expression $p_O = \frac{T(\phi_H - T)}{\phi_H + T}$ that the equilibrium payment per-use first increases and then decreases with T. ■

ELECTRONIC APPENDIX 5: Proof of Proposition 3

To prove that the seller's profits in the duopoly are always greater than those of the firm that offers on-demand pricing, we have to prove that (using expressions from above):

$$\Pi_{DS} = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_{DS}\phi_H}{(p_{DO}+T)D} + \frac{p_{DS}}{D}log\{\frac{p_{DS}}{\theta_H(p_{DO}+T)D}\}]p_{DS} > \Pi_{DO} =$$
$$\frac{1}{2\phi_H\theta_H}[\phi_H - (p_{DO} + T)][\frac{p_{DS}}{(p_{DO}+T)D}]^2 p_{DO}D$$

Note that for the selling price in a duopoly, the FOC is given by:

$$\theta_H\phi_H - \frac{p_{DS}\phi_H}{(p_{DO}+T)D} + \frac{p_{DS}}{D}log\{\frac{p_{DS}}{\theta_H(p_{DO}+T)D}\} = \frac{p_{DS}\phi_H}{(p_{DO}+T)D} - \frac{p_{DS}}{D}log\{\frac{p_{DS}}{\theta_H(p_{DO}+T)D}\} - \frac{p_{DS}}{D}$$

Substituting the right hand side into the expression for Π_{DS},we have to prove that:

$$p_{DS}[\frac{p_{DS}\phi_H}{rD} - \frac{p_{DS}}{D}log\{\frac{p_{DS}}{\theta_H rD}\} - \frac{p_{DS}}{D}] > \frac{1}{2}(r - T)(\phi_H - r)\frac{p_{DS}^2}{r^2 D} \quad \text{where } r = p_{DO} + T = \frac{2T\phi_H}{\phi_H+T}.$$

This reduces to proving that $\frac{\phi_H}{r} - log\{\frac{p_{DS}}{\theta_H rD}\} - 1 > \frac{1}{2}\frac{(r-T)(\phi_H-r)}{r^2}$. After simplification, this reduces to proving that $(\phi_H - r - T)r + \phi_H T - 2r^2 log\{\frac{p_{DS}}{\theta_H rD}\} > 0$ or $(\phi_H - r)(r + T) > 2r^2 log\{\frac{p_{DS}}{\theta_H rD}\}$.

Note that $\phi_H > r$ as $r = \frac{2T\phi_H}{\phi_H+T}$, and by assumption, $T < \phi_H$. The term $(r + T) = \frac{3T\phi_H+T^2}{\phi_H+T}$ is positive, hence, the LHS is positive. Now, $\frac{p_{DS}}{rD} = \frac{p_{DS}}{(p_{DO}+T)D}$ is the cut-off frequency for which the on-demand pricing mechanism gives the same utility surplus as selling in Section 3.2. Hence, $\frac{p_{DS}}{rD} < \theta_H$ and $\frac{p_{DS}}{\theta_H rD} < 1$. The natural logarithm of a number less than 1 is always negative, hence, the RHS is negative. Hence, $(\phi_H - r)(r + T) > 2r^2 log\{\frac{p_{DS}}{\theta_H rD}\}$ always holds true. ■

ELECTRONIC APPENDIX 6: Proof of Proposition 4a

We first need to derive the optimal payments per-use, prices, and profits when the basic information good is introduced at the outset and an upgrade is introduced in period k. There are four cases to consider:

Case 1: This pertains to the situation where a monopolist adopts on-demand pricing and consumers are myopic. The upgrade is introduced in period k. When the information good is first introduced all consumers with $\phi_i > p_{O1} + T$ use the good, where p_{O1} denotes the per-period payment for the basic (non-upgraded) good. Therefore, the market fraction initially using the good on demand is $\frac{\phi_H-(p_{O1}+T)}{\phi_H}$. The average usage frequency for consumers in this fraction in any period is $\frac{\theta_H}{2}$. Between the k^{th} and N^{th} periods (i.e., post-upgrade), if the firm charges a per-period payment of p_{O2}, then the market fraction using the good on demand is $\frac{a\phi_H-(p_{O2}+T)}{a\phi_H}$. The average usage frequency for consumers in this fraction in any period is again $\frac{\theta_H}{2}$. Accordingly, the firm's profits are $\Pi_{O1} = \frac{\phi_H-(p_{O1}+T)}{\phi_H}\frac{\theta_H}{2}p_{O1}D_{k-1}$ for the first $k-1$ periods, and . For the periods between and including the k^{th} and N^{th} periods, its profits are $\Pi_{O2} = \frac{a\phi_H-(p_{O2}+T)}{a\phi_H}\frac{\theta_H}{2}p_{O2}(D-D_{k-1})$. It can be verified that the total profits ($\Pi_O = \Pi_{O1} + \Pi_{O2}$) are quadratic with respect to both p_{O1} and p_{O2}. Accordingly, the FOCs with respect to each of these yield the optimal per-period payments: $p_{O1} = \frac{\phi_H-T}{2}$ and $p_{O2} = \frac{a\phi_H-T}{2}$. Substituting them back into the profit function yields the total profits denoted by $\Pi_O = \frac{\theta_H}{8}[\frac{(\phi_H-T)^2}{\phi_H}D_{k-1} + \frac{(a\phi_H-T)^2}{a\phi_H}(D-D_{k-1})]$. It is easy to see that under on-demand pricing with myopic consumers, there is no coupling between the profits before and after the upgrade has been introduced.

Case 2: This pertains to the situation where a monopolist adopts on-demand pricing and consumers are strategic. Strategic consumers expect the future upgrade, but their decision to use the information good in any given period will depend solely on the per-use payment charged by the monopolist during that period. Therefore, the fact that consumers are strategic will not impact the pricing behavior of the monopolist. The optimal payment per-use and the profits are identical to Case 1 above, where consumers are myopic.

