Post-Sale Service and the Limits of Reputation*

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Abstract

In the standard durable-goods-quality model (e.g., Klein and Leffler, 1981; Shapiro, 1982, 1983), the prospect of repeat sales is often adequate to support the provision of high-quality durable goods even when quality is not observable at the time of purchase. We show that when durable goods require costly post-sale service, a reputational equilibrium may not exist at any price, even with a flow of profitable new sales indefinitely into the future. More generally, we characterize the size of the premium needed to make promises to provide post-sale service self enforcing. We then apply the model to United Shoe Machinery, IBM, and Xerox, using historical records to estimate the self-enforcing post-sale service premia that would have been necessary for each of these companies.

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1. Introduction

Economists have long recognized the potential for the underprovision of quality in the manufacture of durable goods whose attributes are difficult for consumers to determine at the time of purchase: Having received payment up-front, a supplier of durable goods has no direct interest in the subsequent performance of products previously sold and, knowing this, consumers will discount manufacturers' representations of their value. At the same time, economists have also recognized that the prospect of future sales gives a firm an indirect stake in its products' performance. Provided that firms have sufficiently long lives and that quality can be evaluated and communicated ex post, the threat of lost future business may be sufficient to induce the manufacture and sale of high-quality products (Klein and Leffler, 1981; and Shapiro, 1982, 1983).

A feature of many durable goods not contained in the standard durable-goods-quality model, however, is their dependence on various types of post-sale service provided by the producer. The value of a machine — particularly technologically advanced ones like early computers and copiers — often depends on the availability of spare parts, ancillary products, and competent repair and other support services. Intangible assets also sometimes require post-sale support. The value of a franchise, for example, typically depends on the franchisor's continuing efforts to promote the brand and police franchisee compliance with quality standards. Similarly, software manufacturers often incur significant post-development costs sustaining (debugging and improving) software products and providing customer service and support. In all of these cases, what customers are willing to pay for the asset will depend on their confidence in the continued availability of service after purchase. Producers could, of course, back their support commitments with warranties or service contracts. But, as in other contexts, contractual solutions are costly and imperfect, and the parties stand to gain to the extent that reputational considerations make resort to legal enforcement unnecessary.

At a basic level, the analysis of credible post-sale service provision follows the standard logic for the assurance of ex ante quality — customers will find producer promises to provide post-sale service credible as long as the present value of the rents accruing to future sales exceeds the gain from reneging on those promises — but with one important difference: Unlike the cost of supplying ex ante quality, which is a function of the flow of new production, the cost of providing post-sale service depends on the stock of durable goods outstanding and, thus, on the level of past sales. The greater the level of prior sales, the higher will be the producer's cost of honoring its service commitments and, hence, the larger the "reputational capital" needed to make those commitments self-enforcing. Moreover, whereas the reputational capital needed to sustain durable-goods quality increases dollar-for-dollar with the cost of producing high quality, the rents required to make post-sale service provision self-enforcing involve a multiple of expected service costs. As a consequence of this "multiplier," producer promises to provide post-sale service may not be self-enforcing *at any price*, even with a constant flow of new sales indefinitely into the future.

To gauge the significance of the post-sale service multiplier in practice, we examine, retrospectively, the possibility of self-enforcing post-sale service provision for early mainframe computers, shoe machines, and plain paper copiers. These applications are interesting for several reasons. First, these machines were, in their day, technologically advanced and notoriously prone to breakdown. Purchasers therefore faced considerable uncertainty at the time of acquisition about both the reliability of the machines and the availability and cost of repair and support services. Second, various authors have attributed the practice of leasing, as opposed to selling, these machines to the difficulty of guaranteeing machine quality and support services contractually.¹ A shortcoming of this explanation, however, is that the dominant producers of these machines — United Shoe Machinery

¹See Flath (1980); Levy (1988); Wiley, Rasmusen and Ramseyer (1990); and Masten and Snyder (1993).

Corp., IBM, and Xerox, — were well-known, served primarily commercial customers, and were closely watched by industry analysts, attributes that should have facilitated reliance on reputation. Presumably, the reputational capital at stake for these firms was at least as great as that of manufacturers of other machinery that survived and prospered selling, rather than leasing, their products. Finally, in all three cases, the firms' leasing practices were successfully challenged on antitrust grounds. To the extent that reputation was adequate to address customers' quality and service concerns, the quality-assurance justification for leasing is weakened, and the charge that the leasing policies of these firms had anticompetitive motives gains credence (e.g., Waldman, 1997).

We begin our analysis in the next section with a brief introduction to the issues posed by postsale service requirements. In section 3, we develop a simple model in which, in contrast to the durablegoods-quality literature, quality is fixed and observable (contractible) but post-sale service is noncontractible, and then characterize the condition for the existence of a self-enforcing post-sale service equilibrium as a function of a good's durability and expected service costs. In section 4, we discuss briefly leasing and separate service contracts as alternatives to bundling sales and service. Section 5 contains our application of the results to shoe machines, computers, and copiers. Conclusions appear in a final section.

2. The Problem of Post-Sale Service Commitment

In the now familiar durable-goods quality model, a durable goods manufacturer has an incentive to misrepresent low-quality goods as high quality to obtain the price premium commanded by high-quality products. Consumers who are unable to distinguish high-quality from low-quality goods ex ante will discount such representations and, in the one- (or finite-) period model, only low-quality goods will be supplied in equilibrium. The production of high-quality goods can, however, be supported, without recourse to formal contracts, if durable goods manufacturers have ongoing businesses and the performance of previously sold goods can be communicated to potential future consumers. With the prospect of indefinitely repeated trade, promises to supply high-quality goods will be self-enforcing if the one-period savings from producing low- rather than high-quality, say, $(c_h - c_l)$, is less than the present discounted value of the stream of rents that the producer stands to earn from continuing to produce and sell high-quality products, $(p - c_h)/r$, where *r* represents the single-period real rate of interest (Klein and Leffler, 1981; Shapiro, 1982, 1983).

A feature of many durable goods not captured in this standard model, however, is their need for various types of post-sale service. For reasons of both expertise and incentives, it is often the producers themselves that are best suited both to provide and to bear the cost of those services. Especially on technologically advanced products, manufacturers may have superior knowledge, acquired through development and production, about how to repair complex machines or, to use a more recent example, debug and support software. Manufacturer servicing of its own products also provides a potentially valuable source of feedback on problems and operations that can suggest improvements on existing products and advance development of new models or versions. Even in the absence of such information economies, incentive considerations often favor manufacturer liability for services: As we know from the literature on warranties (e.g., Priest, 1981; Cooper and Ross, 1985), assigning (financial) responsibility for product failures to manufacturers provides manufacturers the incentive to produce more reliable products in the first place.² Although warranties can be — and often are — used to assign liability for product failures, warranties are contracts and, like other contractual arrangements, are costly

²The existence of scope economies in the production of durable goods and provision of service does not imply that manufacturers should necessarily bear the cost of service provision; a manufacturer could sell service to its customers for a price. By the same token, the efficiency of manufacturer liability for product failures does not require that manufacturers physically provide the service, only that they bear the financial cost of failures. In the applications we consider below, manufacturers were arguably both the low-cost service providers and the efficient bearers of liability for product failures. We ignore buyer incentives (moral hazard and adverse selection) in the model but discuss their implications briefly in considering service contracts in section 4. See also Blair and Herdon (2000), who argue that provision of free service efficiently shifted risk from shoemakers to United Shoe Machinery Corp.

to write and depend ultimately on court enforcement (see, e.g., Chapman and Meurer, 1989). Where judicial assessment of the performance of service obligations is difficult — as is often the case with novel and complex products — reliance on reputation is likely to be especially attractive.

At the most basic level, the logic of the ex ante quality model extends to provision of post-sale service: Consumers will be willing to pay more for durable goods accompanied by a credible promise of post-sale service than for products of equal quality without that service. Producers, for their part, will find it profitable to offer durable goods accompanied by promises to provide post-sale service as long as the discounted value of rents on future sales exceeds production costs plus the present value of expected future service costs. Unlike ex ante investments in quality, however, post-sale service represents a future liability for the manufacturer. As the stock of machines outstanding grows, that liability — and therefore the producer's incentive to renege on its service commitments — rises, making self-enforcement harder to sustain. As Masten and Snyder (1993, p. 42, fn. 38) noted:

[T]he combination of machine durability and fallibility may itself combine to undermine the reputation function. While the cost of supporting existing machinery is proportional to the stock of machines in use, the incentive to continue that support is related to the flow of new machine sales. As the stock of machines outstanding rises relative to the level of sales, the cost of supporting existing machines may eventually exceed the loss of the reputation premium on future sales.

