Exercising Market Power in Proprietary Aftermarkets

by

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Abstract. In many recent antitrust cases, manufacturers of complex high-technology equipment have been accused of exercising market power in the sale of proprietary service or parts necessary to maintain the machines they produce. The manufacturer generally concedes that it has market power in selling the aftermarket service or parts, but argues that it would not exercise such power because high aftermarket prices would cause consumers to select a different brand in the competitive market for the original equipment. We study the incentive to exercise market power in aftermarkets when the original equipment market is perfectly competitive, a differentiated duopoly, or monopolized. In all cases, we show that the price in the aftermarket will exceed marginal cost. Furthermore, our analysis indicates that aftermarket prices may actually be higher when the equipment market is more competitive. Nonetheless, we suggest that in a richer model – in which equipment sellers might want to price discriminate, create barriers to entry, or influence the pace at which users upgrade to newer models – firms in less competitive equipment markets are likely to have a greater incentive to maintain a monopoly position in the sale of their aftermarket products.

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1. Introduction

In the past decade, many independent providers of service for high-technology products have sued equipment manufacturers for allegedly excluding them from providing maintenance services. Some twenty-odd antitrust cases have been brought against manufacturers such as Kodak, Prime Computer, Data General, Northern Telecom, Picker, Unisys, Xerox, and Siemens. The common feature in these cases is that the defendants manufacture complex durable equipment for which customers demand service, support, parts, or upgrades over many years after the initial sale. In these cases, the economic interaction between an original equipment market and aftermarkets is central to the analysis.

Most of the cases have a similar plot. The manufacturer sells one brand of complex equipment in a market that is fairly competitive (*e.g.,* the market for minicomputers). In addition, the manufacturer sells aftermarket products to customers who purchased the original equipment. Examples of aftermarket products include hardware maintenance contracts, spare parts, and software upgrades. Due to proprietary rights, the original manufacturer is often the exclusive seller of at least one aftermarket product, such as replacement parts or upgrades to the operating system software. Plaintiffs charge that the manufacturer exploits its aftermarket position in violation of the antitrust laws, usually by tying the purchase of an aftermarket product that is also available from the plaintiffs to the manufacturer's proprietary good.

Plaintiffs in these cases point out that once a customer purchases a particular brand of equipment, she is likely to be "locked in" to that manufacturer to some extent. There are often significant costs of switching to another brand: retraining; sunk investments in custom software; capital losses on the sale of the used equipment; etc. It would seem that these switching costs could provide the manufacturer with room to collect some monopoly rents by raising aftermarket prices above cost.[1]

[1] A number of papers demonstrate how the presence of switching costs can endow a firm with market power after

While defendants usually acknowledge some degree of lock-in for incumbent equipment owners, they argue that it would not be profitable to exploit these customers with high aftermarket prices, because this would make their equipment less attractive at the stage that they compete with other manufacturers.

It is important, therefore, to consider the interaction between the primary equipment market and the aftermarkets. Although the manufacturer might appear to have an opportunity to exercise its economic power over service customers, doing so might be unprofitable (at least in the long run) because of customer losses in the equipment market.[2] If the manufacturer is no longer able to sell any equipment, it soon will have no service customers to exploit.

In this paper we analyze the manufacturer's two competing incentives: extracting profits from consumers who are locked in to a brand of equipment by raising prices on the associated aftermarket products versus increasing profits from new equipment sales by establishing a reputation for selling equipment with low maintenance costs. We do this by investigating the pricing of an a proprietary aftermarket product under different levels of competition in the equipment market. We show that even competitive firms that earn zero profits overall – due to competition in the equipment market – will charge prices above marginal cost in the aftermarkets, and that this will harm welfare. Further, when firms have some degree of market power in the equipment market, profits will be maximized by exercising the aftermarket market power.

In section 2 we review the recent legal history, emphasizing how the central economic question has emerged from the facts of the cases. In the following sections, we then develop some simple theoretical models to address the critical question of the incentive to exercise market power in the aftermarket and its effect on welfare. We reveal in section 3 an important flaw in the common argument that a competitive equipment market prevents anticompetitive pricing of the aftermarket product: the strategy of exploiting locked-in customers in the short run and then exiting the market is likely to be more attractive than remaining in a market that will return zero economic profits in

consumers make their initial choice. See, e.g., Klemperer (1987) and Farrell and Shapiro (1987). Well-known examples include computers with proprietary operating software and airlines with frequent-flier programs.

[2] Kodak unsuccessfully argued before the Supreme Court that this proposition must hold as a matter of theory: "even if it concedes monopoly *share* of the relevant parts market, it cannot actually exercise the necessary market *power* for a Sherman Act violation . . .. equipment competition precludes any finding of monopoly power in the derivative aftermarkets' " (*Kodak*, 112 S. Ct. 2072 (1992) at 2081–82, emphasis in original).

the long run. Basically, if a firm facing free-entry competition expects to earn zero profits, then it has no incentive to maintain a reputation for having low service prices.

Recognizing the tension between free entry and pursuit of a low-price reputation, in sections 4 and 5 we study models of imperfect competition and monopoly in the equipment market. The opportunity to earn above-competitive profits gives firms an incentive to build a reputation for low service prices. We find that reputation does have some value and that firms will therefore price the aftermarket product below its monopoly level. However, we also find that firms will always price above cost for the aftermarket product. The incentive to price the aftermarket product near marginal cost increases as the firm values future profits in the market more relative to current profits. This comparison is affected by both the firm's discount rate and the rate of growth or decline of the market. A declining market for the original equipment increases a firm's incentive to raise aftermarket prices.

The equilibria in these simple models indicate that aftermarket prices will be highest when the equipment market is competitive and closest to marginal cost when the equipment market is monopolized. In these models, however, we have ignored (1) the use of aftermarket products to price discriminate based on intensity of use; (2) the use of aftermarket control to limit competition from used equipment; and (3) the possibility that the firm has an incentive to manipulate aftermarket offerings to induce consumers to upgrade equipment prematurely. In section 6 we relax some of the assumptions of the model in order to explore these issues. In each of these cases, we find that firms with more market power in equipment may have a stronger incentive to monopolize the aftermarket than do more competitive firms.