Case 3: This pertains to the situation where the monopolist sells the information good and consumers are myopic. Denote the selling price of the basic good by p_S and let p_U be the price of the upgrade introduced in period k. There are two classes of consumers here. The first class of consumers purchase the basic information good at the outset. The second class of consumers, which is a subset of the first class, purchase the upgrade in period k. Their surpluses are, respectively, $U_1(S) = \theta_i\phi_i D - p_S$ and $U_2(S) = \theta_i(a-1)\phi_i(D - D_{k-1}) - \delta^{k-1}p_U$. For the basic information good in the first period, all consumers with usage probability in the range $\theta \in [\frac{p_S}{\phi D}, \theta_H]$ derive (weakly) positive utility from their purchase. Similar to the scenario without the upgrade, the fraction of the market purchasing the basic good and the resulting profits are, respectively:

$$MS_{S1} = \frac{1}{\phi_H\theta_H}\int_{\phi=\frac{p_S}{\theta_H D}}^{\phi_H}[\theta_H - \frac{p_S}{\theta_H D}]d\phi = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log(\frac{p_S}{\theta_H\phi_H D})]$$
$$\Pi_{S1} = MS_{S1}p_S = \frac{p_S}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log(\frac{p_S}{\theta_H\phi_H D})].$$

For the upgrade in the k^{th} period, all consumers with usage probability in the range $\theta \in [\frac{\delta^{k-1}p_U}{(a-1)\phi_i(D-D_{k-1})}, \theta_H]$ derive (weakly) positive utility from their purchase. The fraction of the market purchasing and the resulting profits for the upgrade are, respectively:

$$MS_{S2} = \frac{1}{\phi_H\theta_H}\int_{\phi=\frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})\theta_H}}^{\phi_H}[\theta_H - \frac{\delta^{k-1}p_U}{(a-1)\theta_H(D-D_{k-1})}]d\phi =$$
$$\frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})} + \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})}log(\frac{\delta^{k-1}p_U}{(a-1)\theta_H\phi_H(D-D_{k-1})})]$$
$$\Pi_{S2} = MS_{S2}\delta^{k-1}p_U = \frac{\delta^{k-1}p_U}{\phi_H\theta_H}[\theta_H\phi_H - \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})} + \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})}log(\frac{\delta^{k-1}p_U}{(a-1)\theta_H\phi_H(D-D_{k-1})})]$$

Note that if the firm uses the selling mechanism only, its profits from selling the base information good are: $\Pi_{S1} = MS_{S1}p_S = \frac{p_S}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S}{D} + \frac{p_S}{D}log(\frac{p_S}{\theta_H\phi_H D})]$. From Proposition 4, these profits are optimized if $p_S = 0.285\ \theta_H\ \phi_H D$ and the firm's profits from the basic information good are: $\Pi_{S1} = 0.1018\ \theta_H\ \phi_H D$. From the upgrade, the firm's profits are: $\Pi_{S2} = MS_{S2}\delta^{k-1}p_U = \frac{\delta^{k-1}p_U}{\phi_H\theta_H}[\theta_H\phi_H - \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})} + \frac{\delta^{k-1}p_U}{(a-1)(D-D_{k-1})}log(\frac{\delta^{k-1}p_U}{(a-1)\theta_H\phi_H(D-D_{k-1})})]$. The FOC with respect to p_U yields: $\frac{2\delta^{k-1}p_U}{\theta_H\phi_H(a-1)(D-D_{k-1})}log\{\frac{\delta^{k-1}p_U}{\theta_H\phi_H(a-1)(D-D_{k-1})}\} - \frac{\delta^{k-1}p_U}{\theta_H\phi_H(a-1)(D-D_{k-1})} + 1 = 0$. The solution to this implicit equation is: $\delta^{k-1}p_U = 0.285\ \theta_H\ \phi_H(a-1)(D - D_{k-1})$. This yields the same market share for the upgrade as the basic information good, implying that all consumers who purchase the basic good also purchase the upgrade. Substituting this back into the profit function yields: $\Pi_{S2} = 0.1018$ θ_H $\phi_H(a-1)(D-D_{k-1})$. The total profits of the seller from the base information good and the upgrade are $\Pi_S = \Pi_{S1} + \Pi_{S2} = 0.1018\ \theta_H\ \phi_H\ [D + (a-1)(D - D_{k-1})]$.

Case 4: This pertains to the situation where the monopolist sells the information good and consumers are strategic. When consumers are strategic, the monopolist can simply price the basic good and forthcoming upgrade as a bundle. When buying the bundle, consumer i will use the basic good for k-1 periods and then shift to the upgraded product in period k. Accordingly, the expected net surplus in period 1 of the consumer from purchasing the bundle is: $U_1(S) = \theta_i[\phi_i D + (a-1)\phi_i(D-D_{k-1})] - (p_S + \delta^{k-1} p_U)$. Equating this surplus to zero, the critical usage utility above which the consumer will purchase the bundle is: $\phi_i = \frac{p_S\ +\ \delta^{k-1}p_U}{\theta_i\ \widetilde{D}}$, where $\widetilde{D} = D + (a-1)(D - D_{k-1})$. We integrate out the fraction of customers who satisfy this condition from the lower limit of ϕ_i (corresponding to the case where $\theta_i = \theta_H$) to the upper limit of ϕ_i (corresponding to the case where $\phi_i = \phi_H$):

$$MS_S = \frac{1}{\phi_H\theta_H}\int_{\phi=\frac{p_S+\delta^{k-1}p_U}{\theta_H\widetilde{D}}}^{\phi_H}[\theta_H - \frac{p_S+\delta^{k-1}p_U}{\theta_H\widetilde{D}}]d\phi = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S+\delta^{k-1}p_U}{\widetilde{D}} + \frac{p_S+\delta^{k-1}p_U}{\widetilde{D}}log(\frac{p_S+\delta^{k-1}p_U}{\theta_H\phi_H\widetilde{D}})]$$

