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THE OPTIMAL SOFTWARE LICENSING POLICY UNDER QUALITY UNCERTAINTY

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Abstract

The rapid rate of standard software development, and the need of users to stay current, has unleashed unprecedented levels of process and product innovations in the software industry. A new service model has emerged which delivers application software and services over the Web on a lease or subscription basis. Software vendors such as Sun, Oracle, and Microsoft have already adopted this innovative business model. They have expanded their sales offerings with lease contracts that augment their traditional one-time purchase transactions.

Our paper studies the optimal licensing policy of a software vendor that uses that business model. We look at software vendors that are both selling (at a posted price) or leasing their products where as lessor they guarantee that the lessee will always have the latest version of the software on their desktop. We address some of the specific issues of implementing this policy at the packaged software market, including the impact of network externality, negligible marginal production costs, and upgrade compatibility. We show that by properly defining their pricing structure, software vendors can segment the market and realize effective second-degree price discrimination and show how and when software vendors can maximize their profits through the use of this new licensing policy.

1 INTRODUCTION

The development of information technology, especially the Internet, has unleashed unprecedented levels of process innovation, as well as product innovation, in the software industry. The way software is sold is also changing rapidly. Many software publishers are abandoning traditional perpetual licensing in favor of software rental, leasing, or subscription models. They deliver application software and services (software maintenance, upgrades, staff training, etc.) over the Web on a lease or subscription basis. Some software vendors such as Sun, Oracle, and Microsoft have followed suit into this new business model. They have expanded their sales methods by offering lease contracts beside their traditional one-time purchase transactions. For example, on May 10, 2001, Microsoft released new licensing agreements—Software Assurance (SA)—for enterprise customers. Microsoft will also lease software through annual leasing contracts, rather than selling software outright. Microsoft encourages customers to enter Software Assurance contracts by emphasizing the cost savings: “reduce your costs across the entire product life cycle,” “a new simpler way of obtaining upgrades to the latest and most innovative Microsoft products,” etc. Some analysts, however, have described this approach as a trick that Microsoft is playing to “effectively commit the consumers to buying operating system and application upgrades for an annual fee” (Wilcox 2001).

This paper addresses the above issue by studying the optimal licensing policy of a monopolist software vendor who provides packaged off-the-shelf products—selling or leasing his products exclusively, or adopting a mixed strategy of both sales and leases. We show that by charging different prices, the monopolist software vendor can segment the consumers based on their sensitivity to product quality and realize second-price discrimination of the consumers through their self-selection behavior.

Software vendors continuously invest in research and development to improve product quality in response to the threat from potential entrants. There are several important dimensions to software quality including speed, compatibility with available operating systems, functionalities, user interface, ease of learning, warranty, service and support, and other characteristics that affect the users' valuation of the product. It may be the *perceived quality*, which includes both real improvement and a successful marketing component. Potential buyers can assess the quality of existing software, yet the quality of the next version (upgrade) is uncertain. Users who choose early on the lease option with periodic upgrades are exposed to the risk of buying into future upgrades with unknown quality. On the other hand, users who just purchase the software can decide on buying an upgrade after the quality of the new version has been realized.

Software can be used for a period of time without replacement, although its value may depreciate. In this sense, it is a kind of a durable good. Yet software as a commodity has some special characteristics that differentiate it from other durable goods. First, it is hard to resell or appropriate because of intellectual property rights. There is no other source of a license but the original vendor, the retailers, or service providers. A second-hand market like that for used cars, therefore, does not exist for software. Second, with the development of information technology, it is easy to improve the value of already installed software through upgrades without interfering with the original customization. In addition, the use of software has a strong network externality coming from two sources:

- (1) *direct externality*: the larger the population of consumers using the software, the easier it is to get information, training, and communication about the product, so it becomes attractive to more users;
- (2) *indirect externality*: supports and other complementary products also increase with the population of adopters.

This network externality, therefore, is like the “chicken-and-egg” problem (Katz and Shapiro 1986). As a result, selling and leasing software have some common features with selling and leasing other durable goods and some special characteristics, too.