2. Aftermarket Economic Power in the Courts

There are numerous cases before the federal courts that involve claims of antitrust violations in aftermarkets for service products. Two have recently reached the Supreme Court. In the first case, firms selling service for Kodak micrographic equipment alleged that Kodak adopted a restrictive policy on the availability of spare parts, including tying sales of spare parts to the purchase of other maintenance services from Kodak. The Court upheld the Circuit Court's denial of Kodak's motion for summary judgment, concluding that "it is clearly reasonable to infer that Kodak has market power to raise prices and drive out competition in the aftermarkets ... [and] ... to infer that Kodak chose to gain immediate profits by exerting that market power where locked-in customers, high information costs, and discriminatory pricing limited and perhaps eliminated any long-term loss" (*Kodak*, 112 S. Ct. 2072 (1992) at 2088). While the Court felt that it is *possible* for competition in the original equipment market to enforce competitive behavior in the service aftermarkets, it is not assured: the theory's applicability must be analyzed on a case-by-case basis. In another case, an independent service company alleged that Prime (now Computervision) had tied the sale of software support and upgrades to the purchase of hardware maintenance from Prime. Prior to the Supreme Court decision in *Kodak*, the Sixth Circuit had accepted Prime's argument that competition in the equipment market would necessarily discipline aftermarket prices. The Supreme Court overturned this decision shortly after deciding *Kodak*. The Sixth Circuit then decided that sufficient evidence had been presented to support a finding that it was profitable for Prime to monopolize the service aftermarket.

Two main features that distinguish aftermarkets have emerged in the many antitrust cases before the courts: the role of customer lock-in in establishing market power and the possibility that reputation effects will prevent manufacturers from profitably exploiting whatever economic power they have in service aftermarkets. We discuss these factors now, before proceeding to our formal model.

Customer Lock-In

The availability of substitutes limits a manufacturer's ability to charge above-competitive prices for its aftermarket products. An aftermarket customer would choose to sell or scrap the used equipment and purchase anew from a different manufacturer if the original seller raised the service price sufficiently. How much room the manufacturer has to raise the service price depends on the extent to which switching costs discourage a customer from changing brands.

The equipment involved in most of the recent antitrust cases is quite sophisticated. The products include minicomputers, hospital CT scanners, telephone PBX switches, high-volume photocopiers and micrographic reproduction equipment. In every case, users and experts have testified to the high costs of switching.[3] Evidence introduced in the *Wang*[4] case showed that typically about eighty

[3] For example, a senior design systems manager for Ford Motor Co. testified in *Virtual* that switching from Prime minicomputers to another brand would shut Ford down. See also, *Kodak*, 112 S. Ct. 2072 (1992) at 2087.

[4] *Systemcare, Inc.* v. *Wang Laboratories*, D.C. Colo., No. 89-B-1778.

percent of minicomputer consumers buy the same brand when they replace their equipment.

Previous work has demonstrated the role of switching costs in creating market power, but they have focused on a single product to which the customer becomes locked in.[5] There has been little attention to a firm that sells equipment in a competitive market but sells service to locked-in customers.[6] When there are two interrelated markets, the central question becomes the ability of the manufacturer to *profitably exercise* economic power in one market without a larger adverse impact on profits in the other market.

Reputation and Imperfect Competition

Manufacturers face two types of customers: those who already own equipment and those who are purchasing for the first time. Although customers who already own equipment may face significant costs of switching brands and thus provide the manufacturer with an opportunity to price supracompetitively, *de novo* customers do not. The claim that potential new customers provide the competitive discipline in the service market is central to the position taken by defendants in the recent cases. The argument depends on reputation effects. The manufacturer claims it cannot afford to exploit locked-in service customers because the information will become widespread and new consumers will purchase other brands. The direction of this reputation incentive is clear, but its magnitude has not been shown to be great enough to keep aftermarket prices at competitive levels.

The tradeoff between earning profits by exercising market power in aftermarkets and losing profits in equipment sales from a reputation for exploiting locked-in service customers has caused some confusion in the courts. The appellate court in *Virtual* argued that “lock-in theory is viable only when the producer can charge its customer monopoly prices without fear of being replaced by competitors due to the customer’s substantial investments” (*Virtual*, 957 F.2d 1318 at 1328). However, it is not necessary to charge full monopoly prices for service in order to exploit economic power, nor does the loss of *some* customers for new equipment necessarily offset the profits from

[5] See, for example, Beggs and Klemperer (1992), Farrell and Shapiro (1987), and Klemperer (1987).

[6] For an exception, see Chen and Ross (1995). In that paper the authors argue that firms charge above-cost service prices to recover higher costs from heavy users during a warranty period.

service. The Supreme Court observed in *Kodak* that even monopolists have to give up sales when they raise prices, yet they find it profitable to charge higher than competitive prices (112 S. Ct. 2072 (1992) at 2084), and that short of charging the full monopoly price for service, “there could be a middle, optimum price at which the increased revenues from the higher-priced sales of service and parts would more than compensate for the lower revenues from lost equipment sales” (id.). The proper question, then, is how severe an impact anticompetitive behavior in the service aftermarket has on profitability in the equipment market.

Suppose manufacturers do raise service prices to obtain economic profits. If the original equipment market is competitive, the prospect of profits in the aftermarket will lead firms to “buy market share” by lowering prices on the equipment. Free entry would assure that equipment prices will be lowered below cost until the expected combined profit is zero. This scenario does not require that equipment customers have any particular expectations about the manufacturer’s service prices and policies: the forces of competition among equipment manufacturers drive the equipment price down.

Suppose, however, that a manufacturer is able to establish a reputation among consumers for competitive aftermarket prices despite having economic power over locked-in customers. This firm might be able to charge higher equipment prices than its competitors and earn some profits in the equipment market. The strategy is sensible if the profit potential in the equipment market is greater than the profits that would be foregone on service.

To have an incentive to establish a reputation, the manufacturer must anticipate the possibility of earning above-normal profits after it has built up the reputation. Thus, there must be some product differentiation or other source of profits or quasi-rents in the equipment market. To fully address the role of reputation, we consider below the possibility that the equipment market is not perfectly competitive.