The corresponding profits are:

$$\Pi_S = MS_S(p_S + \delta^{k-1}p_U) = \frac{p_S+\delta^{k-1}p_U}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S+\delta^{k-1}p_U}{\widetilde{D}} + \frac{p_S+\delta^{k-1}p_U}{\widetilde{D}}log(\frac{p_S+\delta^{k-1}p_U}{\theta_H\phi_H\widetilde{D}})].$$

Now, the FOCs with respect to p_S and p_U yield: $p_S + \delta^{k-1}p_U = 0.285\ \theta_H\ \phi_H\ \widetilde{D}$. The firm's total profits are: $\Pi_S = 0.1018\ \theta_H\ \phi_H\ \widetilde{D}$. Substituting the value of $\widetilde{D}$ back into the profit function yields: $\Pi_S = 0.1018\ \theta_H\ \phi_H[D + (a-1)(D - D_{k-1})]$. Interestingly, the profits of the monopolist when consumers are myopic is identical to the case where they are strategic. This is because the fact that consumers are strategic does not affect their adoption decision for either the base good or the upgrade. Every consumer who purchases the basic good also purchases the upgrade.

Having solved the four cases, we are now ready to demonstrate that the cut-off transaction cost below which on-demand pricing yields higher profits than selling increases in the presence of the upgrade. Because profits from on-demand pricing and selling are identical across the cases where consumers are myopic or strategic, it is sufficient to analyze just the case where consumers are myopic. Recall that in the scenario without upgrades, the firm's profits from on-demand pricing are $\Pi_O = \frac{1}{8}\frac{\theta_H(\phi_H - T)^2}{\phi_H}D$, and those from selling are $\Pi_S = 0.1018\ \theta_H\ \phi_H\ D$. Here, the cut-off transaction cost below which on-demand pricing yields higher profits is $T = 0.0976\ \phi_H$.

Now, if the firm offers an upgrade, then profits under on-demand pricing are $\Pi_O = \frac{\theta_H}{8}[\frac{(\phi_H - T)^2}{\phi_H}D_{k-1} + \frac{(a\phi_H - T)^2}{a\phi_H}(D - D_{k-1})]$ and, as demonstrated above, those under selling are $\Pi_S = 0.1018\ \theta_H\ \phi_H[D + (a-1)(D - D_{k-1})]$. To find the cut-off transaction cost in the scenario with upgrades, we equate these profits:

$$\frac{\theta_H}{8}[\frac{(\phi_H - T_C)^2}{\phi_H}D_{k-1} + \frac{(a\phi_H - T_C)^2}{a\phi_H}(D - D_{k-1})] = 0.1018\ \theta_H\ \phi_H[D + (a-1)(D - D_{k-1})]$$
$$\text{Therefore, } (1 - \frac{T_C}{\phi_H})^2 D_{k-1} + (a - \frac{T_C}{\phi_H})^2 \frac{D - D_{k-1}}{a} = 0.1018 * 8[D + (a-1)(D - D_{k-1})]$$

Rewrite the LHS as $(1 - \frac{T_C}{\phi_H})^2[D + (a-1)(D - D_{k-1})] - (1 - \frac{T_C}{\phi_H})^2[D - D_{k-1} + (a-1)(D - D_{k-1})] + (a - \frac{T_C}{\phi_H})^2 \frac{D - D_{k-1}}{a}$. If the first term is set equal to the RHS, it yields $T_C = 0.0976\ \phi_H$, because the solution to $(1 - \frac{T_C}{\phi_H})^2 D = 0.1018 * 8D$ is $T_C = 0.0976\ \phi_H$. We will first show that the sum of the other two terms on the LHS is positive. To do this, we need to show that:

$$(a - \frac{T_C}{\phi_H})^2 \frac{D - D_{k-1}}{a} > (1 - \frac{T_C}{\phi_H})^2[D - D_{k-1} + (a-1)(D - D_{k-1})]$$
$$\text{or to show that } (a - \frac{T_C}{\phi_H})^2 > a^2(1 - \frac{T_C}{\phi_H})^2$$
$$\text{or to show that } a - \frac{T_C}{\phi_H} > a - \frac{aT_C}{\phi_H}.$$

Now this is true by assumption because $a > 1$ for the upgrade. Now, given that the sum of the other two terms is positive, the first term on the LHS has to be lower so that the equality continues to hold. Therefore, in order to make the term $(1 - \frac{T_C}{\phi_H})^2$ smaller, T_C with the upgrade will be higher than T_C without the upgrade. Accordingly, the cut-off transaction cost below which on-demand pricing is more profitable than selling is higher with the upgrade than without the upgrade. ■

ELECTRONIC APPENDIX 7: Proof of Proposition 4b

In the duopoly, if consumers are strategic (rational) and the competing firms offer the base information good and the upgrade as a bundle with either the selling or the on-demand mechanisms respectively, note that the utility surpluses to consumer i from on-demand pricing and selling are denoted respectively by:

$$U_{iO}(p_{O1}, p_{O2}) = \theta_i[(\phi_i - T - p_{O1})D_{k-1} + (a\phi_i - T - p_{O2})(D - D_{k-1})]$$
$$U_{iS}(p_S, p_U) = \theta_i\phi_i[D + (a-1)(D - D_{k-1})] - (p_S + \delta^{k-1}p_U).$$

Consumer i uses on-demand pricing only if $U_{iO}(p_{O1}, p_{O2}) > U_{iS}(p_S, p_U)$. Thus, consumers will buy purchase the good only if they have a frequency of usage that is higher than a certain critical frequency denoted by $\theta_c = \frac{p_S+\delta^{k-1}p_U}{(p_{O1}+T)D_{k-1}+(p_{O2}+T)(D-D_{k-1})}$. The market share of the on-demand mechanism is $\theta_c\frac{(p_{O1}+T)D_{k-1}+(p_{O2}+T)(D-D_{k-1})}{D_{k-1}+a(D-D_{k-1})}$, where the second part of the expression which multiplies θ_c is obtained by setting $U_{iO}(p_{O1}, p_{O2}) = 0$. Similarly, for consumers with a greater usage frequency than θ_c, the marginal consumer satisfies $\theta_i\phi_i = \frac{(p_S+\delta^{k-1}p_U)}{D+(a-1)(D-D_{k-1})}$.