Many researchers in such academic fields as economics and marketing, as well as in business management, have studied durable goods. Coase (1972) conjectured that leasing could be more profitable than selling, because the current sale of the monopolist would cannibalize his future sale—the time-inconsistent problem. Bulow (1982) and Gul et al. (1986) have rigorously verified his conjecture. Bucovetsky and Chilton (1986), however, propose threat of entry as a reason for the monopolist to mix selling and leasing. Desai and Purohit (1998) find that leasing does not dominate selling in all cases if the depreciation of the durable goods is taken into account, and that a mixed strategy is optimal when the depreciation rates differ between selling and leasing. Yet, based on the above analysis, it is unclear whether we can apply marketing theory about selling and leasing durable goods to the distribution strategy of packaged software. Choudhary et al. (1998) study the problem of renting software from a different point of view, arguing that renting software in the first period to otherwise later adopters can increase the seller's profit. When product upgrades occur within the lease contract period, our paper demonstrates that leasing may provide a smaller profit margin than selling the software and selling the upgrade separately. However, the mixed strategy can help the monopolist seller segment the consumers into various consumption groups and successfully price discriminate based on the segmentation.

Another related stream of literature concerns product upgrades.¹ This paper discusses the upgrade problem from a different perspective from that of Fudenberg and Tirole (1998) and Padmanabhan et al. (1997), both of which suggested product upgrade as a way to deal with demand uncertainty. Our paper endogenizes the demand for goods of different qualities and distributions and relates that to the uncertainty in future product quality.

We investigate whether the “Coase conjecture” holds for special durable goods like software, that is, whether Web-based leases will become the dominant way of delivering software. We discuss leasing and selling software in a monopolist context, trying to explain the motivation for different strategies when buyers are uncertain about the future quality of the product. We analyze the optimal software distribution strategies and discuss the impact on users: (1) to provide insights into independent software vendors (ISVs); (2) to examine the differences in strategies regarding software and other durable products; and (3) to understand the effect of the selling strategies on the consumers' decision to use the software.

The rest of the paper is organized as follows. Section 2 describes the model of consumer choices and firm strategies. Section 3 provides the equilibria under pure selling and pure leasing strategies. In section 4, we present the equilibrium under the hybrid

¹This paper studies intertemporal product quality improvement, which differs from vertical product differentiation, as studied by Bhargava and Choudhary (2001), Moorthy (1984), and Mussa and Rosen (1978), among others.

licensing policy and compare it with the pure strategies. Subsection 4.3 shows the impact of network externality on market shares and firm profits. Section 5 concludes the paper.

2 MODEL

We model the intertemporal consumer behavior and the firm's strategic licensing policy with a simple two-period model. We introduce our model by first detailing the assumptions about the players—consumers and the monopoly software vendor (the ISV).

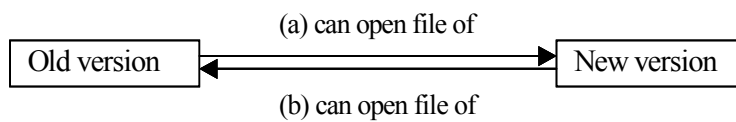
Assume that the consumers of the software product have the following form of net utility:

$$U(q,x) = \theta q + ex - p \quad (1)$$

where p and q are the price paid and the quality of the software product, respectively; x represents the population of the adopters of the product; and θ and e are the intensity of the quality preference and the network externality, respectively. Consumers are heterogeneous in their quality preference θ but are homogeneous in their sensitivity to network externality e . Consumers are indexed by their quality preference θ and are uniformly distributed on the support $[0,1]$. Similar utility functional forms can be found in Ellison-Fudenberg (2000), Mussa-Rosen (1978), and Salant (1989).

The ISV can provide the software to the market through one-time sales, leases, and sales of upgrades. Assume that there are two versions of the software. Version I, with quality q_1 , is released at the beginning of period 1. Because of ongoing development, an upgraded version with quality q_2 is released at the beginning of period 2, and $q_2 > q_1$. When the consumer makes her decision (at the beginning of period 1), q_1 is known, but the quality of the new version, q_2 , is unknown. The level of q_2 is stochastic because of the risk in doing research and development and market condition changes during period 1 and will be realized at the beginning of period 2. Consumers only know the distribution of q_2 : with probability ρ , the quality is high ($q_2 = q_2^H$) and with probability $1 - \rho$ the quality is low ($q_2 = q_2^L$). Assume that the low realized quality level in period 2 is higher than that in period 1: $q_2^L > q_1$ because the new adopters would not care to upgrade to the new version without a quality improvement.