Vigorous but imperfect competition characterizes many durable equipment markets. Complex, high-technology products tend to be differentiated, even if they are similar enough that customers can consider them as partial substitutes. For example, it might be that Wang minicomputers were favored by customers who needed strong document and image processing capabilities; DEC computers by scientific and engineering users; and IBM minicomputers by those with large databases to process. Northern Telecom PBX telephone switches are designed to maintain complete “upward” compatibility so that customers can expand and upgrade their system without replacing it; ATT produced different lines of switches that are not all upwardly compatible.

In this section, we have shown that the courts have begun to recognize that durable equipment manufacturers face a tradeoff between above-competitive aftermarket profits from locked-in customers and competitive losses in the equipment market. In the next section we analyze this tradeoff in a model with a perfectly competitive equipment market that yields a proprietary aftermarket for each of the producers. However, if long-run profits in a perfectly competitive market are zero, we argue that there is no role for reputation effects. We model imperfectly competitive equipment sellers in section 4, and a equipment monopolist in Section 5. We use these models to study the role of reputation.

3. A Competitive Equipment Market and a Monopoly Aftermarket

Consider the markets for some durable good – which we will continue to call "equipment" – and an associated aftermarket product – which we will now call "service." In period i, a consumer buys either one or zero units of equipment. In period $i + 1$ she will have a demand function for service, given by $q(p)$. The equipment lasts at most two periods.

We assume that there is a free-entry, perfectly competitive market for the equipment, but that the equipment manufacturer is the only seller of the service associated with that brand. Thus, after buying and using equipment in period i, in period $i + 1$ the consumer can (1) use the product in its depreciated state with no addition of service, (2) buy some quantity of service from the same seller to enhance the equipment, or (3) re-enter the equipment market. The equipment and service products each have constant unit production costs, C and c respectively, identical for all firms.

All consumers are identical. They consider the equipment and service products homogeneous *ex ante*. They receive gross surplus from owning the equipment, $CS_1 = s$ for a new product and $CS_2 = s - h + f(q)$ for a period-old product that has been augmented with q units of service, where h represents the depreciation in the quality of the product from one period of use. The function $f(\cdot)$ is just the integral of the inverse demand for service with $f(0) = 0$, $f'(\cdot) > 0$, and $f''(\cdot) < 0$.

To make the analysis informative, we assume that (1) $s - h + f(q(c)) - cq(c) > s - C$ for some $q \geq 0$ and (2) $f'(0) > c$. The first assumption ensures that re-using the period-old product would be preferred to buying a new unit each period if both the new equipment and service were priced at cost.[7] The second assumption assures that purchase of at least a small quantity of service would give positive net consumer surplus if it were priced at cost. Together, the two assumptions imply that the first-best solution in this market is for consumers to use each unit of the equipment for two periods and to purchase some positive quantity of service in the second period.

The Two-Period Model

We first solve the model in a two-period context where no new consumers enter the market after the first period. This abstracts from issues of reputation, but it allows us to demonstrate the generic inefficiencies that can result from the absence of competition in the aftermarket.

Consider the second period when each firm must decide its price for service. Normally a monopolist would maximize profits in period 2 by finding the monopoly price $p^m = \arg\max_p (p - c)q(p)$. However, here the monopolist must account for the constraint that at sufficiently high service prices equipment owners will abandon their used equipment and buy new. From the strict inequality in assumption (2) and assuming continuity of the consumer surplus functions, we know that there are prices $p > c$ at which consumers will choose to buy a positive quantity of service. Similarly, there is some price $\bar{p_m}$ at which consumers are indifferent between buying a new unit or enhancing the period-old unit, defined implicitly by $s - P = \max_{\bar{p}_m} s - h + f(q(\bar{p_m})) - \bar{p_m} q(\bar{p_m})$, where P is the price of the equipment. Thus, the seller sets service price to maximize monopoly profits subject to the constraint that service price cannot be so high as to drive consumers to re-enter the equipment market: $p^* = \min(p^m, \bar{p_m})$.

In period one, each of the perfectly competitive sellers realizes that in period two it will be able to make profits of $\pi_2 = (p^* - c)q(p^*)$ by providing service for each unit sold in period one. Free entry implies that the firms break even overall, so the equilibrium price for the equipment would be $P^* = C - \delta\pi_2 = C - \delta(p^* - c)q(p^*)$, where δ is the discount factor.

Though the competitive firms earn zero profits, the equilibrium creates deadweight loss in comparison to the outcome that obtains if both equipment and service are sold in competitive markets. In period one, the gain in consumer surplus in the equipment market from below-cost pricing is exactly equal to the loss in producer profits. In period two, however, the loss in consumer

[7] Purchasing a new unit each period would generate net consumer surplus of $s - C$ every period. Servicing the used units would replace every other $s - C$ with surplus of $s - h + f(q(c)) - cq(c)$.

surplus from above-cost pricing is greater than the associated profit gain since consumers reduce their purchase of service in the face of a higher service price. Thus, if overall profits remain at zero, consumer surplus over the two-period lifetime of the equipment must fall relative to the outcome with competition in both markets. The result is inefficient underconsumption of service in period two or, possibly, a decrease in sales of the original equipment.[8]

The Discrete-Period Finite Horizon Equilibrium

The N-period finite horizon solution follows immediately from the two period solution. Consumers know that in period N all sellers will charge p^* for service. Realizing that it cannot credibly commit to charging a price below p^* for service in period N, each seller has no incentive to charge less than p^* for service in $N-1$ in an attempt to establish a reputation. Solving backwards from the last period, the only equilibrium is one in which service is priced at p^* by each seller and the equipment has a competitive price of $P^* = C - \delta(p^* - c)q(p^*)$.

Equilibrium in a Discrete-Period Infinite Horizon Model

Suppose that firms plan for an infinite horizon when considering a low-service-price reputation. Is the price pair (P^*, p^*) still a pure strategy equilibrium? We show that it is not as long as discount rates are not too high, but we also show that a strategy of charging $p = c$ for service is also not a pure strategy equilibrium (regardless of the discount rate).

