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Leasing versus selling: marketing strategy choice in durable goods oligopolies

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Abstract This paper examines firms' strategic choice between leasing and selling in a market for horizontally differentiated durable goods. We show that firms' decisions on marketing strategy may lead to socially inefficient outcomes: firms choose leasing even though direct sales are socially more desirable. Moreover, a prisoners' dilemma situation may arise: firms choose leasing while they could be better off by selling together. We also discuss on the impact of the advance of information infrastructure on the marketing practice in software markets.

Keywords Leasing, Durable Goods, Horizontal Differentiation, Software.
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1 Introduction

Many durable goods are not only sold outright but also leased. Traditional examples include automobile, photocopy machine, ship and aircraft, computer and factory machinery. In this paper, we pay a particular attention to software industries which are now experiencing a major shift in firms' marketing strategies from direct selling to leasing (renting). Since the late 1990's there has been a rapid growth in the number of software products which are rented rather than bought outright. The main idea is treating software as a service (SaaS) and delivering it as a subscription-based utility, like water or electricity. Many application service providers (ASPs) have emerged recently. They typically own, operate and maintain their own servers supporting software services over the Internet, and bill on a per-use basis or on a monthly/annual fee. For instance, Salesforce.com, one of the leading company in the market, is reported to have more than 2,000 customers, mostly small and medium-sized firms, which pay a monthly fee of $50 per salesperson hooked up to its leasing service.[1] Nowadays it is not only small venture IT firms who have a stake in this new business. Several large-sized renowned companies, such as Microsoft, Oracle and Google, have started to compete in the rent-a-software market. IDC, a market research company, estimates that ASPs' overall revenues will grow to $9 billion by 2008.[2]

It is well known that a durable-goods "monopolist" suffers from time consistency, and leasing can be used as a solution to this problem (see Bulow (1982) and others).[3] This result, however, is valid only in monopoly, and the strategic implication of the two marketing strategies, selling or leasing, in "oligopoly" has not been fully explored. Bulow (1986) analyzes a two-period quantity setting game and finds that firms generally use a mixture of sales and leasing in equilibrium. He also shows that selling tends to be a more attractive strategy when the firms face high demand elasticities (they choose to sell rather than lease under severe competitive pressure from the rivals). Saggi and Vettas (2002) extend Bulow's model by allowing marginal costs of production to vary across firms. They show that the inefficient firm leases more than the efficient firm, and an increase in unit costs leads to a higher ratio of leased units to sales.[4] Their analyses rely on quantity competition frameworks à la Cournot, in which prices are still constrained by time consistency, which does not seem to fit well with the nature of competition in software markets.

[1] See "Gathering steam", *Economist*, 04/14/2001 and also "At your service", *Economist*, 5/10/2003.

[2] "If in doubt, farm it out". *Economist*, 10/30/2004.

[3] The result, however, may change if, for instance, the monopolist faces the threat of entry (Bucovetsky and Chilton, 1986) or adverse selection problems (Hendel and Lizzeri, 2002), or when consumers can invest in a bypass technology (Laffont and Tirole, 1996). See Waldman (2003) for an excellent survey of economic issues related durable good markets.

[4] Desai and Purohit (1999) carry out an empirical study in new car leasing markets where firms are engaged in oligopolistic competition.

This paper examines firms' decisions on marketing strategy (i.e. leasing versus selling) in a market where they compete in price with horizontally differentiated products à la Hotelling.[5] As usual in the Hotelling model, we assume that the market is covered in equilibrium. So, our analysis rules out the role of leasing in solving the traditional time-inconsistency problem. Instead, we focus on the pure strategic interaction between firms over the choice between leasing and selling and its welfare consequence.[6] We simplify the model by neglecting other factors that may affect firms' choice between leasing and selling such as adverse selection and moral hazard.[7] Depending on the relative cost of leasing to selling, three different equilibria can emerge: i) both leasing, ii) both selling, and iii) one leasing and the other selling. Leasing is a more attractive option than selling in asymmetric equilibria where firms' marketing strategies are differentiated. Consumers shirk from buying, expecting sale or rental price reductions in the future, which hurts the selling firm by reducing its sales in the early stage. This strategic effect may lead firms to adopt leasing, even though selling is socially more efficient than leasing.[8] This is in contrast with the previous result obtained under Cournot competition (Bulow, 1986; Bucovetsky and Chilton, 1986; Saggi and Vettas, 2000), where leasing is less attractive since it results in loss of the future market share. We also find a situation of prisoners' dilemma can occur: firms choose to lease even though profits would be larger if they could coordinate on selling together.[9] Not surprisingly the marketing revolution in the software market explained above is mainly due to the information and communications technologies, notably the Internet, which made it possible to offer software as a rental service. In the conclusion, we briefly discuss on the impact of the advance of information infrastructure on firms' marketing strategy choices and its welfare implication.