To illustrate the problem, consider a setting (a special case of our more general model below) in which consumers are willing to purchase q units per period of a machine from a particular manufacturer at a (premium) price of p conditional on the manufacturer promising to provide service on the machine, free of charge, for the life of the machine. Suppose, also, that each machine costs c to produce, generates an expected per-period service cost of s and, for present purposes, lasts forever.³ Under these

³Service costs can be thought of as either (i) the product of actual service costs and the product failure rate or (ii) the per-machine cost of maintaining a staff and the parts and equipment needed to meet expected service needs each period.

assumptions, a machine sold with a commitment of perpetual post-sale service will cost the manufacturer *c* plus

$$\sum_{t=1}^{\infty} \frac{s}{\left(1+r\right)^t} = \frac{s}{r}.$$

Given these costs, a manufacturer would find it profitable to offer a machine for sale with a longterm commitment to provide service as long as $p \ge c + s/r$. If we designate the per-machine expected surplus p - c - s/r as w and assume constant sales of q machines each period from 0 to infinity, the present discounted value of the firm's profits from machine sales with perpetual service commitments viewed from time 0 will be

$$W_0 = \sum_{t=0}^{\infty} \frac{wq}{(1+r)^t} = wq \frac{(1+r)}{r}.$$

Under the assumption of constant per-period sales, the present value of the firm's expected profits on current and future sales in each future period, W_t , will also be $W_0 = wq(1 + r)/r$. Hence, as long as w is positive, a firm selling machines with perpetual service commitments will remain profitable: The price the firm receives on each sale is more than enough both to cover the cost of manufacturing the machine and to finance its future service obligations.

But even if the price on each new sale exceeds the full expected costs of that machine, a firm must also find it profitable to continue to provide service on those machines it has previously sold: In each period after time 0, the firm carries a liability for servicing machines sold in earlier periods. After one period of sales, there will exist a stock of q machines, for which the firm will still have an obligation for current and future service costs equal in present value to $S_1 = sq (1 + r)/r$; after two periods, the stock will be 2q with expected service cost obligations of $S_2 = s2q (1 + r)/r$; and so forth. Incorporating the present value of expected service costs on existing machine stocks, S_r , into the firm's profit calculation, the present value to the firm of continuing to sell and service machines in period t will be:



Figure 1. Expected net revenues and service costs over time

$$V_t = W_t - S_t = W_0 - stq(1+r)/r.$$
 (1)

Equation (1) shows that the present discounted value of continuing to sell and service machines falls over time as the stock of previously sold machines grows. As illustrated in Figure 1, $W_t = W_0 =$ wq(1 + r)/r is time invariant, whereas the term $S_t = stq(1 + r)/r$ increases linearly over time. In words, even if the price of each machine were sufficient to make sale of that machine with a perpetual service commitment profitable (w > 0), the liability for servicing the accumulated stock of machines previously sold would eventually (here, for t > t = w/s) make the firm's discounted profits from continuing to sell and service machines negative, $V_t < 0$. In effect, the savings to the firm from reneging on its service obligations on previously sold machines, $S_t = stq(1 + r)/r$, eventually exceeds the stream of profits it could earn on future sales from that time forward, W_t , and, in the absence of third-party enforcement, the firm would be better off reneging. Moreover, by the usual backward induction logic, the existence of a date in the future at which reneging on service commitments becomes profitable makes cheating profitable from the outset. Thus, for the provision of post-sale service to be credible in any period, V_t must be greater than 0 *in every period*. And because the cost of servicing accumulated stocks of machines increases without limit (in the current example), there is no finite premium that can support the self-enforcing provision of post-sale service on machines. The more general point, developed more fully below, is that post-sale service introduces a form of state dependence into the reputation calculus that may, depending on machine durability and service costs, undermine the credibility of service commitments even though the firm faces a large, positive stream of economic rents on current and future sales indefinitely into the future.

3. Self-Enforcing Post-Sale Service Provision

In this section, we offer a somewhat more general model that allows for growth in sales and machine depreciation.⁴ For computational convenience, we also conduct the analysis in continuous time. We retain the following notation from the previous section:

- c = the firm's constant per-unit production costs;
- s = expected per-period, per-unit service costs;
- r = the one-period real interest rate;
- p = the per-machine purchase price.

In addition, we define v to be the per-period value to consumers of a machine's services, and δ

 \in [0, 1] to be the rate at which machines depreciate or "go out of service."⁵ The maximum price

⁴The example in section 2 corresponds to the special case (in discrete time) of no depreciation and constant sales.

⁵Two interpretations of the effects of δ on machine value are consistent with the model. One is to view machines as providing *v* in value each period that they are operational (and zero otherwise) and δ as the rate at which machines go out of service; the other is to interpret δ as reducing the value of the services obtained from a machine over time. We are also implicitly assuming that service costs are not a function of a machine's age. In a more general model, the value of the services provided by a machine relative to the cost of keeping it running would determine its economic life. None of our assumptions, adopted for simplicitly, affects the essential insights of the model.

consumers would be willing to pay to purchase a machine with a credible promise of service over its life would therefore be

$$p_{\nu} = \int_{0}^{\infty} v e^{-(\delta+r)t} dt = \frac{v}{(\delta+r)}.$$
(2)

As in the previous section, we assume that (per-period) demand is rectangular, that is, consumers either (i) buy q machines at price p if $p \le p_v$ and they believe that the firm will provide service for the life of the product, or (ii) buy nothing if $p > p_v$ or they do not consider the firm's service promises credible.

To model growth in demand, we adopt a limited (or inhibited) growth specification. Specifically, we assume that the per-period demand for machine services and, thus, the stock of machines consumers wish to own in a given period, Q(t), equals $M(1 - e^{-gt})$, where *M* represents long-run "market saturation" — a (arbitrarily large) limit on the stock of machines (services) demanded — and *g* is a growth parameter; larger *g* implies Q(t) approaches *M* more quickly.

Given total demand for machine services, the quantity of new machines demanded in a given period, q(t), will be

$$q(t) = Q(t) + \delta Q(t), \tag{3}$$

that is, the demand for new machines in period *t* is equal to the change in the desired stock of machines in period *t*, $\dot{Q}(t)$, plus the number of units needed to replace depreciated machines, $\delta Q(t)$. Given the specification for growth in demand for machine services above, the rate of change in the desired stock of machines is $\dot{Q}(t) = Mge^{-gt}$. Substituting into equation (3) yields the quantity of new machines demanded in period *t*, $q(t) = Me^{-gt}(g - \delta) + \delta M$.

In addition to affecting the price consumers are willing to pay, p_v , and per-period sales, q(t), the rate of depreciation affects the manufacturer's expected costs of post-sale service: With machines "going out of

service" at a rate of δ , the present discounted value of future expected service costs on a given machine becomes $s/(r + \delta)$. Incorporating machine depreciation, the present discounted surplus from the sale of a machine with service commitment, defined in the preceding section, now becomes

$$w = p - c - \int_0^\infty s e^{-(r+\delta)t} dt = p - c - \frac{s}{r+\delta}.$$

We assume that the firm and consumers cannot contract on the provision of post-sale service but are otherwise fully informed about the model and, in particular, that machine quality is fixed and observable (contractible). Consumers purchase q(t) units of machines at price p only if the firm's promise to provide post-sale service is credible (self enforcing). The firm, for its part, will find it in its interest to provide service in a given period only if the discounted stream of profits on future sales exceeds the one-time gain from reneging on its service commitments. Because anticipated reneging in the future eliminates the return to service provision today, the condition that the firm's discounted profits on future sales exceed its gains from reneging must hold in every period. Formally, a self-enforcing post-sale service (SPS) equilibrium will exist only if

$$V(t) = W(t) - S(t) \ge 0 \quad \text{for all } t \in [0, \infty), \tag{4}$$

where

$$W(t') = \int_{t'}^{\infty} wq(t)e^{-r(t-t')}dt = \int_{t'}^{\infty} w[Me^{-gt}(g-\delta) + \delta M]e^{-r(t-t')}dt, \text{ and}$$
$$S(t') = \int_{t'}^{\infty} sQ(t')e^{-(r+\delta)(t-t')}dt.$$