The profits of the two firms are given by:

$$\Pi_S(p_S, p_U, p_{O1}, p_{O2}) = \frac{(p_S+\delta^{k-1}p_U)}{\phi_H\theta_H}[\theta_H\phi_H - \frac{(p_S+\delta^{k-1}p_U)\phi_H}{(p_{O1}+T)D_{k-1}+(p_{O2}+T)(D-D_{k-1})} + \frac{(p_S+\delta^{k-1}p_U)}{D_{k-1}+a(D-D_{k-1})}log\{\frac{(p_S+\delta^{k-1}p_U)\phi_H}{(p_{O1}+T)D_{k-1}+(p_{O2}+T)(D-D_{k-1})}\}]$$
$$\Pi_O(p_S, p_U, p_{O1}, p_{O2}) = \frac{1}{2\phi_H\theta_H}[\{\phi_H - \frac{(p_{O1}+T)D_{k-1}+(p_{O2}+T)(D-D_{k-1})}{D_{k-1}+a(D-D_{k-1})}\}\{p_{O1}D_{k-1} + p_{O2}(D - D_{k-1}\}][\frac{(p_S+\delta^{k-1}p_U)\phi_H}{(p_{O1}+T)D_{k-1}+(p_{O2}+T)(D-D_{k-1})}]^2$$

which gives us the same result as the competitive case without the upgrade, with p_S being replaced by $p_S + \delta^{k-1}p_U$ and $(p_O + T)D$ being replaced by $(p_{O1} + T)D_{k-1} + (p_{O2} + T)(D - D_{k-1})$ and D being replaced by $D_{k-1} + a(D - D_{k-1})$. ■

If consumers are myopic, then when the firms introduce the base information good, as in the duopoly case in Section 3.2, the profits of the two firms from the base information good are:

$$\Pi_S(p_S, p_O) = \frac{1}{\phi_H\theta_H}[\theta_H\phi_H - \frac{p_S\phi_H}{(p_O+T)D} + \frac{p_S}{D}log\{\frac{p_S}{\theta_H(p_O+T)D}\}]p_S$$

$$\Pi_O(p_S, p_O) = \frac{1}{2\phi_H\theta_H}[\phi_H - (p_O + T)][\frac{p_S}{(p_O+T)D}]^2 p_O D$$

From Proposition 3, we know that the firm that adopts the selling mechanism has higher profits from the base information good than the firm that adopts the on-demand mechanism. When the two firms introduce the upgrade, they no longer compete with each other for the upgrade, as consumers have chosen either the on-demand mechanism or the selling mechanism for the base good (under certain conditions that prevent consumers from switching to the other mechanism, which can be seen to be easily satisfied for the upgrade to yield positive utility to either set of consumers). Because the market share of the selling mechanism for the base information good is higher under competition, the firm adopting selling can price the upgrade to extract a higher profit than the firm adopting the on-demand mechanism. Therefore, if consumers are myopic, the firm using selling has a higher profit from the upgrade as well. ■

ELECTRONIC APPENDIX 8: Proof for endogenous competition case:

To demarcate the market shares for the two firms across the two segments (see Figure 10), we first note three properties:

(i) Consumers with higher frequencies of use in segment 1 prefer to buy information good 1 rather than 2. This is because, in segment 1, the utility $U_1(S_1) = \theta D - p_{S1}$ from buying good 1 is greater than the utility $U_1(S_2) = \lambda\theta D - p_{S2}$ that accrues from buying information good 2 at higher frequencies of use. A similar argument can be made for consumers in segment 2.

(ii) When on-demand pricing is available, consumers with lower usage frequencies prefer to adopt it, whereas consumers with higher frequencies prefer to buy the good. The utility from adopting on-demand pricing is lower than from buying information good 2 in segment 2. This is because $U_2(O_1) = (\phi - T - p_{O1})\theta D < U_2(S_1) = \theta\phi D - p_{S1}$ when the frequency of use θ is higher. A similar argument can be applied to demonstrate that consumers in segment 1 with low frequencies of use will adopt on-demand pricing.

(iii) Both firms cannot use on-demand pricing for consumers in the same segment. Comparing the utilities from on-demand pricing of the two information goods reveals that if one consumer in a segment prefers to use a particular good, all consumers in that segment will use the same good. Therefore, if in segment 2, $U_2(O_2) = (\lambda\phi - T - p_{O2})\theta D > U_2(O_1) = (\phi - T - p_{O1})\theta D$ for one consumer, it will be satisfied for all consumers in that segment. A similar argument can be made for consumers in segment 1. Because consumers in segment 1 are more quality conscious, they will prefer to use good 1 on demand, and because consumers in segment 2 are more price-conscious, they will use good 2 on-demand.