The new version of the software is backward incompatible with the previous version. Contrary to the backward compatibility shown in Figure 1, backward incompatibility refers to the inconvenience that the users of the old version encounter when they communicate with the users of the new version.² The adopters of the new version cannot enjoy the network externality from the installed base—the users of the old version of the software. Hence, consumers who upgrade can use the new features of the latest version but cannot share applications (for example, data files) with those consumers who continue to use the old version of the software.



(a) shows forward compatibility; (b) shows backward compatibility

Figure 1. Software Compatibility

The ISV sets the selling price p_1 , the upgrade price p_u , the second-period selling price p_2 for the new version, and the per period rent p_r at the beginning of period 1. In the lease contract, the vendor is committed to keep the rent, p_r , the same during the two periods. Since the software vendor would like to attract the users to purchase in the first period and can not tell whether a buyer in the second period owns the first version, he can not charge an upgrade price p_u higher than the sale price of version II, p_2 ; that is, $p_u \leq p_2$. The consumers who purchase in the first period have the option of upgrading to the new version in period 2 at a cost of p_u , but the consumers who enter the lease contract in the first period will use the new version software without any additional charge besides the per period rent. The ISV sells only version II in the second period. Figure 2 depicts all of the available consumer choices.

²We will look at the backward compatibility problem in our later research.

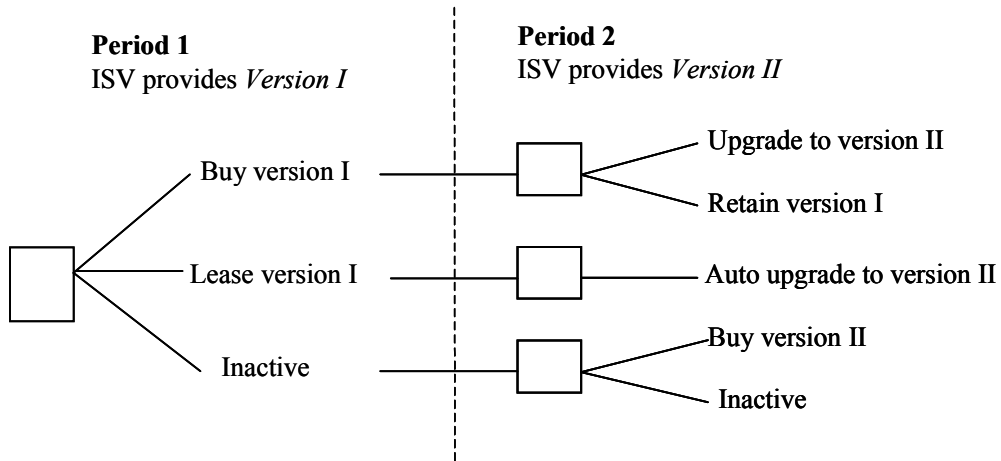


Figure 2. Consumer Strategies

The value for a risk-neutral consumer buying in the first period is

$$V_B(\theta) = \theta q_1 + ex_0 - p_1 + \beta E[\max\{\theta q_2 + ex_2 - p_u, \theta q_1 + ex_1\}]. \tag{2}$$

The total value for the buyer in (2) is given by the sum of the net utility for the users in period 1, as defined in (1), and the discounted value from the second period, when the buyer can decide to upgrade the software or to keep using version I. The discount factor is $\beta \in [0, 1]$. Here x_0 denotes the adoption population of version I of the software in the first period (including both the buyers and the lessees), x_1 denotes the adoption population that continues using version I in period 2 (those buyers in period 1 who do not upgrade to new version), and x_2 is the number of users using version II in period 2 (including both the buyers in period 1 who upgrade and the lessees).

After entering a lease contract, the lessee receives continuous streams of product with updates for a fixed annual payment. The value for entering the lease contract in the first period is

$$V_L(\theta) = \theta q_1 + ex_0 - p_r + \beta E[\theta q_2 + ex_2 - p_r]. \tag{3}$$

This value is the sum of the lessee’s net utility of using the latest version of the software over the two periods. According to the contract, she has to pay the rent p_r every period during the lease.³

Finally, the expected discounted value for a consumer inactive in the first period is

$$V_I(\theta) = \beta E[\max\{\theta q_2 + ex_2 - p_2, 0\}]. \tag{4}$$

If a consumer cannot get a positive net utility from buying the first version of the software, she will be inactive in the first period. She will wait to buy the second version of the software in period 2 if her utility of buying q_2 would be higher than the sale price p_2 .