In words, W(t') is the present discounted value of expected profits on the sale and servicing of future machines sold from t' forward, and S(t') is the cost, in present value, of continuing to service the stock of machines sold in previous periods and still in operation in t'. Using the preceding definitions and assumptions, we derive the following result. **Proposition 1.** A self-enforcing post-sale service equilibrium will exist only if

$$(p_v - c) \ge \frac{s}{\delta}.$$
(5)

Proof. Evaluating the integral in W(t') yields

$$W(t') = wM\left[\frac{(g-\delta)}{(g+r)}e^{-gt'} + \frac{\delta}{r}\right].$$
(6)

Doing the same for S(t'), we obtain

$$S(t') = \frac{s}{r+\delta} M(1 - e^{-gt'}).$$
 (7)

Substituting (4) and (5) into (2), we get

$$V(t') \ge 0$$
 for all $t' \in [0,\infty)$ \Leftrightarrow

$$\frac{w\delta}{r} - \frac{s}{(\delta+r)} \ge -e^{-gt'} \left[\frac{w(g-\delta)}{(g+r)} + \frac{s}{\delta+r} \right] \quad \text{for all } t' \in [0,\infty).$$
(8)

Both the LHS and the expression in squared brackets on the RHS of (8) are constants. Given that $-e^{-gt'}$ is monotonically increasing in t' with $-e^{-gt'} = -1$ at t' = 0, and $\lim_{t'\to\infty} e^{-gt'} \to 0$, the RHS of (8) will reach its maximum at t' = 0 if the expression in brackets is negative, and will approach its maximum (of 0) in the limit as $t \to \infty$ if the expression is positive.

It is straightforward to show that the sign of the bracketed expression depends on the sign of $(p-c)(g-\delta) + s$. Consider first the case of $(p-c)(g-\delta) + s < 0$: In this case, the bracketed expression on the RHS of (8) will be negative. Since $-e^{-gt'} = -1$ at t' = 0, (8) will be satisfied for all *t* if

$$\frac{w\delta}{r} - \frac{s}{(\delta+r)} - \left[\frac{w(\delta-g)}{(g+r)} - \frac{s}{(\delta+r)}\right] \ge 0,$$
(9)

which reduces to

$$\frac{\delta g + rg}{rg + r^2} \ge 0. \tag{10}$$

Since (10) is always satisfied for δ , g, $r \ge 0$, the condition for a reputation equilibrium to exist is always satisfied if $(p-c)(g-\delta) + s < 0$ or, because the latter can hold only if $g < \delta$, if $(p-c) > s/(\delta - g)$.

Consider next the case of $(p-c)(g-\delta) + s \ge 0$: In this case, the bracketed expression on the RHS of (6) will be positive (or 0 in the case of equality), and the RHS of (8) will approach a maximum of 0 as $t' \rightarrow \infty$. Setting the RHS of (8) equal to zero and rearranging terms, we get

$$\frac{w\delta}{r} \ge \frac{s}{(\delta+r)},$$

which, after substitution for w and manipulation, reduces to

$$(p-c)\geq \frac{s}{\delta}.$$

Finally, because the parameter values characterizing case 1 above — $(p-c) > s/(\delta-g)$ and $g < \delta$ imply $(p-c) > s/\delta$ (because $s/(\delta-g) > s/\delta$), and noting that p must be $\leq p_v$ for consumers to participate, a self-enforcing post-sale service equilibrium will exist unless $(p_v - c) < s/\delta$.

Figure 2 plots W(t) and S(t). Graphically, the existence of a self-enforcing post-sale service equilibrium depends on whether W(t) and S(t) cross (as occurs with $S^2(t)$) or not (as with $S^1(t)$). Under our demand specification, sales, q(t), approach a steady state of δM , the level needed to replace depreciated machines and maintain the stock at M, as t gets large. Consequently, W(t) asymptotically approaches $(w\delta M)/r$.⁶ S(t), meanwhile, increases over time, approaching $sM/(\delta + r)$, reflecting steady state service costs of sM. W(t) will therefore lie above S(t) for all t if $(w\delta M)/r \ge sM/(\delta + r)$, which reduces to $(p-c) \ge s/\delta$.

⁶W(t) may be either increasing or decreasing in t depending on whether δ is greater than or less than g.



Figure 2. Net revenue and service costs paths with growth and depreciation

In words, Proposition 1 says that consumers will find manufacturer promises of (machine life-time) service provision credible only if the mark-up on machine sales (p - c) is greater than per-machine service costs (*s*) times the expected life of machines $(T = 1/\delta)$. Notice that this condition is more restrictive than the requirement that firms earn a positive expected profit on the sale of machines with service. Specifically, whereas profitability requires that $w \ge 0$, condition (5) requires that $w \ge sr/[\delta(r + \delta)]$.⁷ The term $sr/[\delta(r + \delta)]$ represents, in effect, a premium by which the firm's profit on machine sales must exceed break-even to make post-sale service provision self-enforcing.

Figure 3 plots this self-enforcing post-sale service (SPS) premium, $sr/[\delta(r + \delta)]$, along with the present value of expected post-sale service costs, $s/(r+\delta)$, and the sum of the two, $s/\delta = sT$, as a function of expected machine life, *T*. As seen in the figure, expected service costs increase with average machine life but, because future costs are discounted, rise at a decreasing rate, approaching a maximum of s/r as $T \to \infty$ ($\delta \to 0$). The SPS premium, by contrast, increases at an increasing rate in machine life. Because self-enforcing

⁷The term $sr/[\delta(r+\delta)]$ is the difference between s/δ , the amount by which p must exceed c to make service provision credible, and $s/(r+\delta)$, the present value of expected service costs.



Figure 3. SPS premium, service costs, and durability (s = 1, r = .05)

provision of post-sale service requires that the mark-up over production costs, (p - c), exceed s/δ , which is unbounded, rather than just $s/(\delta + r)$, violation of the condition for the existence of an SPS equilibrium will always occur for assets of sufficiently long life. Or more precisely, after substituting the definition of p_v into equation (3) and rearranging terms, the condition for the existence of an SPS equilibrium becomes

$$\frac{v-s}{(\delta+r)}-c \geq \frac{sr}{\delta(\delta+r)}.$$

As $\delta \to 0$ ($T \to \infty$), the left-hand side of this expression approaches a constant, ((v - s)/r) – c, while the right-hand side goes to infinity. Hence, if assets are durable enough, no SPS equilibrium will exist no matter how much the value of the asset exceeds its costs.

To gain a sense of how restrictive the requirement for an SPS equilibrium is, note that the SPS premium needed to sustain post-sale service provision is $r/[\delta(\delta + r)]$ times per-period service costs, *s*, or equivalently, (r/δ) times the present value of life-time service costs, $s/(\delta + r)$. Table 1 shows values of the "SPS multiplier," defined as $r/[\delta(\delta + r)]$, for several combinations of discount rates and expected asset lives. For example, with an annual discount rate of five percent and an expected asset life of twenty years, the SPS premium would be ten times the annual cost of post-sale service, *s*, or the equivalent of doubling (rT = .05.20)

			$T = 1/\delta$		
r	5	10	20	25	30
.03	0.65	2.31	7.50	10.71	14.21
.05	1.00	3.33	10.00	13.89	18.00
.10	1.67	5.00	13.33	17.86	22.50

Table 1. Selected Values of the SPS Multiplier, $r/[\delta(\delta + r)]$

= 1) the present value of expected lifetime service costs, $s/(\delta + r)$. With the preceding parameters, a machine requiring annual service costs equal to five percent of its production costs (*c* in the model) would have expected lifetime service costs (in present value) equal to fifty percent of production costs (.05c/(.05+.05)) and require an *additional* premium of fifty percent of production costs for provision of that service to be self enforcing.