To analyze a reputation-building strategy, we must specify the process by which consumers form expectations about future service prices. We suppose that consumers follow an informed, but unsophisticated, method: they assume that the price of service next period will be equal to the current price of service, and they include their discounted consumer surplus from service consumption in the comparison of equipment offerings ("life-cycle pricing").[9]

[8] The consumer surplus if both goods were sold in perfectly competitive markets would be $CS = s - C + \delta(s - h + f(q(c)) - q(c)c)$. In the equilibrium with lock-in $CS = \max(0, s - (C - \delta q(p^*)(p^* - c)) + \delta(s - h + f(q(p^*)) - q(p^*)p^*)$. Assuming that the equipment is purchased in both cases, the consumer surpluses differ by an amount equal to the discounted deadweight loss "triangle" in the service market that occurs when $p^* > c$.

[9] Testimony in many of the legal cases cited in the previous section indicates that consumers who consider service costs at all in choosing among brands make roughly this assumption. We are unaware of any cases in which attempts to calculate "lifetime" costs of equipment have included forecasts of future *changes* in real service prices.

It is easy to see that there will be no pure-strategy, low-service-price Nash equilibrium. Consider starting from a point at which all firms are offering the price pair (P^*, p^*). Suppose a firm considers "investing" in a low-service-price reputation by charging a service price of $p = c$, making the Nash assumption that all other firms continue to charge (P^*, p^*). Such a strategy sacrifices profits in the investment period (since locked-in customers pay $p = c < p^*$) in exchange for excess profits in subsequent periods.[10] If the firm's discount rate is not too high, and if it assumes that other firms continue to charge (P^*, p^*), then the strategy would be profitable.

If the strategy is profitable, however, other firms will adopt it as well. Equipment prices will decline towards marginal cost as long as there are excess profits to be made. But now firms find themselves in the situation we originally contemplated: from a zero-profit position it is profitable to raise the service price in order to extract excess profits from the locked-in customers. When profits from the low-service-price strategy decline sufficiently, and strictly before they decline to zero, any firm would prefer to exploit its reputation by suddenly reverting to monopoly service pricing.

Thus, if firms have sufficiently high discount rates, there will be a pure strategy Nash equilibrium with high service prices. With lower discount rates, the market will have no pure-strategy equilibrium. Instead, we will observe some firms adopting a low-service-price strategy and then (randomly) abandoning it as other firms (randomly) adopt it.[11] The low-service-price reputation will not be a long-term profit maximum for a firm in a competitive free-entry market.

4. Imperfect Competition in the Equipment Market

>From the previous section, it is clear that free-entry competition makes it attractive for a firm to deviate from efficient pricing of service in order reap the short-term profits. Such models of perfect competition, however, do not describe well the actual equipment markets in which these aftermarket issues have arisen. Such markets are typically reasonably competitive, but the equipment brands are differentiated. In this section, we explore the incentive to exercise market power in the service

[10] The low-service-price firm charges $P = C + f(q(c)) - f(q(p^*))$, leaving consumer surplus at the same level as before the price change.

[11] Shapiro, 1982, notes that firm behavior may oscillate between reputation-building and exploitation. His model is different in that a firm may run down its reputation to exploit a large consumer following, not in response to entry by "good reputation" competitors.

market when the equipment market is imperfectly competitive. In this case, a firm has positive economic rents to protect via its reputation. We modify a standard spatial model of duopoly to include lock-in for an aftermarket service product.[12]

Suppose firms a and b are located at opposite ends of a unit-length characteristic-space line. Consumers' preferences are distributed uniformly along the line, with the total number of consumers normalized to one. All consumers have identical reservation prices for the good, s, and this value is high enough that each consumer buys one unit of the good from the dealer that offers the highest expected discounted consumer surplus. All consumers have equal "travel" costs, t per unit distance. To find the quantity sold by each firm, we locate the consumer who gets equal consumer surplus from the two brands. A consumer located a distance d from firm a gets consumer surplus from brand a of

$$CS_a = s - td - P_a + \delta[s - h + f(q(p_a)) - p_a q(p_a)], \tag{1a}$$

where capital P (and Q) now refer to equipment and small p and q refer to the service product. Consumer surplus from firm b is given by

$$CS_b = s - t(1-d) - P_b + \delta[s - h + f(q(p_b)) - p_b q(p_b)]. \tag{1b}$$

Setting these equal and solving for the d to find the market boundary between the firms (denoted $\hat{d}$) gives

$$\hat{d} = \frac{t + P_b - P_a + \delta\phi}{2t}, \tag{2}$$

where ϕ, a function of p_a and p_b, is the difference in the net surplus of each brand, a and b, that the consumer would receive in the second period after buying service, $\phi = [f(q(p_a)) - p_a q(p_a)] - [f(q(p_b)) - p_b q(p_b)]$.[13]

[12] Alternatively, one could assume that firms are price takers in the equipment market but that entry is costly and the sunk entry cost is recouped because marginal cost of incumbent firms is upward sloping. In that case, incumbent firms would be earnings quasi-rents and could have an incentive to maintain a reputation. While the sunk entry costs do reflect reality, the price-taking assumption in equipment markets does not seem to. For this reason, we pursue the imperfect competition model and examine outcomes, among others, in which there is very high degree of substitutability between brands.

[13] To guarantee that the duopolists cover the entire market, we also assume that the gross surplus from service-augmented equipment is sufficiently large compared to the travel cost: $s + \delta[s - h + f(q(p_a))] > 1.5t$. If the inequality does not hold, then the duopolists will earn higher profits by pricing in such a way that the markets of the two do not overlap; each duopolist chooses to be a local monopolist.