For a consumer with quality preference θ , the expected total discounted value from using the software over the two periods is

$$V(\theta) = \max\{V_B(\theta), V_L(\theta), V_I(\theta)\}. \tag{5}$$

³Assume the penalty is large enough that breaching the contract is not optimal.

We focus our attention on the consumers' buy-or-lease decision with uncertainty regarding the quality of the next version of the software. To avoid addressing the cannibalization of the two products, we ignore the option of buying version II for the consumers who were inactive in period 1. This assumption is valid under an equilibrium in which the second-period sale price cannot be low enough to allow the early adopter to take advantage by pretending to be a new customer in period 2, or in which the quality of the new generation software only has a minor improvement from the previous version.⁴ Based on this restriction, the consumers are deprived of the option of jumping into the new version software without using the first version of the product; that is, V_I is fixed at 0.

3 PURE STRATEGIES

In this section, we analyze the pure selling or leasing strategy of the ISV and compare the effects on market competitiveness and consumer surplus. We first look at the case in which the software vendor only sells to consumers and then consider the case in which he only leases to consumers.

3.1 Pure Selling

The ISV announces the sale price for the first version of the software, p_1 , and the upgrade price, p_u , that rational consumers in period 1 should expect to pay to get version II in the next period.

At the beginning of period 1, consumers make the decision whether to buy version I. In period 2, those users who have bought version I can choose to upgrade to version II at a cost of p_u or to keep using version I. The consumers have four possible choices:

- (1) Buy version I in period 1 and upgrade to version II in period 2—(BU). The total expected discounted value over the two periods is

$$V_{BU}(\theta) = \theta(q_1 + \beta E(q_2)) + e(x_0 + \beta x_2) - (p_1 + \beta p_u). \quad (6)$$

- (2) Buy version I in period 1 but upgrade only when the quality of version II of the software is q_2^H ; otherwise, keep using version I—(BC). The total expected discounted value over the two periods is

$$V_{BC}(\theta) = \theta q_1 + ex_0 - p_1 + \beta[\rho(\theta q_2^H + ex_2 - p_u) + (1 - \rho)(\theta q_1 + ex_1)]. \quad (7)$$

- (3) Buy version I in period 1 and do not upgrade in period 2—(BH). The total expected discounted value over the two periods is

$$V_{BH}(\theta) = \theta q_1 + ex_0 - p_1 + \beta(\theta q_1 + ex_1). \quad (8)$$

- (4) Stay inactive in both periods. The value from the software product is 0.

Lemma 1: *Consumers with quality preference $\theta \in [0, q_0]$ are inactive; those with $\theta \in [q_0, q_{HC}]$ buy version I in the first period and do not upgrade in the second period when version II is available; consumers with $\theta \in [q_{HC}, q_{CU}]$ will buy the software in period 1 and upgrade contingent on the realized quality of version II in period 2; the rest of the consumers will always use the latest version of the software during the two periods.*

Proof: Since the slopes of the values from the different options, $V_{BU}(\theta)$, $V_{BC}(\theta)$, and $V_{BH}(\theta)$, with respect to q are different, $0 < V'_{BH}(\theta) < V'_{BC}(\theta) < V'_{BU}(\theta)$, we can conjecture the segmentation of the market as shown in Figure 3 if $\theta_0 > 0$.

⁴We will relax this assumption and discuss its validity in detail in future research.

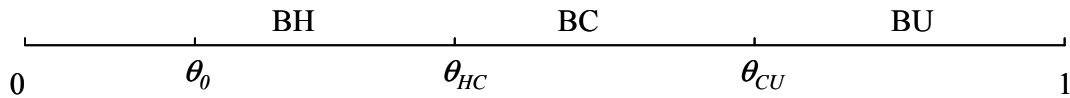


Figure 3. Market Segmentation in the Pure Selling Market

Let consumer θ_0 be the marginal consumer who is indifferent to being inactive and the BH strategy. Then the value of θ_0 can be solved from $V_{BH}(\theta_0) = 0$. We get $\theta_0 = \frac{p_l - e(x_0 + \beta x_1)}{(1 + \beta)q_1}$. The cutoff values θ_{HC} and θ_{CU} can be obtained by equating the values to which the consumer is indifferent; that is,

$$V_{BH}(\theta_{HC}) = V_{BC}(\theta_{HC}) \tag{9}$$

$$V_{BC}(\theta_{CU}) = V_{BU}(\theta_{CU}) \tag{10}$$

Solving (9) and (10), we get

$$\theta_{HC} = \frac{p_u - e(x_2 - x_1)}{q_2^H - q_1} \tag{11}$$

$$\theta_{CU} = \frac{p_u - e(x_2 - x_1)}{q_2^L - q_1} \tag{12}$$

Because the population of potential user is uniformly distributed on the $[0, 1]$ support by assumption, we plug