4. The Timing of Payments

Because the incentive to renege on service commitments in the preceding analysis arises from the divergence between the timing of payments and the cost of providing service, a natural solution to the problem is to defer payments and make their receipt conditional on service delivery. Although a full analysis of alternative payment structures is beyond the scope of this paper, a brief consideration of some of relevant issues and tradeoffs shows the problem is not costlessly remedied. For example, "unbundling" service from asset sales and charging a price for service sufficient to cover its cost would make service provision self enforcing but, by shifting the cost of product failures from producers to buyers, would weaken producers' incentives to reduce failures. Similarly, limiting service provision to a period less than the life of the asset would reduce the SPS premium but, again, sacrifices to some degree manufacturer incentives to improve quality.⁸ Formal lifetime warranties could, in principle, address the commitment problem without sacrificing ex ante quality. But, as previously noted, the efficacy of warranties depends on the competence and cost of judicial enforcement.⁹

One response to the reneging problem that avoids many of the drawbacks of these other alternatives is leasing. Leasing — and equivalent arrangements in other contexts such as franchising and some forms of licensing — alters the economics of durable goods transactions in two ways: First, it spreads payments for assets out over the life of the asset, and second, it makes those payments contingent on continued performance.¹⁰ A manufacturer that reneged on promised service on leased machinery thus stands to suffer a loss of income on currently leased machinery as well as on prospective rentals from future leases. Retaining the previous definitions and assumptions, and letting φ be the perperiod rental rate, a manufacturer would find it profitable to offer machinery for lease with a commitment to provide service without separate charge if

$$\int_0^\infty (\varphi - s) e^{-(r+\delta)(t)} dt \ge c.$$

Integrating and rearranging terms, we get

$$\varphi \ge s + c(r+\delta) = s + rc + \frac{c}{T}.$$
(11)

⁸Reducing the durability of assets, or otherwise hastening product obsolescence, below the efficient level, would also reduce the SPS premium but at a cost of truncating the value produced by more durable assets and increasing production costs for replacement.

⁹The credibility considerations discussed here may, however, help to explain the "well known empirical observation that the duration of warranties is much shorter than the life expectancy of the product they accompany" (Emons, 1989: 287). See also, Priest (1981: 1326-27).

¹⁰Strictly speaking, these features of leasing depend on the structure of the lease. A lease that covered the fulllife of the asset and that set large penalties for early termination would approximate a sale and thus suffer the same incentive compatibility problems. The advantages of leasing discussed here and elsewhere in the literature (see fn. 1) require that leases either be short term (or easily terminable) or tie payments to machine use or performance. The leases used by United Shoe Machinery Corp., IBM, and Xerox all satisfied this requirement. Note that franchising is, in all material respects, equivalent to leasing in the present analysis.

In words, offering machines for lease with "free" service will be profitable for a manufacturer as long as the per-period rental (φ) covers the sum of (i) expected per-period service costs (*s*); (ii) perperiod interest on machine production costs (*rc*); and (iii) prorated machine production costs (*c/T*).

A manufacturer's promise to service leased machinery will be self enforcing if the loss in profits on current and future rentals exceeds the savings from reneging. Using the notation above, the manufacturer's per-machine expected surplus on a leased machine will be

$$w^{\ell} = \int_{0}^{\infty} (\varphi - s) e^{-(r+\delta)(t)} dt - c = \frac{(\varphi - s)}{(r+\delta)} - c.$$

At any point in time t', the present discounted value of newly leased machines will thus be

$$W^{\ell}(t') = \int_{t'}^{\infty} w^{\ell} q(t) e^{-r(t-t')} dt = \int_{t'}^{\infty} w^{\ell} [\delta M + M e^{-gt} (g-\delta)] e^{-r(t-t')} dt.$$

As under sales, a manufacturer that reneges on its service commitments under leasing stands to save the present value of expected service costs on the existing stock of leased machines, or

$$S(t') = \int_{t'}^{\infty} sQ(t')e^{-(t+\delta)(t-t')}dt.$$

But unlike with sales, a leasing manufacturer that reneges on service stands to lose the present value of rental revenue on machines previously leased and still in the field, or

$$R^{\ell}(t') = \int_{t'}^{\infty} \varphi Q(t') e^{-(r+\delta)(t-t')} dt.$$

The condition for servicing of leased machinery to be self enforcing, corresponding to (4) for sales, is

$$V^{\ell}(t) = W^{\ell}(t) + R^{\ell}(t) - S(t) \ge 0 \text{ for all } t \in [0, \infty).$$
(12)

It is straightforward to show that equation (12) is satisfied as long as $\varphi \ge s$. Given that φ must be greater than $s + c(r + \delta)$ for leasing to be profitable (see condition (11)), service provision on leased machines will always be self enforcing. And because leasing involves no time inconsistency problem, the present value of rentals need only cover machinery costs plus discounted expected lifetime service costs, i.e., $\varphi/(r+\delta) \ge c + s/(r+\delta)$; leasing thus avoids the premium required to make service provision self enforcing with sales.¹¹

Unlike warranties and service contracts, leasing is both (relatively) self-enforcing and, because manufacturers bear service costs, retains manufacturer incentives to invest in ex ante quality.¹² The argument here, however, is not that leasing is the best or only response to the problem of reneging on service provision.¹³ Rather, the point is simply that the inability of reputation alone to sustain post-sale service provision affects the pricing and distribution arrangements for assets that require such services. The choice among those arrangements, each of which has its own costs and limitations, will depend on the particulars of the setting.

Note also that, manufacturer incentives under leasing, in contrast to reputational solutions, do not depend on communication of cheating to other potential customers.

¹¹Note that leasing with "free" repairs also addresses the problem identified by Carlton and Waldman (2009) that consumers will replace machines too infrequently if repairs are priced at marginal cost and machines are priced above marginal cost. With the leasing manufacturer bearing both machine and repair costs, the manufacturer has the incentive to make optimal retirement decisions.

¹²Replicating the incentives of leasing with service contracts is likely to be difficult for several reasons. As Masten and Snyder (1993: 43) note:

To replicate fully the incentives of leases, manufacturers would have to provide machines (virtually) free and collect compensation exclusively through cancelable charges for service. Under such terms, however, a customer who discovers that he has received a high quality machine will wish to cancel the contingent payments to avoid paying for the machine, to which the manufacturer would have no effective recourse. Alternatively, a sale that capitalized a large part of the expected value of a machine in an initial payment (with correspondingly lower contingent payments) would invite the manufacturer to produce poor quality equipment and either deteriorate service or contrive cancellation of the contract by claiming customer mistreatment of the assets. Whereas the only recourse available to disputants under a service contract is litigation, leasing relies on self-help. Specifically, under leasing, the manufacturer has the unilateral option of retrieving and the customer of returning the machine if the other behaves opportunistically.

¹³For some of the drawbacks of leasing, see Masten and Snyder (45-6).

5. Reputation and the Provision of Post-Sale Service in Practice

To gauge how large an obstacle to the self-enforcing provision of post-sale service the SPS premium might be in practice, we researched the literature and historical records for information on the durability and service costs of machines offered by United Shoe Machinery Corp., IBM, and Xerox during the period before antitrust interventions altered their practices.¹⁴ As noted earlier, all three firms were innovators in their respective industries, offering technologically advanced machines mainly to commercial customers. All three also originally offered their major machines for lease only and provided a wide range of services on their leased machinery without explicit charges. United, the earliest of the three, offered shoe machinery for lease from its founding in 1899. Between then and 1950, United had produced over eight hundred machine models (Kaysen, 1956: 167-8) and, at the initiation of the antitrust case in 1947, offered 343 types of machines, of which a little over half (179) were offered for lease only.¹⁵ Among the government's complaints was United's practice of supplying "without separate charge ... repair service and many kinds of other service useful to shoe manufacturers."¹⁶

Like United, IBM also originally offered its main products for lease only, as did other early computer manufacturers (see, e.g., Fisher, et al., 1983b: 17, 21, 172). And like United, IBM did not charge for repair and other services it provided lessees (Fisher et al., 1983b: 34). Although the 1956 consent decree required IBM to offer its machines "at prices and upon terms and conditions which shall not be substantially more advantageous to IBM than the lease charges, terms and conditions for such

¹⁴Both United and IBM have been the subject of detailed studies by economists. For IBM, see Fisher at al. (1983a, b). For United, see Kaysen (1956) and Masten and Snyder (1993). The information available on Xerox is sparser.

¹⁵Exhibits B, C, D1, D2, and D3, annexed to the Defendant's Answer to the Complaint, *United States v. United Shoe Machinery Corporation*, 110 F. Supp. 295 (D. Mass. 1953), affirmed; 347 U.S. 521 (1954).