In terms of the model structure, this paper is closely related to the customer poaching model of Fudenberg and Tirole (2000), where two firms selling differentiated nondurable goods can offer short-term and long-term contracts (which are similar to leasing and selling in our model respectively). However, the focus of analysis differs between the two. Fudenberg and Tirole analyze consumer poaching via price discrimination based on consumer recognition, and show that long-term contracts play the role of hindering rivals

[5] An advantage of using Hotelling-style address models is that we can clearly identify who actually buys and rents, which is not clear in the Cournot framework.

[6] Even with full consumer participation, a dynamic price pattern arises when firms choose different marketing strategies, the source of which, however, is quite different from the standard monopoly Coasian dynamics.

[7] See, for example, Johnson and Waldman (2003) for an analysis of leasing policy with adverse selection in new car markets.

[8] This result echoes the Bulow's general result in the sense that the firms in our model face inelastic demands because of product differentiation.

[9] There is a prisoners' dilemma in Cournot competition as well. However, in Cournot competition it turns out that firms choose to sell even though leasing is more profitable, the opposite to this Hotelling case.

from poaching consumers. In contrast, our main focus is on the firms' strategic choices between two marketing strategies incurring different implementation costs. The main message and its welfare implication are also quite different. In our model the welfare loss comes from firms choosing more expensive marketing strategies in equilibrium, while in Fudenberg and Tirole the source of inefficiency is the increased transportation costs induced by customer switching.

2 The model

Following Hotelling (1929), product differentiation is captured by assuming that there is a product space characterized by the unit interval $[0, 1]$. There are two firms located at the extremities of the interval; firm A at $x = 0$ and firm B at $x = 1$. The goods produced by the firms last two periods, and are perfectly durable without depreciation. For simplicity, the marginal and fixed costs of production are assumed to be constant, and moreover normalized to zero. Consumers are uniformly distributed with density 1 along the interval. They have unit demands per period, and derive a per-period gross surplus from consumption equal to v. Assume that v is sufficiently large so that the market is covered in equilibrium in both periods (more precisely, $v \geq \frac{3}{2}t$). In each period, a consumer located at $x \in [0, 1]$ incurs a transportation cost (disutility) of tx when consuming firm A's good and $t(1 - x)$ when consuming firm B's good, where $t > 0$ denotes unit transportation costs.

We analyze a three-stage game. In period 0, the two firms simultaneously decide on their marketing strategy, i.e. whether to sell or lease their products.[10] Implementing the chosen marketing strategy is costly (e.g. setting up distribution channels, personnel, IT, and training systems, etc.), and the cost is constant and is given by $F_l > 0$ and $F_s > 0$ for leasing and selling respectively.[11] We also examined a setup with positive marginal costs of selling and leasing and found that the qualitative results remain the same. In order to focus on firms' strategic choice between leasing and selling, we assume that both costs are large enough that the firms do not wish to use both marketing strategies simultaneously.[12] Note that the firms do not have incentives to change their marketing strategy between periods since leasing and selling are virtually the same in period 2 (the

[10] Here we assume that under leasing, contracts are renewed every period. That is, we rule out long-term leasing contracts that are essentially the same as selling in this two-period setup.

[11] We do not impose any restriction on F_l and F_s other than strict positivity. In reality, however, the setup cost seems higher for leasing than selling. Leasing involves many additional business activities, such as maintenance, record-keeping, billing, and inspection, other than just handing over the property right of the good.