$$\begin{aligned} x_0 &= 1 - \theta_0 \\ x_1 &= (1 - \rho)(\theta_{CU} - \theta_{HC}) + \theta_{HC} - \theta_0 \\ x_2 &= 1 - \theta_{CU} + \rho(\theta_{CU} - \theta_{HC}) \end{aligned}$$

into (11) and (12). Solving them simultaneously, we get the market segmentation of the consumers in response to the seller's price schedule p_l and p_u .

Taking into account the consumers' self-selection behavior, the ISV sets prices p_l and p_u to maximize his discounted total profit over the two periods:

$$\begin{aligned} \max_{p_l, p_u} \Pi^s(p_l, p_u) &= p_l x_0(p_l, p_u) + \beta p_u x_2(p_l, p_u) \\ \text{s.t.} \quad \begin{cases} x_0 \geq 0 \\ x_2 \geq 0 \end{cases} \end{aligned} \tag{13}$$

The profit function is joint concave in a range of parameters Ω_1 . If the value of the parameters $\beta, \rho, e, q_l, q_2^H, q_2^L \in \Omega_1$, we have the optimal price schedule for the ISV, which is

$$p_l^s = \frac{(1 + \beta)q_1}{2} \quad \text{and} \quad p_u^s = \frac{(q_2^H - q_1)(q_2^L - q_1)}{2((1 - \rho)q_2^H + \rho q_2^L - q_1)} \tag{14}$$

Here we use the superscript s of the prices to represent the equilibrium under the pure selling strategy. The ISV gets profit $\Pi^s(p_1^s, p_u^s)$.

3.2 Pure Leasing

With the emergence of Internet technologies, software can be delivered through the Web, so leasing becomes a selling option for the software vendor. Suppose that the ISV offers a take-it-or-leave-it lease contract over two periods. If a user takes it, she will pay rent p_r at the beginning of each period and enjoy the latest version of the software without any additional charge.

The expected discounted value for a consumer who takes the lease is given in (3). Consumers with $\theta \geq \theta_L$ will get positive utility from the contract. The level of θ_L can be obtained by solving $V_L(\theta_L) = 0$:

$$\theta_L = \frac{(1 + \beta)p_r - e(x_0 + \beta x_2)}{q_1 + \beta E(q_2)}. \quad (15)$$

Replacing x_0 and x_2 by $1 - \theta_L$, we have

$$\theta_L = \frac{(1 + \beta)(p_r - e)}{q_1 + \beta E(q_2) - e(1 + \beta)}. \quad (16)$$

Given the consumers' choice (15), the ISV sets the optimal rent in the lease contract to maximize his discounted total profit from the two-period contract:

$$\begin{aligned} \max_{p_r} \Pi^l(p_r) &= (1 + \beta)p_r(1 - \theta_L) \\ \text{s.t. } \theta_L &\leq 1 \end{aligned} \quad (17)$$

When the value of the parameters $\beta, \rho, e, q_1, q_2^H, q_2^L \in \Omega_2 = \{q_1 + \beta E(q_2) > (1 + \beta)e\}$, we have the optimal price schedule for the ISV, which is

$$p_r^l = \frac{q_1 + E(q_2)}{2(1 + \beta)}. \quad (18)$$

Here we use the superscript l of the price to represent the equilibrium under the pure leasing strategy. The ISV gets profit $\Pi^l(p_r^l)$.

4 CONCURRENT LEASING AND SELLING

The monopolist ISV offers consumers a hybrid choice of buying and leasing the software at the beginning of period 1. In this section, we develop the optimal pricing policy for this hybrid selling strategy and compare the results with those under the pure selling or pure leasing. For simplicity, we ignore the inactive consumers in the first period and focus on the consumers' buy-or-lease decision.

The consumers make decisions about whether to pay an up-front fee to buy the software and have the choice of upgrading in the second period or to lease and get the upgrade automatically without knowing the exact quality of the next version. To buy and upgrade later provides an option to the consumers with respect to the two-period lease of the software.

We consider the equilibrium with the consumer segmentations as shown in Figure 4.