¹⁶United States v. United Machinery Corporation, 110 F. Supp. 295 (D. Mass. 1953): 142-3 (hereafter cited as District Court Opinion).

machines" (id.), leasing remained the predominant means by which IBM placed mainframe computers throughout the 1950s and '60s.¹⁷

Finally, Xerox's highly successful Model 914, introduced in 1959, was the first automatic plain-paper xerographic copy machine. For a fee of \$95 per month, Xerox's 914 leases allowed customers to make up to two thousand copies per month, with additional copies at four cents each, and gave the customer the "absolute right to return the copier at any time, on fifteen days' notice, for any cause whatever or for no cause at all" Dessauer, 1971: 147). Again, as with United and IBM, repairs on leased Xerox copiers were included in the rentals: According to Xerox founder Joseph Wilson, "We own the machines we lease....We bear the cost of repairs or of replacing parts. That's written into the contracts we sign with our customers" (Dessauer, 1971: 130, 132). In 1975, Xerox' practice of "following a lease only policy pursuant to which Xerox refuses to sell and discourages the sale of its office copiers" was ruled to violate Section 5 of the Federal Trade Commission Act.¹⁸

All three companies thus offered complex machines for which they provided repair and other services without separate charges. The question we seek to explore here is whether reputation considerations would have been adequate to make such service provision self enforcing if the machinery had been sold instead of leased or, more specifically, how high the sale price of machines would have had to have been to sustain the self-enforcing provision of post-sale service given the durability (*T*) of and service costs (*s*) associated with each manufacturer's machines.¹⁹

¹⁷Fisher at al. (1983b: 174). Moreover, sales of IBM computers following the decree were often made to computer leasing companies, i.e., firms that leased the equipment to final users (id.: 406).

¹⁸In the matter of Xerox Corp., 86 FTC 364 (1975): 367.

¹⁹In addition to ordering that machines be available for sale, the government required that United and IBM charge separately for service. See District Court Opinion: 321; and *United States v. International Business Machines Corporation*, 1956 Trade Cas. (CCH) P68,245: 11.

5.1. Reliability and Service Costs

Shoe machines. Mechanization of shoe production posed formidable engineering challenges related to the varied and irregular shapes of shoes and the heterogeneity of construction materials and methods. The machines developed to accomplish those tasks were complex and prone to breakdown: "No matter how skillfully designed, these complicated machine types will require frequent service."²⁰ United devoted considerable resources to servicing its machines: "To meet repair needs, United kept an inventory of 107,000 types of spare parts and maintained a staff of 1,500 employees in sixteen branch and twenty-nine suboffices in seventeen states, who were responsible for keeping its machines in good working order" (Masten and Snyder, 1993: 40). United also provided ongoing advice, through its planning and "Shoe-Ex" departments, on production methods and the solution of shoe making problems *(id.)*.

United explicitly estimated and incorporated service costs when setting machine rental rates.²¹ For example, United estimated annual service costs for its USMC Universal Heat Activating Machine –Model A, a lease-only machine of moderate complexity, at five percent of the machine's manufacturing cost (\$26.50 and \$530, respectively).²² More broadly, Kaysen estimated that United's overall expenditures on service accounted for approximately 20% of its annual expenses, with roughly equal parts of the remainder going to manufacturing, research, distribution, and overhead (Kaysen, 1956: 118). To convert that figure to annual per-machine service costs, recall that service costs are a function of the stock of outstanding machines (sQ_i), while production (manufacturing and distribution) costs depend on

²⁰District Court Opinion: 302. For a more detailed description of the problems of shoe production and shoe machinery design, see Masten and Snyder, 1993.

²¹Request for Findings of Fact of the United Shoe Machinery Corporation in the District Court of the United States for the District of Massachusetts: 481. (Hereafter cited as United Facts).

²²"Memorandum to Mr. A.W. Todd, President, USMC Universal Heat Activating Machine – Model A," May 5, 1947, (Plaintiff Exhibit S-247.A). This machine had 506 parts, compared to an average of 542 (see table 7 below).

current production (cq_t). As of 1947, United had 115,787 machines in the field (District Court Opinion: 304-5), compared to expected shipments for 1951 of 11,355 machines (Kaysen, 1956: 37). Using these figures as estimates of Q_t and q_t , respectively, and Kaysen's estimated breakdown of annual expenses implies average annual per-machine service costs of roughly ten percent of manufacturing costs (i.e., $s = (11,355/115,787) \cdot c \approx 0.1 c$). United's service costs thus appear to have averaged approximately ten percent of manufacturing costs, or five percent of manufacturing plus distribution costs.

Mainframe computers. In addition to developing and manufacturing hardware, IBM supplied computer users with a full range of support services: "These support services include such vital adjuncts to computers and punched-card machines as machine maintenance; 'software,' or programming languages and systems for directing equipment in doing the job; guidance in designing a new processing system; training customer employees; and in planning the physical installation of the new equipment, and 'debugging' and updating programs" (*Wall Street Journal*, Dec. 9, 1968: 3).

The service needs of early computers and peripherals were frequent. Computer hardware failures were a common occurrence (Phister, 1974: 116):

The average of two to three system failures per day is not at all unusual for medium-size business data processing systems. In fact, [a study by] Yourdon [1972] reports that larger systems like the IBM 360/91 and 360/95 usually suffer four or five system failures per day, and he mentions that CDC established a goal of reducing failure on their 7600 systems to an acceptable level of fifty per month.

To meet hardware repair needs, IBM maintained a staff of highly trained engineers and an inventory of spare parts. But operation of computers depended on software as well, which also required frequent and ongoing support (Phister, 1974: 218):

When [software] product verification is complete the development project terminates, the program is released to users, and a maintenance or sustaining activity begins — a state of affairs entirely analogous to that which exists when a hardware product is released. Users will encounter difficulties, and a sustaining group will be assigned the job of resolving the difficulties.

			-		
	1956	1960	1965	1970	1974
Annual hardware maintenance costs	\$18,852	\$13,530	\$12,498	\$14,286	\$17,556
Annual hardware maintenance costs as a percent of system price (\$500K)	3.8	2.7	2.5	2.9	3.5
Annual hardware maintenance costs as a percent of manufacturing costs (\$125K)	15.1	10.8	10.0	11.4	14.0
Source: Phister (1974)					

Table 2. Hardware service costs for a representative IBM computer system over time

Source: Phister (1974)

Although the service costs associated with mainframe computer systems varied over time and among systems, a detailed analysis by Phister (1974) of the life-cycle costs of a representative IBM computer system provides a sense of their magnitude.²³ Table 2 contains annual hardware service costs based on Phister's estimates of system maintenance costs, including preventative maintenance, spare parts, and repair costs, on a \$500,000 computer system consisting of a central processing unit and memory, nine peripherals, and six terminals, at five points in time over nearly two decades (Phister, 1974: 510-11). The second row shows these costs as a percent of the system's price (\$500,000) and the third as a percent of manufacturing costs (\$125,000).²⁴ According to these estimates, the annual cost of hardware maintenance alone (i.e., not including "software maintenance") amounted to ten to fifteen percent of manufacturing costs.

²³Phister (1974) constructs his estimates for a hypothetical system, but bases his figures on actual cost and performance data and checks his model for accuracy against confidential information released in the IBM-Telex trial (Telex Corp. v. International Business Machines Corp., 357 F. Supp. 258 (N.D. Oklahoma, 1973)). See Phister (1974): 235, 506-510.

²⁴Phister (1974: 508-10). Phister estimated IBM's overall manufacturing costs to be about 20% of its revenue, or about \$1,655 million out of revenue of \$8,274 million in 1971 (236). His estimated manufacturing costs for other computer system manufacturers ranged from 25 to 35% (id.).

	Percent of life-cycle processor cost
Development	10.8%
Manufacturing	35.3%
Marketing and sales	26.5%
Maintenance	26.5%
Sustaining	1.7%

 Table 3. Cost breakdown for a \$100K processor

Source: Phister (1974)

Finally, Table 3 presents Phister's breakdown of life-cycle costs (undiscounted) for a one hundred thousand dollar processor (circa 1970). Even though maintenance costs are substantially lower for processors than peripherals (Phister: 236), maintenance and "sustaining"²⁵ costs combined represent over twenty-eight percent of total costs over the life of the processor and amount to eighty percent of manufacturing costs.²⁶

Plain paper copiers. Describing plain paper copiers in the mid-1980's, Bresnahan observed, "Plain paper copiers are complex, highly technical products. Models vary in speed, ability to collate, needed warmup time, and reliability" (1984: 16). The description is generally applicable to earlier copiers as well. Xerox' Model 914, introduced in 1959, had 1,260 parts and needed frequent repairs

²⁵Hardware "sustaining" is a form of ongoing product support and includes "monitor[ing] the manufacturability and maintainability of the product, and ... mak[ing] modifications or corrections to solve problems identified by the manufacturing or customer service organizations – modifying drawings and releasing revised documentation as necessary" (Phister, 1974: 200).