[12] In fact, in the present setup the dual use of leasing and selling leads to prices being determined so that consumers are indifferent between renting and buying in equilibrium. This problem can be circumvented by assuming that consumers are differentiated in their relative preferences for renting and buying.

last period).[13] Given the binary and irreversible decisions on marketing strategy, the firms compete in price in periods 1 and 2 consecutively (more specifically they choose their prices simultaneously in each period). The firms and consumers have a common discount factor, normalized to 1 without loss of generality. All agents have complete and perfect information, and have perfect foresight on future outcomes. Finally, there are no upgrades or technological innovations in the time horizon considered.

3 Price equilibrium

We look for a subgame-perfect (pure-strategy) Nash equilibrium of the three-stage game using backward induction. The firms' marketing strategy decisions in period 0 give rise to three possible subgames: i) both firms sell, ii) both firms lease, and iii) one firm sells and the other leases. We derive the price equilibrium of each subgame in this section. Let p_i^j and r_i^j respectively denote the sale and rental price charged by firm j in period i, where $i = 1, 2$ and $j = A, B$.

3.1 Both firms sell

Suppose that in period 0 both firms decided to sell. First, consider the situation in which all customers buy either product in the first period. This is identical to the standard Hotelling model, except that consumers' (gross) surplus and transport costs are summed over the two periods. A consumer who is indifferent between buying from firm A and buying from firm B in period 1 is located at x_s, where x_s is given by

$$2v - p_1^A - 2tx_s = 2v - p_1^B - 2t(1 - x_s).$$

The standard calculation gives the equilibrium sale prices $p_1^A = p_1^B = 2t$ and each firm's profit $\Pi_{ss}^A = \Pi_{ss}^B = t - F_s$.

In some cases, however, it may not be the unique equilibrium in this subgame. For some parameter values, another equilibrium may exist with some consumers delaying their purchase until the second period. But this does not alter our conclusions qualitatively, as shown in the Appendix.

3.2 Both firms lease

Suppose that in period 0 both firms decided to lease. Then, we have the standard Hotelling pricing game being repeated over two periods. Let x_r denote the location of consumers who are indifferent between renting from firm A and renting from firm B in period i, i.e.

$$v - r_i^A - tx_r = v - r_i^B - t(1 - x_r).$$

[13] This irreversibility may also come from high setup and/or switching costs.

Then, the equilibrium per-period rental prices are $r_i^A = r_i^B = t$, and in equilibrium each firm earns total profit of $\Pi_{ll}^A = \Pi_{ll}^B = t - F_l$.

Note that revenues are the same under selling and leasing, provided both firms adopt the same marketing strategy. This is not surprising given that there is no time-inconsistency problem. A question then naturally arises as to whether a firm has incentives to sell (lease) when their rival leases (sells), which we examine next.

3.3 One firm sells and the other leases

Let us now consider the cases where one firm (firm A) leases and the other (firm B) sells. This subgame, unlike the previous two, exhibits some strategic interactions over the two periods in terms of the firms' pricing policies and consumers' decisions on buying or renting. For instance, consumers who rented in period 1 retain some degree of flexibility and may wish to switch to the other firm's product in period 2. The utility of a consumer located at x is given by

$$\begin{cases} v - r_1^A - tx + \widetilde{v}(x) & \text{if she rents from firm } A \text{ in period 1} \\ v - p_1^B - t(1-x) + \widehat{v}(x) & \text{if she buys from firm } B \text{ in period 1} \end{cases},$$

where $\widetilde{v}(x) = \max\{v - r_2^A - tx, v - p_2^B - t(1-x)\}$ and $\widehat{v}(x) = \max\{v - r_2^A - tx, v - t(1-x)\}$. Let x_1 denote the location of consumers who are indifferent between renting from firm A and buying from firm B in period 1, i.e.

$$v - r_1^A - tx_1 + \widetilde{v}(x_1) = v - p_1^B - t(1-x_1) + \widehat{v}(x_1).$$

Note that if a consumer bought a product in period 1 and decides to rent a different product in period 2 her previously owned product becomes obsolete.