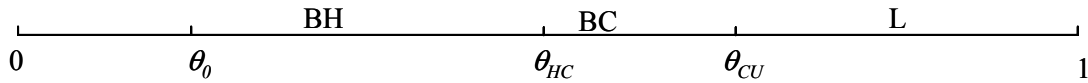


Figure 4. Customer Segmentation in the Concurrent Selling and Leasing Market

This equilibrium requires $(1 + \beta)p_r < p_1 + \beta p_u$; that is, the consumers, who are highly sensitive to software quality, must be encouraged by a discount to participate in the lease contract. Otherwise, with the same gain in using the software, they would prefer the buy-and-upgrade (BU) way of getting the software because of the flexibility of choosing whether to upgrade in period 2. The difference between the two discounted total payments provides an incentive to make the leasing policy attractive to the targeted high θ consumers under the mixed licensing policy. We can see from the following analysis that the vendor, with the optimal pricing, does not incur any loss from providing this discount. The four segments of consumers according to their sensitivity to quality are the following:

- (1) When $\theta \geq \theta_{CL} = \frac{e(x_1 - x_2)}{q_2^L - q_1} - \frac{p_1 + \beta \rho p_u - (1 + \beta)p_r}{(1 - \rho)\beta(q_2^L - q_1)}$, consumers greatly value high quality, so they would always prefer using the latest version of the software product. These consumers can avoid paying the option value embedded in the purchasing method of using software by giving up the option of staying at the status quo. Their expected value from leasing is higher than that from purchasing and upgrading, so they all lease.
- (2) When $\theta \in [\theta_{HC}, \theta_{CL})$, the consumers act contingently in the second period after they buy the software in period 1; that is, they upgrade if the quality of the second version is q_2^H , and otherwise they will hold to the old version. Their expected value can be expressed the same as that for $V_{BC}(\theta)$ in the pure selling model (equation (7)).

A consumer in this segment values the option of keeping the old version more than using a higher quality product at an extra cost of upgrade. She will upgrade contingent on the realized second-period quality.
- (3) When $\theta \in [\theta_0, \theta_{HC})$, the consumers do not care as much about the quality of the software as those in the BC and L segments, so they will not upgrade if they buy in the first period. Their expected value can be expressed the same as that for $V_{BH}(\theta)$ in the pure selling model (equation (8)).
- (4) For consumers with $\theta \in [0, \theta_0)$, the utilities of using the software are negative. They would be inactive in the market for both periods.

Proposition 1: *The optimal prices the ISV charges when he uses the hybrid distribution methods are sale price of the first version $(1 + \beta)q_1/2$, upgrade price $(q_2^H - q_1)/2$, and per period lease price $\frac{\beta E(q_2) + q_1}{2(1 + \beta)}$.*

Proof: See Seidmann and Zhang (2002).

When there exists uncertainty about the quality of the second version of the software, buying the software in the first period has an option value because it allows a decision whether to upgrade after the quality of the second version becomes known. The value of this option for those consumers who always adopt the highest quality product is

$$p_1 + \beta p_u - (1 + \beta)p_r = \frac{\beta}{2}(q_2^H - E(q_2)) = \frac{\beta}{2}(1 - \rho)(q_2^H - q_2^L). \tag{19}$$

This value is zero when the uncertainty disappears: $q_2^H = q_2^L$.

4.1. Without Quality Uncertainty

When there is no uncertainty about the next generation software, that is, $q_2 = q_2^H = q_2^L$, there will be only three possible choices for consumers under the hybrid licensing policy. They can decide to buy and upgrade (BU), buy and hold (BH), or be inactive over the two periods. The consumers are segmented by two cutoff values: $\theta_{HU} = \frac{(1+\beta)p_r - p_1 - e\beta(x_2 - x_1)}{\beta(q_2 - q_1)}$ and θ_0 .

Proposition 2: *In this setting, the consumers are segmented into three parts: Consumers with quality preference $\theta \in [0, \theta_0)$ are inactive; consumers with $\theta \in [\theta_0, \theta_{HU})$ buy the full version in the first period and stay with it for the second period; consumers with $\theta \in [\theta_{HU}, 1]$ are indifferent between leasing for two periods and buying in the first period and upgrading in the second period.*

The equilibrium in the hybrid sales channel leads to the same consumer segmentation and ISV profit as the pure selling equilibrium. Because the quality is public knowledge to all the consumers, the total discounted price charged to lease and buy-and-upgrade customers should be the same in order to eliminate an arbitrage opportunity: $(1 + \beta)p_r = p_1 + \beta p_u$. Given this constraint, the optimal price schedule the ISV charges is as in Proposition 3.