 $^{^{26}}$ Phister's figures include only maintenance and sustaining costs for hardware and thus exclude costs associated with service on associated software. Because Phister's figures are the undiscounted sum of life-cycle costs, the percentages for post-sale costs correspond to *sT* (divided by total costs) in the model. Hence, if a processor has an expected economic life of ten years, this would imply average annual hardware service costs of approximately 2.8 percent of total costs or eight percent of manufacturing costs.

(Dessauer, 1971: 130). From the outset, service costs were a major concern of Xerox management (*id*.: 132, quoting Joseph Wilson):

"A single service call, we have figured, will cost us between fifteen and thirty dollars, depending on how far our serviceman has to travel, how long it takes him to make repairs, and how much it may cost to replace malfunctioning parts. We estimate we face an average of twenty-five dollars a service call. If we eventually place five thousand machines on the market and have to make just one service call a month on each machine, it could cost us \$125,000 a month, or \$1,500,000 a year!"

At \$25 per call, a single service call per month thus represented roughly a quarter of the 914's base monthly rental of \$95, or about twelve percent of the 914's reported production costs of \$2,500 annually (Blackstone, 1975: 191). Reliability had improved little by the late 1970's. By 1978, Xerox estimated that its Model 3600I, at 40,000 copies per month, produced on average 30,211 copies between repairs (*Business Week*, 1978). At the time, Xerox maintained a domestic repair staff of approximately 10,000 and incurred approximately \$400 million annually servicing 470,000 copiers (*id.*), or roughly \$850 per copier per year.

5.2. Durability

Shoe machines. The typical shoe machine was a large, sturdy piece of equipment. United's leased machinery models averaged over eight hundred pounds, and some models exceeded five thousand pounds (Dean [1]). Figure 4 shows two representative machines, the first, a lasting machine, weighed 670 pounds, and the second, an outsoling machine, 3,125 pounds. In general, these machines were very durable. The basic structure of the machines were made to last indefinitely and, with the replacement or reconditioning of moving parts, a machine could operate for fifty years or more. A tabulation of United's leased machinery outstanding on January 1, 1954, included 2,808 machines shipped prior to 1924, and 376 machines shipped prior to 1914, including twenty-one shipped in 1904 (Dean [2]).



Figure 4. United Shoe Machinery Corp. shoe machines

	Mean	Std. Dev.	Min	Max	Obs
$T(BIR)^1$	17.1	4.3	8	30	39**
$T (Dean)^2$	13.0	3.6	6	25	266*
T(AAC)	17.1	3.2	12	20	170*

Table 4. Economic Life (*T*) Estimates of United Shoe Machinery Models

*machine models **machine categories

Sources: ¹ Coles (1955); ² Dean [1]; ³American Appraisal Company

Of course, technological progress could make an otherwise functional machine economically obsolete. In this respect, too, United's shoe machinery exhibited considerable longevity: Kaysen (1956) calculated the median age (the time since introduction) of United's active machine models as of 1950 to be twenty-eight years, and the median life (the interval between introduction and withdrawal) of models discontinued prior to 1950 to be twenty-one years (166-169). United's most important machine models had even greater longevity: According to Kaysen (170), the revenue-weighted average age of United's twenty-five most important machine models (as of 1947) was thirty-two years.

The historical record contains a number of estimates of the economic life of individual shoe machines by type and model. A bulletin published by the U.S. Bureau of Internal Revenue for purposes of determining reasonable depreciation rates reported useful economic lives for various shoe machine types ranging from six to thirty years and concluded "the average composite life of shoemaking machinery is approximately 15 years."²⁷ The durability of thirty-nine categories of shoe machines identified by the Bureau ranged from eight to thirty years and averaged seventeen years. (See row 1 of table 4.)

 $^{^{27}}$ U.S. Bureau of Internal Revenue Bulletin F, as quoted in Coles (1955). Coles does not provide the date that the bulletin was issued.

In addition, two other sets of estimates of the economic lives of United's machines were produced in the course of implementing the judgment against United in *U.S. v United Shoe Machinery Corp* (1953).²⁸ The first, by Joel Dean, a Columbia University business economics professor and economic consultant to United, contained estimates for at least 266 machine models derived from actuarial and turnover data (row 2 of table 4).²⁹ The second set, produced by the American Appraisal Company (ACC) on behalf of the National Shoe Manufacturers Association, assigned 170 United machine models among three economic-life categories: twelve years (thirty-eight models), sixteen years (forty-nine models), and twenty years (eighty-three models). Although the durability estimates of these three sources vary, it is evident that United's machines had substantial economic lives, with an average life (across models) above thirteen years and probably closer to seventeen years; durability averaged over machines, rather than models, was even longer: 15.2 years (Dean) and 18.7 years (AAC).³⁰

Computers. To estimate the economic life of computer systems, we make use of the relation in equation (3), which, in discrete form and after rearranging terms, becomes $Q(t) = [Q(t-1) - \delta Q(t-1)]$

 $^{^{28}}$ The decree required that United make all of its machines available for sale under terms that "do not make it substantially more advantageous for a shoe factory to lease rather than to buy a machine" (District Court Opinion: 351). The economic life of machinery was an important factor in trying to establish prices that satisfied this requirement. Among the other things, the decree also required that United charge separately for all services, including repairs, beginning thirty days after installation (*id.*: 353).

²⁹Two hundred and thirty-six of Dean's economic life estimates were taken from Dean [1]. Dean estimates for an additional thirty models were reported in American Appraisal Company [1]. Dean's methods are described in detail in Dean (1956 [3]); reproduced in Dean, 1979, Vol. 8. Coles (1955) produced a table comparing the Internal Revenue Bureau useful economic lives estimates for thirty-eight machine types with corresponding figures for comparable machine categories derived from the Dean estimates. The average across machine types for the Internal Revenue Service estimates was seventeen years compared to fourteen years for the Dean estimates.

³⁰Inasmuch as Dean's economic life estimates were based on actuarial and turnover data for United's leased machinery, Dean's estimates may underestimate the life of machines under sales: When a leased machine was returned to United, United's practice was to disassemble the machine and use its parts to produce new machines (United Facts: 484). As a result, machinery records of United reflected a machine's life for its first owner only. Under sales, "a machine in identical circumstances will have considerable economic life remaining" and would likely be sold to another shoe manufacturer if its current owner no longer had use for it (Dean, 1956 [3]: I-4). Additional discussion of the durability of United shoe machinery is contained in section 5.6 and the Appendix.

	$\hat{\delta}$	s.e.	R^2	Т
General purpose computers, number	.085	.0070	.89	12
General purpose computers, value	.109	.0077	.92	9
All computers, number	.071	.0044	.94	14
All computers, value	.104	.0071	.92	10

Table 5. Estimated economic lives of computers

 (δ) of last period's stock going out of service plus this period's shipments. Rewriting this expression, we get the number of machines retired in period t - 1 equals

$$\delta Q(t-1) = q(t) - [Q(t) - Q(t-1)].$$

To estimate δ from the preceding equation, we used annual data on the number and value of computer systems shipped and in use for the years 1955-1974 (from Phister, 1974: 251). Estimates for "general purpose" and all computers are reported in table 5. Depending on the measure used, we estimate the rate at which computers went out of service at between approximately 7 and 11% per year, implying expected asset lives between 9 and 14 years.³¹

Copiers. We were unable to data on copier durability, but Blackstone (1975) reports that both plain paper and electrofax (coated paper) copiers were expected to "last for about five years" (191-2).

5.5 Estimated SPS Multipliers

³¹The estimates of δ reported in table 8 are from regressions omitting a constant term. The corresponding estimates including a constant term were .093, .120, .077, and .114, implying average system lives ranging from 8 to 13 years. Using a different method, Phister calculated the average age at retirement of general purpose computers (U.S. only) to be a little over 6 years (see Phister, 1974: 254). A 1968 *Wall Street Journal* article reported that computer leasing firms, which purchased IBM equipment to lease to computer users, set their lease rates to recoup machine costs over a ten-year period (*Wall Street Journal*, 1968, p. 3).