Let x_2 denote the location of consumers who are indifferent between consuming firm A's product and firm B's product in period 2. We first solve for the second-period price equilibrium for a given x_1, and then determine the equilibrium value of x_1 later. The following lemma says that the consumers who bought a product early never choose to rent a different product later in equilibrium.[14]

Lemma 1 *When one firm sells and the other leases, it never holds that $x_2 > x_1$ in equilibrium.*

Proof. See the Appendix. ■

[14] The logic behind this result is quite straightforward. Suppose the leasing firm reduces its second-period rental price in order to enlarge its second-period demand. The price reduction needs to be sufficiently large to attract any previous buyers of firm B's product, and, in fact, the marginal effect from the price reduction (profit gains from market expansion) is always dominated by the inframarginal effect (profit losses from its own previous customers).

What actually happens in period 2 is that the firms compete over a group of consumers who previously rented from firm A. Clearly, given that $t > 0$ firm B will try to poach the former customers of firm A.

Suppose that $x_2 \leq x_1$ in equilibrium, i.e. some of the previous renters from firm A choose to buy firm B's product in period 2. Then the second-period indifference location (x_2) should satisfy

$$\begin{aligned} v - r_2^A - tx_2 &= v - p_2^B - t(1 - x_2) \\ \Longrightarrow x_2 &= \frac{p_2^B - r_2^A + t}{2t}. \end{aligned}$$

The second-period demand is x_2 for firm A and $x_1 - x_2$ for firm B, and each firm's second-period profit is given by

$$\Pi_2^A(r_2^A, p_2^B) = r_2^A \frac{p_2^B - r_2^A + t}{2t}$$

and

$$\Pi_2^B(r_2^A, p_2^B) = p_2^B(x_1 - \frac{p_2^B - r_2^A + t}{2t}).$$

From the first-order conditions of the second-period profit-maximization problem, the equilibrium second-period rental and sale prices are given by $r_2^A = \frac{2x_1 + 1}{3}t$ and $p_2^B = \frac{4x_1 - 1}{3}t$, and the equilibrium second-period indifferent location is $x_2 = \frac{2x_1 + 1}{6}$. Thus, each firm's second-period profit is

$$\Pi_2^A = \frac{t}{18}(2x_1 + 1)^2$$

and

$$\Pi_2^B = \frac{t}{18}(4x_1 - 1)^2.$$

In this case, the first-period indifferent location x_1 should satisfy

$$\begin{aligned} 2v - r_1^A - p_2^B - tx_1 - t(1 - x_1) &= 2v - p_1^B - 2t(1 - x_1) \\ \Longrightarrow x_1 &= \frac{3(p_1^B - r_1^A) + 4t}{10t}. \end{aligned}$$

The total profit for each firm is then given by

$$\begin{aligned} \Pi_{ls}^A(r_1^A, p_1^B) &\equiv r_1^A x_1 + \Pi_2^A - F_l \\ &= r_1^A \frac{[3(p_1^B - r_1^A) + 4t]}{10t} + \frac{\left[p_1^B - r_1^A + 3t\right]^2}{50t} - F_l \end{aligned}$$

and

$$\begin{aligned} \Pi_{ls}^B(r_1^A, p_1^B) &\equiv p_1^B(1 - x_1) + \Pi_2^B - F_s \\ &= p_1^B \frac{[3(r_1^A - p_1^B) + 6t]}{10t} + \frac{[2(p_1^B - r_1^A) + t]^2}{50t} - F_s. \end{aligned}$$

From the first-order conditions we obtain the equilibrium first-period rental and sale prices as $r_1^A = \frac{10}{7}t$ and $p_1^B = 2t$.[15] Then, the equilibrium indifference types are $x_1 = \frac{4}{7}$ and $x_2 = \frac{5}{14}$, and the equilibrium first-period rental and sale prices are given as $r_2^A = \frac{5}{7}t$ and $p_2^B = \frac{3}{7}t$.[16] Hence, these prices constitute an equilibrium of the subgame, at which firm A's total profit is $\Pi_{ls}^A = \frac{15}{14}t - F_l$ and firm B's total profit is $\Pi_{ls}^B = \frac{93}{98}t - F_s$.