Proposition 3: *There exists a feasible set of parameter values such that the profit-maximizing problem of the ISV is joint concave of the sale and lease price. Hence, a unique equilibrium exists under which the ISV charges sale price of the first version $(1+\beta)q_1/2$, upgrade price $(q_2 - q_1)/2$, and per period lease price $\frac{q_1 + \beta q_2}{2(1+\beta)}$.*

Thus, the ISV can price-discriminate based on the users' preference regarding the quality of the software. In the two-period model, the ISV can perfectly discriminate between the consumers who want to upgrade in the next period and those whose perception of the increased value of the new version does not justify the upgrade fee. Without uncertainty about the quality of the next version of the software, the ISV, however, cannot discriminate between the consumers who purchase the upgrade in the second period and those who lease and get the upgrade automatically. When the quality of the new generation software is nonstochastic, the ISV and the consumers gain the same from either the mixed or the pure selling policy.

4.2 Comparison with Pure Selling and Leasing

With the existence of uncertainty about the quality of version II of the software, we compare the market structure and the ISV's profit among the three selling strategies: pure selling, pure leasing, and concurrent selling and leasing.

First, we compare the pure selling model with the hybrid model. We have the following conclusions from our stylized model.

Proposition 4: *The monopolist ISV gets the same market share under both the pure selling and the hybrid licensing policies. Yet with the hybrid licensing policy, he can better segment the market and price discriminate by reducing the number of consumers acting contingently.*

The population of buy-and-upgrade (BU) consumers increases under the hybrid licensing policy, and so does the population of buy-and-hold consumers (BH). The software vendor can better discriminate among the consumers through the mix of licensing policies and the corresponding self-selection behavior by the consumers. Thus, the segment of consumers choosing the option of buying and upgrading contingently (BC) narrows under the hybrid policy.

Proposition 5: *The ISV gets more profit through the hybrid licensing policy. The gain is proportional to the variance of the quality of the version II of the software.*

Under the pure selling licensing policy, the software vendor charges the same upgrade price p_u for all of the consumers with $\theta \geq \theta_{HC}$. Under the hybrid licensing policy, he is empowered with one more decision variable—the rent of the lease contract p_r , which turns out to be a useful tool for him to control the consumers through more refined price discrimination. By narrowing these segments of the consumers, the ISV can reduce the downside risk of the quality uncertainty on his profit. Thus, the higher the variance of quality of version II of the software, the higher the gain of the software vendor from adopting the hybrid licensing policy. This result is consistent with what we have in subsection 4.1 for the zero variance case.

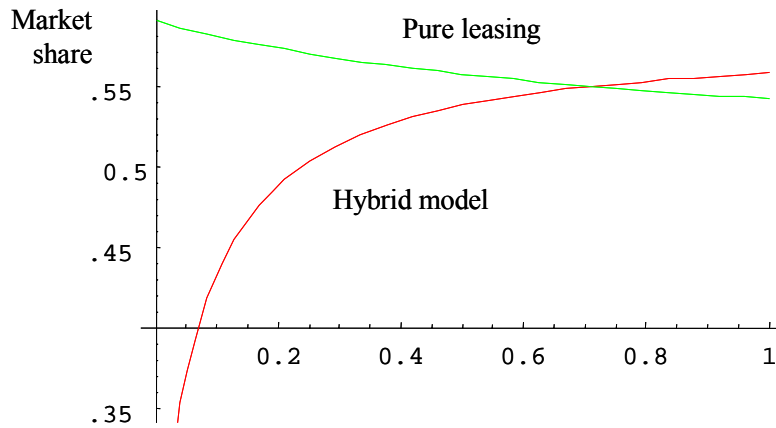


Figure 5. The Market Share of the ISV under the Pure Leasing and Hybrid (Pure Selling) Licensing Policies When ρ ($\Pr[q_2] = q_2^H$) Changes from 0 to 1, Given $\beta = 0.8, e = 0.18, q_1 = 1, q_2^L = 1.4, q_2^H = 4$

Because the analytical results are not very straightforward, we use numerical examples to compare the pure leasing model with the other two models. The total market share under the leasing policy could be higher or lower than that under the other policies (Figure 5), depending on the value of the parameters.