As before, we assume that production costs of both the equipment and service products are linear in quantity. Without further loss of generality, we now assume that all production costs are zero, so that firm a's 2-period profit is given by

$$\Pi_a = P_a \hat{d} + \delta p_a q(p_a) \hat{d} \;=\; \hat{d}[P_a + \delta \pi_a], \tag{3}$$

where $\pi_a = p_a q(p_a)$, the profit per unit of equipment from sales of service, and similarly for firm b. When we substitute for d from equation (2), firm a's profits are

$$\Pi_a = \frac{t + P_b - P_a + \delta\phi}{2t}[P_a + \delta\pi_a]. \tag{4}$$

We can then find the necessary condition for firm a's choice of equipment price,

$$\frac{\partial \Pi_a}{\partial P_a} = \hat{d} - \frac{P_a}{2t} - \frac{\delta\pi_a}{2t} = \frac{t + P_b - 2P_a + \delta\phi - \delta\pi_a}{2t} = 0. \tag{5}$$

Solving (5) for P_a gives firm a's best response function

$$P_a = \frac{t + P_b + \delta(\phi - \pi_a)}{2}. \tag{6a}$$

By similar analysis of firm b's first order condition we find that P_b will be

$$P_b = \frac{t + P_a + \delta(-\phi - \pi_b)}{2}. \tag{6b}$$

Solving (6a) and (6b) simultaneously for P_a and P_b yields two necessary conditions for equilibrium equipment prices that are solely a function of service prices and exogenous factors:

$$P_a = t + \frac{\delta}{3}\left[\phi(p_a, p_b) - \pi_b(p_b) - 2\pi_a(p_a)\right] \tag{7a}$$

and

$$P_b = t + \frac{\delta}{3}\left[-\phi(p_a, p_b) - \pi_a(p_a) - 2\pi_b(p_b)\right]. \tag{7b}$$

As in the previous section, we can show that if the price of service is above its marginal cost, there is a Pareto improving change in prices available if the firm could commit to an efficient service price, $p = c = 0$. With efficient service prices, $\phi = \pi_a = \pi_b = 0$, and thus $P_a = P_b = t$. Each firm gets half of the equipment market, and $\Pi_a = \Pi_b = t/2$. By contrast, if service prices are above marginal cost, we find by substitution that $\Pi_a = \Pi_b = \frac{1}{2}[t - \delta(\pi_a + \pi_b)]$ which is less than

$t/2$. Thus, firms would prefer efficient pricing if they could commit to it. Likewise, customers are made better off by the elimination of deadweight loss that follows when service prices are lowered to marginal cost and equipment prices are raised enough to maintain the firm's profit.

Without the ability to credibly commit to future service prices, a firm faces an incentive to exploit locked-in customers by charging a high price for the service product, even if that means losing future market share. If firm a expects to face a steady stream of customers each period for equipment,[14] then it will earn profits from each customer generation of $\hat{d}[P_a + \delta\pi_a]$. If all market conditions are stationary, and the firm expects stationary equilibrium behavior from its competitor, then, given a current market share of d_0 for already locked-in customers, the present value of its stream of profits forevermore will be

$$V_a = d_0\pi_a(p_a) + d(P_a, P_b, p_a, p_b)\,[P_a(P_b, p_a, p_b) + \delta\pi_a(p_a)]\,[1 + \frac{\delta}{1-\delta}] \tag{8}$$

Assuming again that consumers take a firm's current service price as indicative of its future service price, firm a will want to deviate from marginal-cost service pricing if its value function has a positive derivative with respect to p_a at $p_a = 0$. By substituting for $\hat{d}$ from (2) and for equipment prices from (7a) and (7b), we can rewrite the value function with respect to service price only as

$$V_a = d_0\pi_a(p_a) + \frac{1}{18t(1-\delta)}\,[3t + \delta(\phi + \pi_a - \pi_b)]^2\,. \tag{9}$$

Taking the derivative with respect to p_a yields

$$\frac{\partial V_a}{\partial p_a} = d_0\pi_a' + \frac{\delta}{1-\delta}\left[\frac{1}{2} + \frac{\delta(\phi + \pi_a - \pi_b)}{6t}\right]\frac{2(\phi' + \pi_a')}{3}, \tag{10}$$

where primes indicate derivatives with respect to p_a. The first term is the change in current period profits on service from raising p_a. The second term has three components, the first of which is the present value factor for the infinite horizon stream of profits. The second part is equal to the firm's equilibrium market share or quantity sold of equipment, $\hat{d}$, after substituting in the solutions for optimal equipment prices P_a and P_b. The third part is two-thirds of the difference between the loss in consumer surplus and the gain in profits from an increase in the price for service p_a. The surplus difference is the marginal deadweight loss from raising the price of service.

[14] We discuss growth in the market below.

To evaluate this expression, note that at p_a = 0 (marginal cost), total surplus is maximized, and thus marginal surplus $\phi' + \pi'_a = 0$. That is, to a first order, a slight increase in the price of service from marginal cost raises service profits by the same amount that it lowers consumer surplus. Then,

$$\left.\frac{\partial V_a}{\partial p_a}\right|_{p_a=0} = d_0 \pi'_a > 0. \tag{11}$$

A profit-maximizing firm with an installed base will always set the price of the service product above marginal cost.

This result is quite general, not an artifact of the specific model. If the price of service is equal to its marginal cost, a small increase in that price will have only a second order effect on *future* profits once the price of the equipment is optimally adjusted downward, because this creates only second order deadweight loss, but it will have a first-order effect on *current* period profits from selling the service product, because the associated equipment units already have been sold. For this reason, it will always be profitable for the firm to raise the price of service above marginal cost.

Further examination of (10) leads to the conclusion that the firm will not choose to charge the myopic monopoly price for service, where $\pi'_a = 0$, either. At that point, the first term in (10) would be zero. The second term, however, would be negative,[15] so the derivative of the value function with respect to p_a would be negative. Thus, if an equilibrium exists it will occur with a price of service that is strictly greater than marginal cost, but strictly less than the myopic monopoly price.[16]

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[15] The component $\frac{\delta}{(1-\delta)}$ is positive for the relevant range of $\delta \in (0, 1)$ The second component is positive so long as firm a has positive market share. The component $(\phi' + \pi'_a)$ is negative for $p_a > 0$, because price increases above marginal cost decrease consumer surplus by more than they increase profits, thus creating increased deadweight loss. Hence, the product of these three components will be negative.

[16] The two results on the first-order condition for the value function at $p_a = 0$ (mc) and $p_a = p_m$ are sufficient to guarantee that there is at least one local maximum for $mc < p_a < p_m$. If the demand function for service is not too convex, we can show that there is also at most one local maximum. A sufficient condition for a unique maximum is that

$$\frac{\delta(\pi'_a + \phi')^2}{3(\pi''_a + \phi'')} \tag{F1}$$

increase monotonically in p_a. This guarantees that the second derivative of the value function changes signs at most once. Combined with the fact that the value function is increasing and concave at $p_a = mc$ and decreasing at the point where p_a is equal to the aftermarket monopoly price, condition $(F1)$ assures a unique maximum of the value function in the interval $mc \leq p_a \leq p_m$. Unfortunately, we have not been able to show that there is a unique equilibrium. It is straightforward to show that prices strictly less than marginal cost or strictly greater than the myopic monopoly price would never constitute a global profit maximum.