As described in Figure 10, the market breaks up in consumers who use either of the goods on demand, or purchase either of the goods. The critical usage frequencies that separate the different regions are denoted by:

$$\theta_1 : U_2(O_2) = (\lambda\phi - T - p_{O2})\theta D = U_2(S_2) = \lambda\phi\theta D - p_{S2} \Rightarrow \theta_1 = \frac{p_{S2}}{(p_{O2}+T)D}$$
$$\theta_2 : U_2(S_2) = \lambda\phi\theta D - p_{S2} = U_2(S_1) = \phi\theta D - p_{S1} \Rightarrow \theta_2 = \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}$$
$$\theta_3 : U_1(O_1) = (1 - T - p_{O1})\theta D = U_1(S_2) = \lambda\theta D - p_{S2} \Rightarrow \theta_3 = \frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}$$
$$\theta_4 : U_1(S_2) = \lambda\theta D - p_{S2} = U_1(S_1) = \theta D - p_{S1} \Rightarrow \theta_4 = \frac{p_{S1}-p_{S2}}{(1-\lambda)D}$$

Substituting these critical frequency values into the market shares for selling and on-demand pricing yields the market shares and profits of the two firms respectively.

$$\Pi_{O1} = p_{O1}D\frac{\theta_3^2}{2} = \frac{1}{2}[\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}]^2 p_{O1}D; \quad \Pi_{S1} = p_{S1}[1-\theta_2+1-\theta_4]; \;\; \Pi_1 = \Pi_{S1}+\Pi_{O1}$$
$$\Pi_{O2} = p_{O2}D\frac{\theta_1^2}{2} = \frac{1}{2}[\frac{p_{S2}}{(p_{O2}+T)D}]^2 p_{O2}D; \;\; \Pi_{S2} = p_{S2}[\theta_2-\theta_1+\theta_4-\theta_3]; \;\; \Pi_2 = \Pi_{S2}+\Pi_{O2}$$

Therefore, total profits are:

$$\Pi_1 = \frac{1}{2}[\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}]^2 p_{O1}D + [1 - \frac{p_{S1}-p_{S2}}{(1-\lambda)D} + 1 - \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}]p_{S1}$$
$$\Pi_2 = \frac{1}{2}[\frac{p_{S2}}{(p_{O2}+T)D}]^2 p_{O2}D + [\frac{p_{S1}-p_{S2}}{(1-\lambda)D} - \frac{p_{S2}}{(\lambda+p_{O1}+T-1)D} + \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D} - \frac{p_{S2}}{(p_{O2}+T)D}]p_{S2}$$

We assume at this stage that each competitor adopts both pricing mechanisms. The FOC of Π_2 with respect to p_{O2} yields $\frac{\partial \Pi_2}{\partial p_{O2}} = \frac{p_{S2}^2}{2D}\frac{(p_{O2}+T)^2 - 2p_{O2}(p_{O2}+T)}{(p_{O2}+T)^4} + \frac{p_{S2}^2}{D}\frac{1}{(p_{O2}+T)^2} = \frac{p_{S2}^2}{2D}\frac{p_{O2}+3T}{(p_{O2}+T)^3} > 0$. Therefore, p_{O2} is set to its maximum value of $p_{O2} = \lambda\phi - T$.

The FOC of Π_2 with respect to p_{S2} yields $\frac{\partial \Pi_2}{\partial p_{S2}} = \frac{p_{S2}}{(p_{O2}+T)^2 D} p_{O2} + \frac{p_{S1}}{1-\lambda}(1+\frac{1}{\phi}) - \frac{2p_{S2}}{D}[\frac{1}{1-\lambda}(1+\frac{1}{\phi}) + \frac{1}{p_{O2}+T} + \frac{1}{\lambda+p_{O1}+T-1}] = 0$

The FOC of Π_1 with respect to p_{O1} yields $\frac{\partial \Pi_1}{\partial p_{O1}} = \frac{p_{S2}^2}{2D} \frac{(\lambda+p_{O1}+T-1)^2 - 2p_{O1}(\lambda+p_{O1}+T-1)}{(\lambda+p_{O1}+T-1)^4}$. Note that for customers in segment 2 to use information good 2 on-demand, $U_2(O_2) = (\lambda\phi - T - p_{O2})\theta D \geqslant U_2(O_1) = (\phi - T - p_{O1})\theta D$. Therefore, $p_{O1} = 1 - T$.

The FOC of Π_1 with respect to p_{S1} yields $\frac{\partial \Pi_1}{\partial p_{S1}} = 1 - \frac{2p_{S1} - p_{S2}}{(1-\lambda)D} + 1 - \frac{2p_{S1} - p_{S2}}{(1-\lambda)\phi D} = 0 \Rightarrow p_{S1} = \frac{p_{S2}}{2} + \frac{(1-\lambda)D}{1+\frac{1}{\phi}}$

Substituting these values of the optimal prices into the profit function and numerically evaluating those functions yields the curves plotted in Figure 7. ■

We next consider cases where one or the firms uses only one of the two pricing mechanisms:

Case 1: Firm 1 adopts on-demand pricing and selling, firm 2 adopts only selling:

In this case, the market shares of the two firms are as plotted in Figure E3.

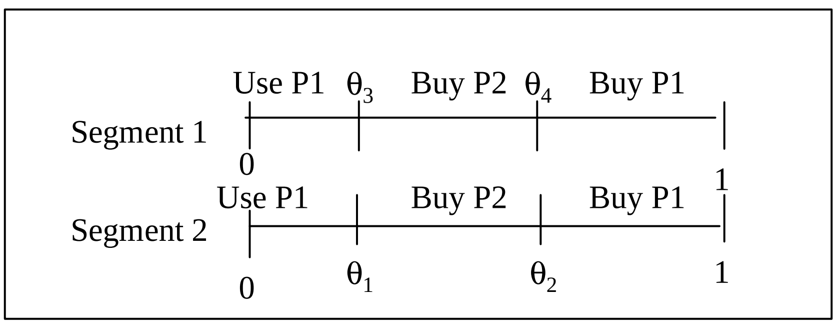

Figure E3: Market shares when firm 2 uses selling only, firm 1 uses both options

The critical usage frequencies that separate the different regions are denoted by:

$\theta_1 : U_2(O_1) = (\phi - T - p_{O1})\theta D = U_2(S_2) = \lambda\phi\theta D - p_{S2} \Rightarrow \theta_1 = \frac{p_{S2}}{(\lambda\phi - \phi + p_{O1} + T)D}$