			<i>r</i> =	.05	r = .10		
	s/c	$T (= 1/\delta)$	SPS multiplier	SPS premium	SPS multiplier	SPS premium	
USMC	10%	14 – 18 yrs.	5.8 - 8.5	58 - 85%	8.2 - 11.6	82 - 116%	
IBM	10-15%	9 – 14 yrs.	2.8 - 5.8	28-86%	4.3 - 8.2	43 - 122%	
Xerox	10-15%	5 yrs.	1	10-15%	1.7	17 – 25%	

Table 6. Estimated SPS Multipliers and Premia as Percent of Manufacturing Costs

Using the service cost and durability estimates of the preceding sections, we can calculate estimates of the premium for each company that, according to the theory, would have been needed to make post-sale service provision self enforcing. To do so, however, we also need an appropriate value for the discount rate, *r*. Rather than trying to identify and defend a particular rate for each company and time period, we calculated the SPS multiplier for discount rates of five and ten percent.³² Columns (1) and (2) of table 6 summarize our estimates of service costs, reported as a percent of manufacturing costs (*s/c*), and average machine life (*T*) for each company. The SPS multiplier, $r/[\delta(\delta+r)]$, represents the amount by which each additional dollar of per-period service cost increases the premium needed for post-sale service promises to be self enforcing. The estimates range from 1 (for Xerox at r = .05) to 11.6 (for United with r = .10). The implied SPS premia, expressed as a percent of manufacturing costs, range in turn from 10% (again, for Xerox at r = .05) to 122% (for IBM at r = .10). In other words, at the low end, Xerox would have had to charge a premium in excess of 10% of manufacturing costs — \$250 on a

³²For purposes of computing "customer equivalent sale prices" for United's leased machinery, Dean estimated an average cost of capital for shoe manufacturers of 10.6% (see Dean, 1956 [3], Appendix III). Consultants for the National Shoe Manufacturers Association argued, by contrast, that the relevant cost of capital for shoemakers was at least 18 percent (Andrews, Anthony & McLean, 1955: 14-19). United, meanwhile, used an interest rate of 6% internally for purposes of setting machine prices and rentals (United Request for Findings of Fact, Vol. III: 481). Presumably, an appropriate rate for calculating the SPS premium would reflect the probability of firm failure and other contingencies (such as antitrust suits) that could prematurely truncate the stream of future profits and, thereby, undermine the credibility of service provision.

machine that cost \$2,500 to produce — for its promises to service purchased machines free of charge over the life of the machine to be credible; at the other extreme, IBM would have had to earn a premium in excess of 122% of manufacturing costs — \$152 thousand on a system that cost \$125 thousand to manufacture — to satisfy the SPS condition (under the least favorable parameters). Even with the more conservative five percent discount rate, the estimates imply significant SPS premia for United and IBM: 58 to 85 percent of manufacturing costs for United, and 28 to 86 percent for IBM.³³

5.6. Shoe Machinery Sales and Leasing

The preceding estimates are based on averages or representative machines. In practice, of course, machinery models changed over time and, in the case of United and IBM, multiple models and products were offered at any given time. As noted earlier, United offered 343 types of machines at the time of the 1947 antitrust case. The complexity and reliability — and, hence, the service needs — of these machines varied with the function they performed and the materials on and with which they were designed to work. Differences in service requirements and in machine durability would have implied differences in SPS premia across machines. Although a manufacturer's reputation is unlikely to be machine-specific — reneging on service commitments for one machine type is likely to affect customers' beliefs about the credibility of a firm's promises to service all of its offerings — the greater a firm's cumulative service liabilities, the greater would be its overall temptation to renege. Selling, rather than leasing, machines with high lifetime expected service liabilities would thus increase the size of the cumulative premium the firm must charge to make post-sale service commitments on its sale machines credible. To economize on reputational capital, a firm would thus have wanted to lease those of its machines with higher expected service costs and longer expected lives.

³³Recall that the service cost estimate for IBM excludes costs associated with "software maintenance."

Variable	obs	mean	sd	min	max
Parts ¹					
Lease only	117	750	598	42	2880
Optional sale or lease	79	310	184	47	849
Sale only	15	151	171	28	614
Material ²					
Lease only	119	.35 (42 obs)	.488	0	1
Optional sale or lease	79	.01 (1 obs)	.113	0	1
Sale only	15	.07 (1 obs)	.258	0	1
$T(Dean)^3$					
Lease only	146	13.5	3.50	6	25
Optional sale or lease	79	12.7	3.68	6	20
Sale only	0	_	_	_	_
$T(AAC)^4$					
Lease only	100	17.1	3.21	12	20
Optional sale or lease	44	17.5	2.87	12	20
Sale only	0	-	-	_	-

Table 7. USMC machinery characteristics descriptive statistics

¹ Source: Masten and Snyder (1993) ² Source: McCarthy (1991) ³ Source: Dean [1]

⁴ Source: American Appraisal Company

In fact, almost half (168 of 343) of United's machine models were available for sale: forty-two for sale only, and 122 models for sale or lease. Of optional lease-or-sale models, thirty-five percent (9,472 of 27,140) of the machines outstanding in 1947 had been sold.³⁴ An analysis of United's leasing practices by Masten and Snyder (1993) found that both the likelihood that a United machine model was offered for lease only, and the percentage of optional lease-or-sale machines that were leased, increased with machine complexity, as measured by the number of parts in the machine (Masten and Snyder, 1993: 52). To explore further the relationship between lifetime service costs and leasing, we augmented

³⁴Complaint Exhibits B, C, D1, D2, D3, G-446, and S-59. Figures for sales include only machines sold over the period 1931 to 1947. Since many machines sold prior to 1931 would still have been in operation, these figures understate to some degree the true number of sale machines outstanding in 1947.

	Constant	Parts/100	Material	T(Dean)	T(AAC)	п	%=1	χ^2	Pseudo R ²
(1)	0.984* (5.19)	- 0.224* (-5.13)	- 1.28* (-3.23)			211	44	79.95*	0.275
(2)	0.036 (0.11)			- 0.032 (-1.32)		225	35	1.76	0.006
(3)	- 0.928 (-1.47)				0.024 (0.67)	144	31	0.46	0.003
(4)	0.534 (1.31)	- 0.205* (-4.26)		0.007 (0.22)		172	36	38.33*	0.151
(5)	0.323 (0.42)	- 0.177* (-3.36)			0.003 (0.07)	121	29	21.60*	0.148

Table 8. Probit estimates of the probability a machine model is offered for sale

t statistics in parentheses; * indicates significance at the .01 level

Masten and Snyder's data with the Dean and American Appraisal Company durability estimates described above. We also added a dichotomous variable, Material, indicating machines that employed accessory materials such as thread, staples, tacks, or nails on the grounds that such machines had a greater tendency to malfunction and required more frequent adjustment and repair (McCarthy, 1991).

Table 7 presents descriptive statistics for the number of parts in a machine (Parts); whether a machine used thread, staples, tacks or nails (Material); and the Dean and AAC economic life estimates (T(Dean) and T(AAC)) partitioned by whether the machine was offered for lease only, optional sale or lease, or sale only.³⁵ On average, the machines that United offered for lease only both had more parts and were more likely to employ accessory materials than the machines United offered for sale; optional term machines also contained more parts than machines offered only for sale. No significant difference

³⁵Masten and Snyder (1993) collected data on the number of parts in United's machines using machine manuals on site at United Shoe Machinery Corp.'s in Wilmington, MA. Masten and Snyder analyzed only the 193 actively offered machines on which they were able to find parts manuals. To make as much use of the economic life data as possible, we have included eighteen additional "inactive" machines for which Masten and Snyder had collected parts information. Neither Masten and Snyder's nor the results reported here are affected by the treatment of these observations.

	Constant	Parts/100	Material	T(Dean)	T(AAC)	m^{\dagger}	n^{\dagger}	χ^2	Pseudo R ²
(1)	0.233 (0.14)	- 0.228* (-4.62)	- 1.53* (-5.08)			100,858	198	57.98*	0.32
(2)	0.110 (0.24)			- 0.108* (-3.30)		94,815	171	10.87*	0.07
(3)	- 0.441 (-0.55)				- 0.071 (-1.68)	82,714	126	2.81	0.02
(4)	-0.020 (-0.04)	- 0.201* (-3.46)		- 0.021 (-0.57)		94,206	161	13.55*	0.24

Table 9. Grouped probit estimates of the probability a machine sold

t-statistics calculated using bootstrap standard errors with 1000 repetitions

 $^{\dagger} m$ = total number of machines; n = number of independent observations.