Three observations are noteworthy. First, both rental and sale prices decrease over time. Note, however, that this price pattern is not ascribed to the standard time-inconsistency problem faced by durable goods monopolists, but to more intense competition induced by the reduced market size (i.e. less heterogeneous consumers) in period 2. Second, the leasing firm gets a larger profit (less costs) than the selling firm; consumers, expecting sales and rental price reductions in period 2, tend to shirk from buying in period 1, which hurts the selling firm by reducing the purchasing demand in period 1. Third, the industry profit (less costs) is greater at this asymmetric equilibrium compared with the previous two symmetric equilibria where both firms sell or rent. We know that in the standard Hotelling model location differentiation loosens price competition. The same logic applies here: the differentiation in marketing strategies between the firms further reduces the intensity of price competition.

4 Marketing strategy decisions

The following table summarizes the total profits obtainable by the firms depending on their choices between leasing and selling in period 0.

Table 1: Marketing strategy game

Firm A \ Firm B	LEASE	SELL
LEASE	$t - F_l, t - F_l$	$\frac{15}{14}t - F_l, \frac{93}{98}t - F_s$
SELL	$\frac{93}{98}t - F_s, \frac{15}{14}t - F_l$	$t - F_s, t - F_s$

To ensure that the firms earn nonnegative profits we assume that $F_l \leq t$ and $F_s \leq \frac{93}{98}t$, which imply

$$-\frac{93}{98}t \leq F_l - F_s \leq t. \tag{1}$$

[15] The second-order conditions are satisfied.

[16] Note that the supposition $x_2 \leq x_1$ is satisfied.

Then, the proposition below together with the equilibrium prices derived in the previous section characterizes the equilibrium of the entire game.

Proposition 2 *Assume condition (1) holds. Then, in equilibrium i) both firms lease if* $F_l - F_s \leq \frac{5}{98}t$*, ii) one firm leases and the other sells if* $\frac{5}{98}t \leq F_l - F_s \leq \frac{7}{98}t$*, and iii) both firms sell if* $F_l - F_s \geq \frac{7}{98}t$

Proof. Immediate from the following two relationships: $t - F_l \gtreqless \frac{93}{98}t - F_s \Leftrightarrow F_l - F_s \lesseqgtr \frac{5}{98}t$ and $\frac{15}{14}t - F_l \gtreqless t - F_s \Leftrightarrow F_l - F_s \lesseqgtr \frac{7}{98}t$. ■

The equilibrium configuration of marketing strategies depends on the relative cost of the two marketing strategies. When the cost of leasing is sufficiently larger than selling, selling turns out to be a dominant strategy for both firms. As the relative cost of leasing falls, we have two Nash equilibria where the two firms differentiate in their marketing strategies. In this case, profit is larger the leasing firm than the selling firm, and therefore there is a first-mover advantage in choosing between leasing and selling in period 0. When the cost of leasing is sufficiently close to that of selling, both firms lease in equilibrium. In particular, for $0 < F_l - F_s \leq \frac{5}{98}t$ the firms face a situation of prisoners' dilemma: they choose to lease in equilibrium even though both could benefit by coordinating on selling together.

5 Welfare analysis

Let us examine the welfare implication of firms' strategic decisions on marketing strategy. As usual, social welfare is defined as the sum of consumer surplus and firms' profit (equivalent to consumers' gross surplus less costs). Given that all consumers participate in equilibrium, the social planner's problem is to choose the firms' marketing strategies that minimize the total cost (the sum of costs and consumers' transportation costs). The total transportation cost is minimized when the market is evenly divided between the two firms.