$\theta_2 : U_2(S_2) = \lambda\phi\theta D - p_{S2} = U_2(S_1) = \phi\theta D - p_{S1} \Rightarrow \theta_2 = \frac{p_{S1} - p_{S2}}{(1-\lambda)\phi D}$

$\theta_3 : U_1(O_1) = (1 - T - p_{O1})\theta D = U_1(S_2) = \lambda\theta D - p_{S2} \Rightarrow \theta_3 = \frac{p_{S2}}{(\lambda + p_{O1} + T - 1)D}$

$\theta_4 : U_1(S_2) = \lambda\theta D - p_{S2} = U_1(S_1) = \theta D - p_{S1} \Rightarrow \theta_4 = \frac{p_{S1} - p_{S2}}{(1-\lambda)D}$

Substituting these critical frequency values into the market shares for selling and on-demand pricing yields the market shares and profits of the two firms respectively.

$$\Pi_{O1} = p_{O1}D[\frac{\theta_3^2}{2} + \frac{\theta_1^2}{2}] = \frac{1}{2}\{[\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}]^2 + [\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}]\}p_{O1}D;$$

$$\Pi_{S1} = p_{S1}[1-\theta_2+1-\theta_4]; \Pi_1 = \Pi_{S1}+\Pi_{O1}$$

$$\Pi_{S2} = p_{S2}[\theta_2-\theta_1+\theta_4-\theta_3]; \Pi_2 = \Pi_{S2}$$

Therefore, $\Pi_1 = \frac{1}{2}\{[\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}]^2 + [\frac{p_{S2}}{(\lambda+p_{O1}+T-1)D}]\}p_{O1}D + [1-\frac{p_{S1}-p_{S2}}{(1-\lambda)D}+1-\frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}]p_{S1}$

$$\Pi_2 = [\frac{p_{S1}-p_{S2}}{(1-\lambda)D} - \frac{p_{S2}}{(\lambda+p_{O1}+T-1)D} + \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D} - \frac{p_{S2}}{(p_{O2}+T)D}]p_{S2}$$

The FOC of Π_1 with respect to p_{O1} yields

$\frac{\partial\Pi_1}{\partial p_{O1}} = \frac{p_{S2}^2}{2D}[\frac{(\lambda+p_{O1}+T-1)^2-2p_{O1}(\lambda+p_{O1}+T-1)}{(\lambda+p_{O1}+T-1)^4} + \frac{(\lambda\phi+p_{O1}+T-\phi)^2-2p_{O1}(\lambda\phi+p_{O1}+T-\phi)}{(\lambda\phi+p_{O1}+T-\phi)^4} > 0$.Hence, $p_{O1} = 1-T$, i.e., p_{O1} is set to its maximum value.

The FOC of Π_2 with respect to p_{S2} yields $\frac{\partial\Pi_2}{\partial p_{S2}} = \frac{p_{S1}}{1-\lambda}(1+\frac{1}{\phi}) - \frac{2p_{S2}}{D}[\frac{1}{1-\lambda}(1+\frac{1}{\phi}) + \frac{1}{\lambda\phi+p_{O1}+T-\phi} + \frac{1}{\lambda+p_{O1}+T-1}] = 0$

The FOC of Π_1 with respect to p_{S1} yields $\frac{\partial\Pi_1}{\partial p_{S1}} = 1-\frac{2p_{S1}-p_{S2}}{(1-\lambda)D}+1-\frac{2p_{S1}-p_{S2}}{(1-\lambda)\phi D} = 0 \Rightarrow p_{S1} = \frac{p_{S2}}{2}+\frac{(1-\lambda)D}{1+\frac{1}{\phi}}$

Substituting the optimal prices into the profit functions and numerically evaluating them yields the profit profiles in Figure E4. It is easy to see that the profits of both firms are higher than those in Figure 7.

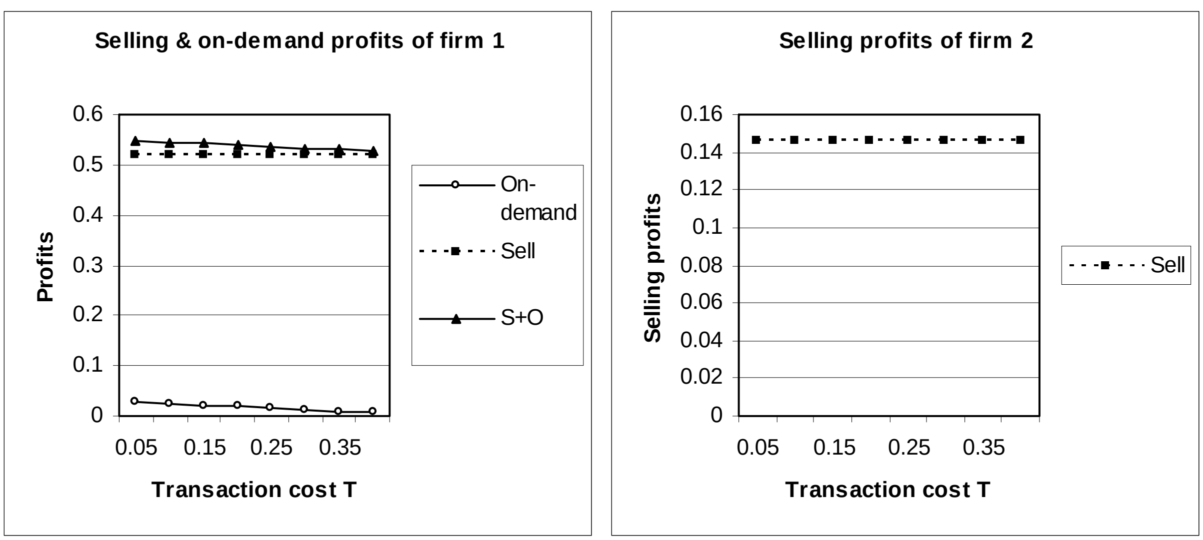

Figure E4: Profits when firm 1 uses both pricing mechanisms, firm 2 uses only selling