>From (10) we can also see the effect of the discount rate. As δ goes to zero, so that future profits receive a decreasing weight, service is priced closer to the myopic monopoly level ($\pi'_a \to 0$). As δ goes to one, so that future profits receive an increasing weight, service is priced closer to marginal cost ($\phi' + \pi'_a \to 0$, which implies $p_a \to 0$), pushing the price of service towards marginal cost. Thus far, we have interpreted δ as simply a discount factor, but it could also embody changes in the expected size of the market. If the market is growing over time, then higher market share for equipment sales in the future is of greater value, assuming that new entrants to the market learn of aftermarket pricing reputations, which could be expressed as an increase in δ. If the market is declining in size, then future market share is less valuable, implying a lower δ and an increase in the price of service towards the monopoly level. Thus, the exercise of market power in the service market will take place to a greater extent if the market is declining, *e.g.*, if the product has been made obsolete by a new generation of the technology.[17]

Equation (10) and the equivalent condition for p_b are best-response functions that together determine an equilibrium at any point in time. In steady state, however, a third condition must hold, $d_0 = \hat{d}$. In this case, the myopic expectations about service prices that we have assumed for consumers are fulfilled. Imposing this condition on (10) and again substituting for $\hat{d}$ from (2), (7a), and (7b), then factoring out the $\hat{d}$ expression gives the steady state conditions

$$\frac{\partial V_a}{\partial p_a} = \left[\frac{1}{2} + \frac{\delta(\phi + \pi_a - \pi_b)}{6t}\right] \cdot \left[\pi'_a + \frac{\delta}{1-\delta} \cdot \frac{2(\phi' + \pi'_a)}{3}\right], \tag{12}$$

and the equivalent expression for p_b. The first term is the equilibrium market share, so for the equilibrium to exist at an interior solution, the second term must be equal to zero. We can see from this that the degree to which the price of service exceeds the cost of providing service depends only on the shape of the demand curve for service and the degree to which the firm discounts future profits, and the growth rate of the market. Notably, t does not appear in the second term. The extent of substitutability among primary market brands, which determines the severity of equipment market competition, does not affect the equilibrium price of the aftermarket product.

Though the model is highly stylized, the result is nonetheless noteworthy. Not only will the price of service always be above marginal cost, in at least one reasonable model of this type of

[17] If the market is expected to grow indefinitely at a rate greater than the discount rate, then firm value would be infinite and the discount terms in (8) and later equations would be incorrect.

market, the degree to which service price will exceed marginal cost is *independent* of the amount of competition in the primary market. Even as t approaches 0, so that the two firms approach homogeneous-good Bertrand competition, the price of service will be unchanged. Similarly, as t approaches the point at which the two firms' markets have no overlap – where the consumer at the market divide gets zero net surplus from either product – the price of service will hold constant.

This surprising result depends on the assumption that a consumer's strength of preference between brands, t, and location on the line is uncorrelated with her demand for the aftermarket product. When this is true, the service price is not a useful policy instrument for maximizing profits as the level of competition changes. The firm sets service price to optimally balance the reputation and lock-in market power incentives. It responds to changes in competition only by adjusting its equipment price. In some situations, however, t may not be independent of the demand for service or the importance of repuation. In those cases, the changes in t can influence the aftermarket price, as we discuss in section 6.

While equation (12) and the equivalent expression for p_b together characterize the steady state in this market, we have not studied the dynamic path to the steady state. Away from the steady state, the optimum conditions for service prices will not be exactly as shown in (10), because there will be a dynamic consideration: a given share of equipment sales this period will affect the optimal service price next period, which will help determine the share of equipment sales next period and thus the optimal service price in two periods, etc. In that process, it appears that t might affect the degree of above-cost pricing of the aftermarket product. Nonetheless, competition will still fail to drive the aftermarket price to marginal cost and the resulting steady state will still be independent of the degree of competition.

5. A Monopoly in the Equipment Market

To complete the analysis, is it useful to consider the case of monopoly in the equipment market. While this does not correspond to the legal cases we have discussed, the monopoly case can be a useful guide to the intuition of the analysis. For purpose of comparison, we continue to use a linear spatial model. We assume that the monopolist is located at the endpoint of the characteristic-space in order to make the set-up most similar to the duopoly setting.[18] A consumer buys equipment if

[18] An alternative interpretation is for t to be sufficiently large that the marginal customer for either firm is outside the

her total surplus is non-negative,

$$s - td - P^m + \delta[s - h + f(q(p^m)) - p^m q(p^m)] \geq 0. \tag{13}$$

The market boundary of the monopolist, $\hat{d}^m$, is determined by the consumer who receives zero surplus:

$$\hat{d}^m = \frac{1}{t}\left[s - P^m + \delta[s - h + f(q(p^m)) - \pi(p^m)]\right], \tag{14}$$

where $\pi(p^m) = p^m q(p^m)$, since we continue to assume that production costs are zero.

If transport costs are high enough, not all customers will purchase equipment.[19] With low transport costs relative to a finite market "length", the monopolist maximizes profits by serving the entire market.