Lemma 3 *The welfare-maximizing configuration of marketing strategies is "both firms leasing" for* $F_l \leq F_s$ *and "both firms selling" for* $F_l \geq F_s$*.*

Proposition 4 *The firms' marketing strategy decisions are inefficient when* $0 < F_l - F_s \leq \frac{7}{98}t$*.*

For $0 < F_l - F_s \leq \frac{5}{98}t$, the firms choose leasing even though it is more costly than selling. In this case, the firms would be mutually better off by selling together (a prisoners'

dilemma). This implies that a (weak) Pareto-improvement can be achieved if the firms coordinate on their marketing strategies. For $\frac{5}{98}t < F_l - F_s \leq \frac{7}{98}t$, the firms choose to use different marketing strategies, leading to an inefficient allocation of transportation costs in addition to the inefficiency caused by the firm adopting the leasing strategy.

6 Conclusion

This paper has shown that in a market for horizontally differentiated durable goods firms' strategic choices between leasing and selling may lead to socially inefficient outcomes. They may well choose to lease even though it is more costly than selling. Also, we identified a situation where a Pareto-improvement is possible when firms can coordinate on their marketing strategy decisions.

As the information technology and infrastructure (e.g. broadband network) advances, the cost of leasing software over the Internet will continue to fall. This change of relative cost between two marketing strategies in favor of leasing will lead firms to adopt leasing rather than selling. But, our analysis reveals that the result may be somewhat paradoxical. In contrast to the casual expectation, the advance of information and communications technologies may have a negative effect on social welfare due to the firms' strategic interactions over the marketing strategy choice, unless the cost advantage of leasing is sufficiently large relative to selling.

Most of literatures on antitrust issues related to the lease-only policy in durable goods markets consider the case of monopoly. Their analyses seem to support the U.S. antitrust authority's decisions in cases of United Shoe, IBM and Xerox, where the authority decided to ban the firms from pursuing lease-only policies.[17] In oligopolies, however, we need to consider firms' strategic interaction in addition to the monopoly incentives towards leasing or selling. As shown in this paper, there is a possibility of divergence between the private and social incentives due to the firms' strategic choices over the marketing strategies. This result sheds a new light on public policy related to leasing practices in oligopolistic durable goods markets such as software and various information services.

Appendix

A1: Derivation of equilibrium when some consumers delay purchase with both firms selling

Let us consider the case where some consumers do not buy a good in the first period so that the market exists in the second period as well.[18] Suppose that customers who

[17] See Waldman (1997, 2007) and Hendel and Lizzeri (1999). Hendel and Lizzeri worry that firms may reduce durability instead of lease-only policy that causes welfare loss if leasing is banned by the authority.

[18] It can be easily shown that consumers never buy two different goods successively in two periods.

are located in $[0, x_1^A]$ buy from firm A, and those in $[x_1^B, 1]$ buy from firm B in the first stage, where $0 < x_1^A < x_1^B < 1$. Denote x_2' as the location of the consumer who are indifferent between buying a good from firm A and from firm B in the second period, i.e. $v - p_2^A - tx_2' = v - p_2^B - t(1 - x_2')$. Then the demands in the second period are

$$D_2^A = \frac{t - p_2^A + p_2^B}{2t} - x_1^A,\ D_2^B = x_1^B - \frac{t - p_2^A + p_2^B}{2t}$$

and the equilibrium prices and the profits are

$$\begin{aligned} \widehat{p}_2^A &= \frac{t(1 - 4x_1^A + 2x_1^A)}{3},\ \widehat{p}_2^B = \frac{t(4x_1^B - 2x_1^A - 1)}{3} \\ \widehat{\Pi}_2^A &= \frac{t(1 - 4x_1^A + 2x_1^A)^2}{18},\ \widehat{\Pi}_2^B = \frac{t(4x_1^B - 2x_1^A - 1)^2}{18}. \end{aligned}$$

Also, by the definition of x_1^A and x_1^B the following must holds:

$$\begin{aligned} v - \widehat{p}_2^A - tx_1^A &= 2v - p_1^A - 2tx_1^A \\ v - \widehat{p}_2^B - t(1 - x_1^B) &= 2v - p_1^B - 2t(1 - x_1^B) \end{aligned} \tag{2}$$