Case 2: Firm 1 adopts only selling but firm 2 adopts both selling and on-demand pricing:

In this case, the market share of the two firms are as in Figure E5:

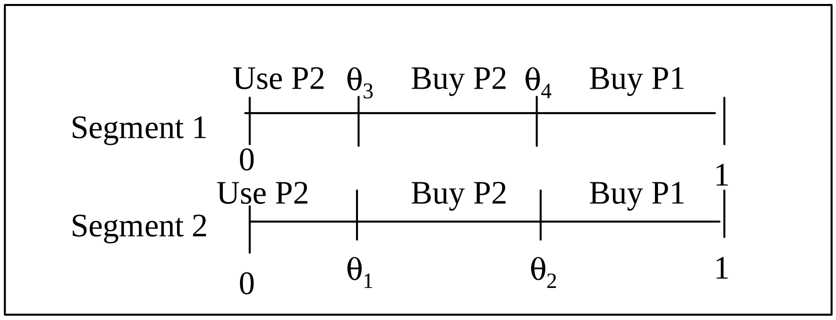

Figure E5: Market segments when firm 1 uses selling only, firm 2 uses both options

The critical usage frequencies that separate the different regions are denoted by:

$\theta_1 : U_2(O_1) = (\lambda\phi - T - p_{O1})\theta D = U_2(S_2) = \lambda\phi\theta D - p_{S2} \Rightarrow \theta_1 = \frac{p_{S2}}{(p_{O2}+T)D}$

$\theta_2 : U_2(S_2) = \lambda\phi\theta D - p_{S2} = U_2(S_1) = \phi\theta D - p_{S1} \Rightarrow \theta_2 = \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}$

$\theta_3 : U_1(O_1) = (\lambda - T - p_{O1})\theta D = U_1(S_2) = \lambda\theta D - p_{S2} \Rightarrow \theta_3 = \frac{p_{S2}}{(p_{O2}+T)D}$

$\theta_4 : U_1(S_2) = \lambda\theta D - p_{S2} = U_1(S_1) = \theta D - p_{S1} \Rightarrow \theta_4 = \frac{p_{S1}-p_{S2}}{(1-\lambda)D}$

Substituting these critical frequency values into the market shares for selling and on-demand pricing yields the market shares and profits of the two firms respectively.

$$\Pi_{O2} = p_{O2}D[\frac{\theta_3^2}{2} + \frac{\theta_1^2}{2}] = [\frac{p_{S2}}{(p_{O2}+T)D}]^2 p_{O2}D;\ \Pi_{S2} = p_{S2}[\theta_2 - \theta_1 + \theta_4 - \theta_3];\ \Pi_2 = \Pi_{S2} + \Pi_{O2}$$

$$\Pi_{S1} = p_{S1}[1 - \theta_2 + 1 - \theta_4]; \Pi_1 = \Pi_{S1}$$

$$\text{Therefore, } \Pi_1 = [1 - \frac{p_{S1}-p_{S2}}{(1-\lambda)D} + 1 - \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}]p_{S1}$$

$$\Pi_2 = [\frac{p_{S1}-p_{S2}}{(1-\lambda)D} - 2\frac{p_{S2}}{(p_{O2}+T)D} + \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}]p_{S2} + [\frac{p_{S2}}{(p_{O2}+T)D}]^2 p_{O2}D$$

The FOC of Π_2 with respect to p_{O2} yields $\frac{\partial \Pi_2}{\partial p_{O2}} = \frac{p_{S2}^2}{D}[\frac{(p_{O2}+T)^2 - 2p_{O2}(p_{O2}+T)}{(p_{O2}+T)^4} + 2\frac{1}{(p_{O2}+T)^2}] > 0$

Hence, $p_{O2} = \lambda\phi - T$, i.e., p_{O2} is set to its maximum value.

The FOC of Π_2 with respect to p_{S2} yields $\frac{\partial \Pi_2}{\partial p_{S2}} = \frac{p_{S1}}{1-\lambda}(1+\frac{1}{\phi}) - \frac{2p_{S2}}{D}[\frac{1}{1-\lambda}(1+\frac{1}{\phi}) + \frac{p_{O2}}{(p_{O2}+T)^2} + \frac{2}{p_{O2}+T}] = 0$

The FOC of Π_1 with respect to p_{S1} yields $\frac{\partial \Pi_1}{\partial p_{S1}} = 1 - \frac{2p_{S1}-p_{S2}}{(1-\lambda)D} + 1 - \frac{2p_{S1}-p_{S2}}{(1-\lambda)\phi D} = 0 \Rightarrow p_{S1} = \frac{p_{S2}}{2} + \frac{(1-\lambda)D}{1+\frac{1}{\phi}}$

Substituting these values of the optimal prices into the profit function and numerically evaluating those functions yields the curves plotted in Figure E6. It is easy to see that the profits of both firms are lower than those in Figure 7.