* indicates significance at the .01 level

appears, however, in the average economic lives of United's lease-only machines and optional term machines using either the Dean or AAC estimates.³⁶

Table 8 reports results from probit estimations of the probability that a machine model is offered for sale (either exclusively or on optional sale or lease terms) for a variety of specifications. Parts is significant in all specifications in which it appears. An increase by one hundred in the number of parts in a machine decreases the probability that a machine will be offered for sale by eight percentage points (at the means of the explanatory variables) in specification (1); the corresponding marginal effects for specifications (4) and (5) are seven and five percentage points. Machines that employ ancillary materials are thirty-four percentage points less likely to be offered for sale than machines that do not (at the mean of Parts = 542).³⁷ Neither *T*(Dean) nor *T*(AAC) is significant in any of the specifications in which they are included.

³⁶Because Dean and the AAC constructed their economic life estimates as inputs into determining sale prices for leased machines, neither reported economic life estimates for United's sale-only machines.

³⁷The absence of observations with positive values for both the dependent variable and Material prevent the latter's inclusion in the specifications containing T(Dean) or T(AAC).

Finally, we re-estimated the regressions reported in table 8 using machines rather than machine models as the unit of observation, which allows us to make use of variation in the fraction of optional term machines actually sold.³⁸ Results are reported in table 9. Results for Parts and Material are very similar to those based on machine models. Row (2) shows a significant negative correlation between Dean's estimate of a machine's economic life and the probability of a machine being sold (or, alternatively, of the proportion of machines sold). A weaker negative correlation with sales (significantly different from zero at the 0.10 level) is also found with the AAC machine-life estimates. The effect of durability disappears, however, when Parts is included in the regression (row (4)).

Overall, the results show a greater tendency for United's machines to be leased the more complex the machines, as measured both by the number of parts in the machine and whether the machine employs accessory materials. The results show no consistent, independent relation between leasing and either of the available measures of machine durability. The fact that the available data contain no economic life estimates for sale-only machines (predicted to have the shortest lives) and that sophisticated analysts with access to an enormous quantity of historical data on shoe machinery shipments and retirements produced such disparate estimates of machine durability (see the Appendix) may account for the latter. Whereas a machine's complexity — and, thereby, its likely service needs — can be gauged by inspection, a shoemaker would likely have had a much harder time forecasting whether a given machine would remain useful ten, fifteen or more years in the future.³⁹

³⁸Approximately, thirty-three percent of optional term machines and ten percent of all United machines in the sample were sold. The sample under-represents sale-only machines both because economic life estimates were not produced for sale-only machines and because disproportionately fewer part manuals were located for sale-only machines (see Masten and Snyder, 1993: 52, fn. 63).

³⁹Machine durability was one of the most hotly disputed issues during implementation of the United decree. See, e.g., Andrews, Anthony, & McLean, "An Appraisal of the Estimating Techniques for Economic Lives of the 30 Major Shoe Machine Types Used in the Dean Report."

6. Conclusion

Reputation is a potentially important force facilitating exchange and cooperation. In transactions between firms and between firms and consumers, the value of repeat business from satisfied trading partners provides both sides an incentive to honor their commitments and, thereby, reduces the need for costly contracting and legal enforcement. Reputation acts, in effect, as a valuable lubricant reducing transactional frictions. Yet, beyond characterizing the necessary conditions for the existence of reputational equilibria, fairly little research has been done on the factors that foster and impede reputation. As a consequence, we are often able to do little more than infer the adequacy or inadequacy of reputation from observed outcomes: The decision to enter a formal contract or the occurrence of a dispute is taken as evidence that reputation must not have been strong enough to secure the parties' cooperation.

In this paper, we have analyzed the effects of post-sale service on the existence of reputational equilibria. In the process, the analysis also offers an explanation for the puzzle of why prominent durable goods suppliers such as IBM, Xerox, and United Shoe Machinery Corp. used leasing to distribute their products rather than direct sales: Why would firms with such well-established reputations for product quality find leasing attractive when other less reputable manufacturers of durable goods prospered selling rather than leasing their products? At least part of the answer, we argue, lies in the high-cost of post-sale service associated with these products: Whereas the cost of providing ex-ante quality relates to the flow of new machine production, the cost of repairs and maintenance depends on the installed base of existing machines and, thus, on the level of past sales. Depending on the durability of machines, the costs of servicing the stock of outstanding machines may come to exceed the stream of incoming rents from new sales so that, over time, the gain from reneging on service commitments will outweigh the gain from future sales.

Corp., IBM, and Xerox would have had to add to the price of their machines (in addition to the present value of service costs) to make the provision of post-sale services self enforcing. The values we found ranged from ten to over one hundred percent of manufacturing costs. Because such premia are unnecessary with leasing, these figures indicate a substantial advantage to leasing over sales for these machines and help to explain why leasing was so widely preferred for these manufacturer's machines. This pattern of leasing complex, service dependent machinery appears elsewhere. A study of five industrial-machinery manufacturers (Engelbourg, 1966) noted the following similarities (52):⁴⁰

Each of these firms marketed its major machines only by leasing, tied machine use and service, followed a price policy which directly or indirectly related the rental to output, and was historically dominant in its industry. The machinery leased by these lessors was complex and relatively expensive, had unusually heavy advisory, service, and maintenance requirements, and had a rental cost that constituted a small fraction of the user's total cost.

Although we have focused on post-sale service of machines, the analysis here applies as well to other types of assets that require ongoing support. Examples include franchisor expenditures in support of brand names, and customer technical support, fixes, and upgrades for software. The use of franchising (with royalty payments) in the former, and fixed-term licensing in the latter, are consistent with the postsale considerations analyzed in this paper.

Finally, the issue of reputation and post-sale service bears on the controversy in antitrust over pricing of aftermarket products and services for durable equipment. Following the U.S. Supreme Court's decision in *Eastman Kodak Co. v. Image Technical Service*, 112 S. Ct. 2072 (1992), most of the recent literature on the pricing of post-sale or "aftermarket" services has focused on the problem of overpricing, the concern being that durable goods manufacturers may be able to impede competition for parts or service and thereby charge monopoly prices in the aftermarket.⁴¹ Important earlier cases, however, were

⁴⁰In addition to United Shoe Machinery Corp. and IBM, discussed here, the five included Hartford-Empire (glass container machinery), American Machine & Foundry (cigar production machinery), and American Can.

⁴¹See, e.g., Shaprio (1995); Klein (1999); Carlton (2001); Joskow (2002), Kaserman (2007), and Carlton and Waldman (2009).

often directed at the opposite problem: the underpricing of post-sale services and, specifically, the bundling of post-sale service in the price of the durable good. Understanding better the circumstances that lead durable goods manufacturers to provide post-sale services free of charge (as under warranties) and the duration of such service commitments would seem an important to assessing the overall merits aftermarket pricing.⁴²

⁴²Borenstein et al.'s (2000) finding that a manufacturer's incentive to price services above marginal cost increases with the firm's "installed base" and the durability of equipment is highly congruent with our analysis.

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APPENDIX

Because durability was an important consideration in determining sale prices for United Shoe Machinery Corp. machines that would satisfy the court's order that United offer its machines for sale on terms that made sale attractive, durability estimates were a contentious issue. Using different methods, experts for United and for the National Shoe Manufacturers Association produced widely divergent estimates. As seen in table 2 in the text, the Dean economic life estimates were significantly lower than those of American Appraisal Company. Closer examination shows remarkably little agreement between the Dean and AAC durability estimates. Figure A-1 plots the Dean and AAC durability estimates for the 170 machine models in common. The simple correlation between the two sets of estimates is only 0.14 (albeit significant at the 0.06 level).⁴³

The Coles study compared the "average use life" for 38 machine types reported in Bulletin F of the Internal Revenue Bureau with the "average actuarial life" on "comparable USMC machines" based on Dean's estimates. As shown in table 4 in the text, the average across machine types for BIR figures was 17 years with a range of 8 to 30 years. For Coles' set of comparable USMC machines, the average of Dean's economic life estimates was 14 years with a range of six to nineteen years. The two sets of estimates are uncorrelated (correlation coefficient of 0.09 and significance level of 0.61).

⁴³The mean, standard deviation, and range of the Dean estimates for the sample of 170 machines covered by the AAC are virtually identical to those for the full sample of 266 reported in the text. Neither the Dean nor AAC sample included any sale only machines. To the extent that machines offered only for sale had shorter economic lives than leased machines, both Dean's and the AAC's estimates would overstate average durability.



Figure A-1. Comparison of AAC (—) and Dean (♦) economic life estimates for USMC machinery Sources: AAC: American Appraisal Company; Dean: Dean [1]