The intuition behind this is as follows: because the quality preference is private information for each consumer, the ISV must trade off a higher market share (attracting more low quality preference consumers locked in by the leasing contract) with a higher profit margin (extracting more value from the high quality preference consumers). The optimal strategy for the ISV depends on the relative quality level of the different versions of software, the discount rate, and the intensity of the network externality effect.

The hybrid licensing policy brings about the highest profit for the ISV among the three policies (Figure 6). Compared with the pure leasing model, the hybrid model enables the ISV to set a purchase price in period 1 to capture those low θ consumers with the least conflict with his leasing rents. Thus, this hybrid model proves to be an effective tool to increase the ISV's price discrimination power and makes him better off.

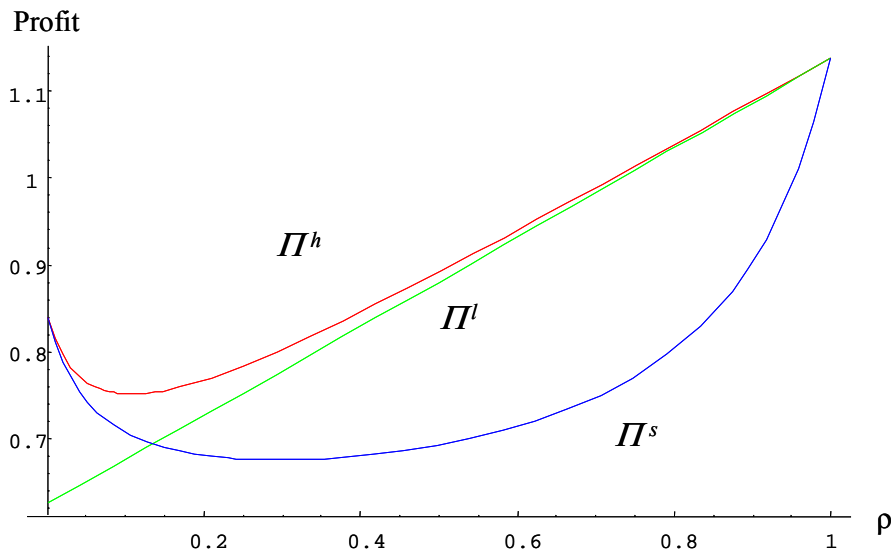


Figure 6. The Profits of the ISV under the Three Licensing Policies When ρ Changes from 0 to 1, Given $\beta = 0.8, e = 0.18, q_1 = 1, q_2^L = 1.4, q_2^H = 4$

4.3 The Network Externality Effect

The optimal prices are independent of the network externality term, but the market share is increasing with the network externality effect. In all of the market structures, the total market share is larger than half, which is the monopoly market share without the network externality effect.

Proposition 6: *The market shares in all of the models are strictly increasing with network externality intensity e .*

The network effect, therefore, helps the vendor to gain a greater market share. Similarly, we can prove that the profit in the pure leasing model is increasing with the network externality intensity e .

5 CONCLUSIONS AND LIMITATIONS

Software is different from conventional durable goods because of the low marginal production cost, the network externality in its distribution, it is easy to upgrade, and strict intellectual property protection exists. Thus, the Coase conjecture discussed in the durable goods literature does not apply to the software distribution strategy. Our paper fills in this gap by developing a model combining vertical differentiation and intertemporal price discrimination. Using the model, we find a market segmentation strategy for a software vendor to classify consumers by their quality preferences through different selling strategies. In the presence of quality uncertainty, the vendor finds it optimal to set different prices and selling methods, catering to the different preferences of the consumers with regard to quality. The monopolist vendor gets the same market share under both the pure selling and the hybrid licensing policies. Yet with the hybrid licensing policy, the vendor can better segment the market and price discriminate the consumers by reducing the number of consumers acting contingently. This paper provides insight into software vending: when there exists heterogeneity of quality preferences among consumers and uncertainty with regard to product innovations and upgrades, it is optimal to adopt the hybrid rather than the perpetual or pure leasing licensing policy.

There are some limitations in this paper. In order to discuss the selling and leasing of software products in a simple and insightful model, we ignore some of the minor issues, which will not affect the results very much. For example, we rule out the case that consumers wait until the second period when the quality of the product is high and the network externality for the product is strong enough to use the software. The backward incompatibility assumption in our model underscores the network externality of the new version of the software product. All of those assumptions reduce the applicability of the paper. But on the other hand, we gain from the assumptions a relatively simple closed form solution. We will certainly address those questions and test our results in the further research.

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