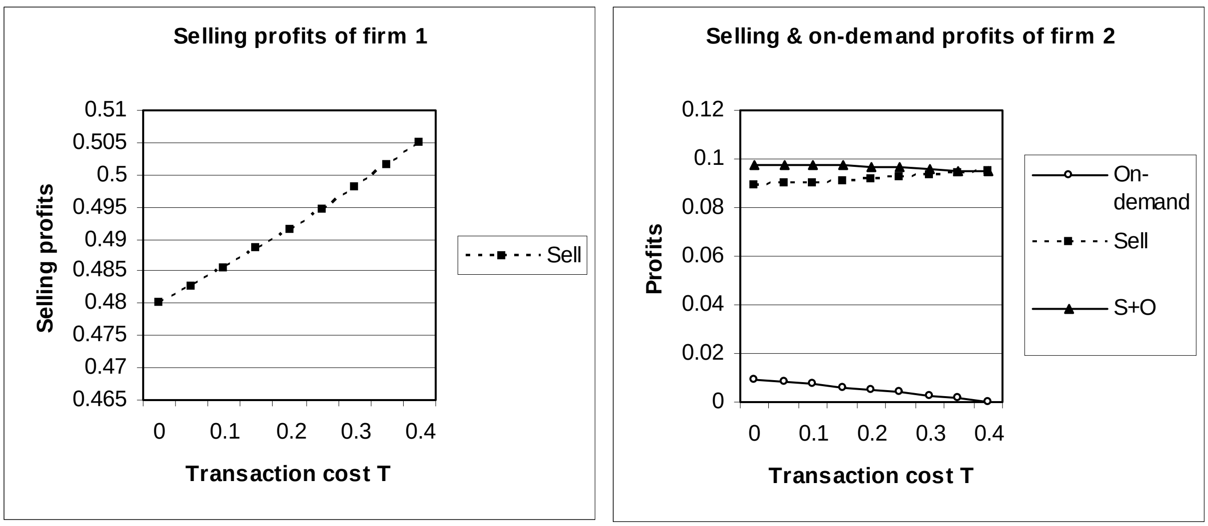

Figure E6: Profits when firm 2 uses both pricing mechanisms, firm 1 uses only selling

Case 3: Firms 1 and 2 use selling only:

In this case, the market share of the two firms are as in Figure E7.

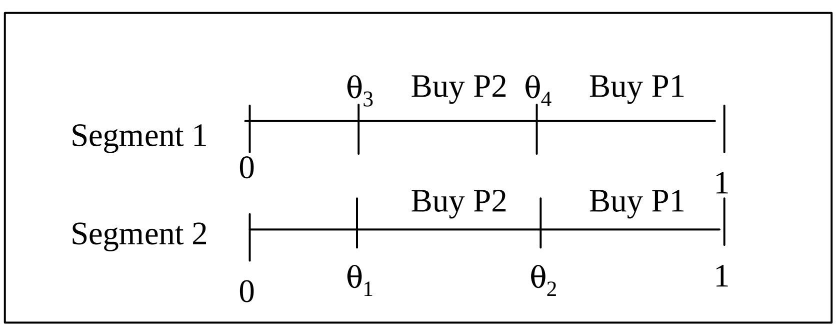

Figure E7: Market segments of both firms when both firms use selling only

The critical usage frequencies that separate the different regions are denoted by:

$\theta_1 : U_2(S_2) = \lambda\phi\theta D - p_{S2} = 0 \Rightarrow \theta_1 = \frac{p_{S2}}{\lambda\phi D}$

$\theta_2 : U_2(S_2) = \lambda\phi\theta D - p_{S2} = U_2(S_1) = \phi\theta D - p_{S1} \Rightarrow \theta_2 = \frac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}$

$\theta_3 : U_1(O_1) = (\lambda - T - p_{O1})\theta D = U_1(S_2) = \lambda\theta D - p_{S2} \Rightarrow \theta_3 = \frac{p_{S2}}{\lambda D}$

$\theta_4 : U_1(S_2) = \lambda\theta D - p_{S2} = U_1(S_1) = \theta D - p_{S1} \Rightarrow \theta_4 = \frac{p_{S1}-p_{S2}}{(1-\lambda)D}$

Substituting these critical frequency values into the market shares for selling yields the market shares and profits of the two firms:

$$\Pi_{S2} = p_{S2}[\theta_2 - \theta_1 + \theta_4 - \theta_3];\ \Pi_2 = \Pi_{S2}$$

$$\Pi_{S1} = p_{S1}[1 - \theta_2 + 1 - \theta_4];\ \Pi_1 = \Pi_{S1}$$

$$\text{Therefore, } \Pi_1 = [1 - \tfrac{p_{S1}-p_{S2}}{(1-\lambda)D} + 1 - \tfrac{p_{S1}-p_{S2}}{(1-\lambda)\phi D}]p_{S1}$$

$$\Pi_2 = [\tfrac{p_{S1}-p_{S2}}{(1-\lambda)D} - \tfrac{p_{S2}}{\lambda D} + \tfrac{p_{S1}-p_{S2}}{(1-\lambda)\phi D} - \tfrac{p_{S2}}{\lambda\phi D}]p_{S2}$$

The FOC of Π_2 with respect to p_{S2} yields $\frac{\partial \Pi_2}{\partial p_{S2}} = \frac{p_{S1}}{1-\lambda}(1 + \frac{1}{\phi}) - \frac{2p_{S2}}{D}[\frac{1}{1-\lambda}(1 + \frac{1}{\phi}) + \frac{1}{\lambda}(1 + \frac{1}{\phi})] = 0$

The FOC of Π_1 with respect to p_{S1} yields $\frac{\partial \Pi_1}{\partial p_{S1}} = 1 - \frac{2p_{S1}-p_{S2}}{(1-\lambda)D} + 1 - \frac{2p_{S1}-p_{S2}}{(1-\lambda)\phi D} = 0 \Rightarrow p_{S1} = \frac{p_{S2}}{2} + \frac{(1-\lambda)D}{1+\frac{1}{\phi}}$

Substituting these values of the optimal prices into the profit function and numerically evaluating those functions yields the following profits for both firms. $\Pi_1 = 0.5208, \Pi_2 = 0.1042$. It is easy to see that the profits of both firms are lower than those in Figure 7. Finally, the case where firm 1 employs on-demand pricing to serve segment 1 and firm 2 employs on-demand pricing to serve segment 2 is not an equilibrium because firm 1 can always increase profits by employing selling in addition, thereby capturing market share from firm 2 in segment 2. ■