Consider the value function for a monopolist with an initial market share of d_0^m. It consists of current service profits plus the discounted stream of future equipment and service profits, assuming that the monopolist's market share will be the same in every subsequent period:

$$V^m = d_0^m \pi(p^m) + \hat{d}^m [P^m + \delta\pi(p^m)] \frac{1}{1-\delta}. \tag{15}$$

Substituting for $\hat{d}^m$ from (14) and taking the derivative with respect to the equipment price yields the first-order condition for the equipment price. Solving for the optimal equipment price as a function of the service price gives:

$$P^m = \frac{1}{2}\Big(s + \delta[s - h + f(q(p^m)) - 2\pi(p^m)]\Big). \tag{16}$$

We can use this directly to substitute for P^m and indirectly to substitute for $\hat{d}^m$ in (15) to obtain profits as a function of service price only:

$$V^m = d_0^m \pi(p^m) + \frac{1}{4t}\frac{1}{1-\delta}\Big(s + \delta[s - h + f(q(p))]\Big)^2. \tag{17}$$

Now we can calculate the first order condition for optimal service pricing. After rearranging and evaluating at the steady state, *i.e.*, $d_0^m = \hat{d}^m$, we have:

$$\frac{\partial V^m}{\partial p^m} = \hat{d}^m(p^m)\left[\pi'(p^m) + \frac{\delta}{1-\delta} f'(q) q'(p^m)\right] = 0. \tag{18}$$

market of the other firm; there is a gap in the middle of the market where consumers do not buy either product, so each firm is a local monopolist.

[19] The formal condition is that $s + \delta[s - h + f(q(p^m))] < 2t$.

As in the previous section, the firm would like to commit to charge a competitive service price, thus maximizing the value of the equipment to the consumer. The monopolist could then extract the surplus through the monopoly equipment price. However, the monopolist is not able to commit to marginal cost pricing in the aftermarket for the same reason a firm facing competition cannot: once the firm has an installed base of locked-in consumers, the firm has an incentive to raise the price of service.[20] At $p = c$, total surplus in the service market is maximized, so marginal surplus, which is $f'(\cdot)q'(\cdot)$ since $c = 0$, is zero. Then the first-order condition becomes

$$\left.\frac{\partial V^m}{\partial p^m}\right|_{p^m=0} = \hat{d}^m(0)\pi'(0) > 0. \tag{19}$$

Thus, the monopolist will charge a price higher than the competitive price in the aftermarket. As in the case of a duopolist, the existence of a locked-in customer base presents an incentive to extract surplus from these customers with a higher service price.

Is the departure from competitive aftermarket pricing more severe for a monopolist than it is for duopolists? To address this question, we evaluate the monopolist's first-order condition at the *duopolist's* optimal service price,

$$\left.\frac{\partial V^m}{\partial p^m}\right|_{p^m=p_a} = \hat{d}^m(p_a)\left[\pi'(p_a) + \frac{\delta}{1-\delta}f'(q)q'(p_a)\right]. \tag{20}$$

Using the fact that, $(\phi' + \pi') = f'(\cdot)q'(\cdot)$, the duopolist's first-order condition, equation (12), can be rewritten as

$$\frac{\partial V_a}{\partial p_a} = \hat{d}(p_a)\left[\pi'(p_a) + \frac{\delta}{1-\delta}\frac{2}{3}f'(q)q'(p_a)\right] = 0. \tag{21}$$

The first-order conditions for the monopolist and duopolist have exactly the same form except for the coefficient of $2/3$ multiplying the marginal surplus in the oligopoly expression.

Why does only two-thirds of the marginal effect on consumer surplus enter the expression for the duopolist? Consider the effect of reducing service price: In the monopoly situation, gross consumer surplus from the service-augmented equipment increases. Because the marginal

[20] In a related model of "open" vs. "closed" systems competition, Kende (1995) shows that when there is demand for variable quantities of equipment, and a taste for aftermarket variety, it will sometimes be in the monopolist's interest to maintain the aftermarket monopoly and extract some of the rents from product differentiation therein, rather than commit to a competitive service market. However, as in our model, welfare in Kende's system is always higher when the aftermarket is competitive.

consumer is choosing between purchasing the equipment or not purchasing the equipment, the monopolist can capture, via the equipment price, the entire increase in surplus of the marginal consumer. The alternative available offers zero surplus, and that alternative is fixed. In contrast, a duopolist is not able to capture the entire increase in consumer surplus to the marginal consumer from a reduction in the service price. This consumer is choosing between purchasing the equipment from the duopolist or from its competitor. The competitor adjusts *its* equipment market price in response to a change in the duopolist's service price. This competition enables the marginal consumer to keep some of her gross surplus.

Since the duopolist's share is positive, $\hat{d}(p_a) > 0$, the following must hold at its service price:

$$\pi'(p_a) + \frac{\delta}{1-\delta}\frac{2}{3}[f'(q)q'(p_a)] = 0. \tag{22}$$

We can use this fact to sign the monopolist's first-order condition evaluated at the duopoly service price. Since $f'(q)q'(p_a)$ is negative,

$$\pi'(p_a) + \frac{\delta}{1-\delta}[f'(q)q'(p_a)] < \pi'(p_a) + \frac{\delta}{1-\delta}\frac{2}{3}[f'(q)q'(p_a)] = 0. \tag{23}$$

That is, evaluated at p_a, the second term in the monopolist's first-order condition is negative. Then, since $\hat{d}^m(p_a) > 0$, we know that the monopolist's first-order condition would be negative if it charged p_a forever. That means it would make higher profits in a steady state in which it charged a $p_m < p_a$ (assuming concavity of the value function). Thus, while the monopolist will exercise its market power over locked-in customers, in this model it will not do so to the same extent as an imperfectly competitive equipment firm.[21]

6. Why Maintain an Aftermarket Monopoly?

In order to focus on pricing and reputation, we have thus far assumed a strong form of independence between the equipment market and the associated aftermarkets. As a result, the models we have

[21] The differing price between monopoly and duopoly may at first seem inconsistent with the claim in the previous section that the aftermarket price is independent of t in the model. The t-irrelevance result holds so long as there is competition between the firms, *i.e.,* the marginal customer for each firm gets positive consumer surplus from the product of the other firm. There is a change in equilibrium behavior at the point that t (relative to the gross consumer surplus from consuming the service-augmented equipment) becomes large enough that the firms act as separate monopolists and each consumer buys either from one of the two firms or not at all.

explored predict that it is only the *inability to commit* that leads to above-competitive aftermarket pricing. It is easy to see why a perfect contractual commitment will typically be infeasible: the service life for durable equipment is often a decade or more; there are many unverifiable dimensions of service quality; and cost changes are difficult to verify.[22]

Manufacturers, however, can increase the credibility of their commitment to competitive aftermarket pricing indirectly, by opening the aftermarket to competition.[23] The antitrust cases that we have discussed indicate that many manufacturers don't find this an attractive strategy. In the cases we have cited, defendants have put forth efficiency explanations for their aversion to open competition in aftermarkets, most notably problems with responsibility and liability when a third party's work on the manufacturer's machine is followed by further problems with the machine. There are, however, less benign reasons for a manufacturer to keep its aftermarkets closed. In this section we discuss some direct linkages between aftermarket monopolization and equipment market profitability. Each of these links between aftermarket control and equipment profitability can explain why a firm would choose to monopolize the aftermarket rather than open it to competition.