The firms' profit-maximization problems are

$$\max_{x_1^A} : \widehat{\Pi}^A \equiv x_1^A p_1^A + \widehat{\Pi}_2^A$$

subject to $p_1^A = \frac{1}{3}(3v + t - 7tx_1^A + 2tx_1^B)$ and

$$\max_{x_1^B} : \widehat{\Pi}^B \equiv x_1^B p_1^B + \widehat{\Pi}_2^B$$

subject to $p_1^B = \frac{1}{3}(3v - 4t + 7tx_1^B - 2tx_1^A)$, where p_1^A and p_1^B are from (2). The equilibrium values are:

$$\begin{aligned} \widehat{p}_1^A &= \widehat{p}_1^B = \frac{11t - v}{8},\ \widehat{p}_2^A = \widehat{p}_2^B = \frac{5t - 3v}{4}, \\ \widehat{x}_1^A &= \frac{3v - t}{8t},\ \widehat{x}_1^B = \frac{9t - 3v}{8t}, \\ \widehat{\Pi}^A &= \widehat{\Pi}^B = \frac{39t^2 - 26tv + 15v^2}{64t}. \end{aligned}$$

Since $0 \leq \widehat{x}_1^A \leq \widehat{x}_1^B \leq 1$ and $v - \widehat{p}_2^Z - t/2 \geq 0$ (the marginal consumer must get a nonnegative utility), the existence of this equilibrium implies that $v \in [t, 5t/3]$. So, given the assumption that $v \geq 3t/2$ we obtain two equilibria when v belongs to the interval $[3t/2, 5t/3]$. Now we show that in this case the firms' profits are always smaller than those realized in the equilibrium with all consumers buying in the first period. The equilibrium per-firm profits at the boundaries of the interval $[3t/2, 5t/3]$ are $\widehat{\Pi}^Z(3t/2) = 135t/256$ and

$\widehat{\Pi}^Z(5t/3) = t/2$ respectively. Note that $\widehat{\Pi}^Z$ is convex in v since $\partial^2\widehat{\Pi}^Z/\partial v^2 = 15/32 > 0$. This proves our claim that $\widehat{\Pi}^Z - F_s < \Pi^Z_{ss} = t - F_s$, $Z = A, B$. We can rule out this inferior equilibrium using the Pareto criterion, or we can just remove it by assuming $v > 5t/3$.

A2: Proof of lemma 1

The proof is by contradiction. Suppose that $x_2 > x_1$ in equilibrium. Given that consumers who bought firm B's product in period 1 have reservation utility of v in period 2, the second-period indifference location x_2 is given by

$$\begin{aligned} v - r_2^A - tx_2 &= v - t(1 - x_2) \\ \Longrightarrow x_2 &= \frac{t - r_2^A}{2t}. \end{aligned}$$

Obviously, firm B has no sales in period 2 and makes no profits. Firm A' will choose r_2^A to maximize its second-period profit $\Pi_2^A(r_2^A) = r_2^A\dfrac{(t - r_2^A)}{2t}$. The first-order condition gives the optimal $r_2^A = \dfrac{t}{2}$. Then, firm A's second-period profit is $\Pi_2^A = \dfrac{t}{8}$, and the equilibrium second-period indifferent location is $x_2 = \dfrac{1}{4}$.

The first-period indifferent location x_1 should satisfy

$$2v - r_1^A - r_2^A - 2tx_1 = 2v - p_1^B - r_2^A - t(1 - x_1) - tx_1,$$

Substituting $r_2^A = \dfrac{t}{2}$ and rearranging gives $x_1 = \dfrac{p_1^B - r_1^A + t}{2t}$. Then, each firm's total profit can be rewritten as

$$\Pi^A_{ls}(r_1^A, p_1^B) = r_1^A\frac{(p_1^B - r_1^A + t)}{2t} + \frac{t}{8} - F_l$$

and

$$\Pi^B_{ls}(r_1^A, p_1^B) = p_1^B\frac{(r_1^A - p_1^B + t)}{2t} - F_s.$$

From the first-order conditions, the equilibrium first-period rental and sale prices are given by $r_1^A = p_1^B = t$. Then, the equilibrium first-period indifferent location must be $x_1 = \dfrac{1}{2} > x_2 = \dfrac{1}{4}$, which is a contradiction to the supposition that $x_1 < x_2$.

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