Price Discrimination

As Oi (1971) and others have demonstrated, a firm may be able to use a multi-part pricing scheme to price discriminate if quantity consumed is an indicator of the consumer's surplus from use of the good. For example, aftermarket indicators of usage intensity, such as the number of service calls or consumption of replacement parts, may be correlated with the user's willingness to pay for the original equipment. This is the standard explanation for IBM's insistence in the 1950s that consumers of its data processing machines use only punch cards purchased from IBM.

In the simple model of imperfect competition that we have presented, however, there is no role for metering or price discriminating through above-cost aftermarket prices. This somewhat surprising result is due to the assumption that gross consumer surplus and the cost of switching equipment brands – which is determined by the parameter t and the location of the consumer along

[22] We discuss problems with contractual commitments more fully in Borenstein, MacKie-Mason, and Netz (1995).

[23] This indirect approach to committing to downstream competitive pricing has been explored in the "second sourcing" literature; see, e.g., Shepard (1987) and Riordan and Sappington (1989). Kende (1995) has extended this literature by modeling the demand for variety in the aftermarket products.

the line – is uncorrelated with the intensity of use. These assumptions, however, often are not realistic.[24] Higher intensity users may derive the greater surplus from the machine and have larger costs of switching to another brand. When usage is correlated with surplus derived and/or the cost of switching between brands, metering *can* be used for price discrimination.[25]

Thus, even absent the incentive to exercise market power over locked-in consumers, an equipment producer may want to exclude competitors from the aftermarket in order to use aftermarket products to extract the greater surplus that higher intensity users derive. Although the welfare (and total consumer surplus) effects of the price discrimination itself are ambiguous, we have shown that once competitors are excluded, an exercise of market power in the aftermarket is likely, and that behavior will harm welfare.

Maintaining Equipment Market Control and Position

An equipment firm with market power may also want to exclude competition in the aftermarket in order to restrict competition in the *equipment* market, as such restrictions may reduce the threat of competition from used machines. Many manufacturers charge high initial fees or outright refuse to provide service contracts on used equipment purchased from an independent broker.[26] If the manufacturer is also the service monopolist, this strategy may effectively foreclose an independent market for used equipment. By reducing the supply of used equipment, the firm prevents the erosion of equipment market power.[27]

Manufacturers may also want to monopolize an aftermarket in order to induce consumers to purchase new equipment or new models earlier. For example, a firm may be able to force consumers

[24] For example, in the *Kodak* case, there were two other sellers of high-volume copiers during the early years: Xerox and IBM. IBM specialized in copiers for the lower end of the high-volume market (50,000 – 100,000 copies per month). Xerox specialized in very-high-volume copiers (300,000+ copies per month).

[25] Indeed, almost all high-volume copier service contracts have a base charge and a per copy (“click”) charge. Clearly, service costs tend to vary with usage, but the click charge *may* be used for metering as well, consistent with the plaintiffs’ allegation that the service prices were substantially above cost. See Chen and Ross (1993) for a model in which firms with equipment market power use the aftermarket to implement price discrimination. They note that, as usual, price discrimination has ambiguous welfare implications. In addition, if product quality is also a choice variable, then there may be ambiguous welfare effects from distorting the quality choice.

[26] This was one of the allegations in the *Kodak* case, for example.

[27] About one-third of the damages awarded to plaintiffs by the *Kodak* jury were for profits lost on brokering used equipment. The jury concluded that Kodak’s refusal to sell repair parts and its consequent monopolization of the service market permitted Kodak to increase its equipment profits at the expense of brokers and consumers.

to move to the newest model of equipment by no longer servicing old models of equipment. This effect will not obtain if service is available from other vendors.[28]

Another motive for excluding aftermarket competition that is observed in practice is the desire to influence the flow of information to customers. This is known in the industry as "account control": regular visits from the manufacturer's field technicians can be used to influence future equipment upgrade and expansion decisions. Service provision by an independent technician may provide the customer with a low cost source of independent information on the advantages of alternative brands for future purchases.

7. Conclusion

Recent antitrust investigations of pricing and practices in aftermarkets have hinged on whether firms in reasonably competitive equipment market could have an incentive to exercise market power in the associated aftermarkets. We have shown that, regardless of the structure of the equipment market, a firm that has market power over sales in its associated aftermarkets will exercise that power at least to some extent, pricing aftermarket goods and services above their competitive price. The tradeoff between establishing a low-aftermarket-price reputation and extracting profits from locked-in customers will always result in elevation of price above the competitive level. This price elevation is likely to be greater when either high discount rates or a declining market lower the value of establishing a low-price reputation.

We have also found that in the simple model we investigated, greater competition in the equipment market does not have a disciplining effect on aftermarket behavior. In our model, it can have either no effect or a perverse effect on aftermarket prices, with higher aftermarket prices resulting from more competitive equipment markets. Intuitively, the incentive to extract profits in the aftermarket is greatest when there is little hope of making profits through an easily-imitated investment in low-price reputation. Of course, if the equipment market is very competitive, the profits from supracompetitive aftermarket prices will be dissipated through lower equipment prices. Even in that case, however, inefficient pricing of the aftermarket good will lead to under-use or premature abandonment of the equipment.

[28] For example, manufacturers often raise parts prices on older equipment to induce upward migration.

Finally, we have argued that even though the assumptions of our formal model would lead firms to commit to low aftermarket prices if they could, there are very credible reasons to think that firms would prefer to maintain aftermarket power in order to price discriminate through metering or to support their position in the equipment market. These reasons explain why firms don't work harder to assure the equipment buyer of low aftermarket prices, by allowing competitive service, second sourcing replacement parts, and taking other such actions.

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