Durability, Reliability and the Limits of Reputation*

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ABSTRACT

We consider the effects of post-sale service requirements for durable goods on the existence of reputational equilibria. In the standard durable-goods-quality model (e.g., Klein and Leffler, 1981; Shapiro, 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. The ability of reputation to sustain cooperation leaves unexplained, however, why such prominent durable goods suppliers — and antitrust targets — as IBM, Xerox and United Shoe Machinery Corp. showed a preference for leasing despite the many drawbacks of leasing relative to sales. We present a model showing that, even with a flow of profitable new sales indefinitely into the future, when durable goods require costly post-sale service, a reputational equilibrium may not exist at any price. More generally we characterize the size of the premium needed to make the promises to provide post-sale service self enforcing. We then apply the model to United Shoe Machinery, IBM, and Xerox. Using historical records, we estimate this premium for United Shoe Machinery and IBM to lie in the range of thirty to one hundred percent of manufacturing costs, explaining the substantial preference for leasing of these firms' products.

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1 Introduction

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.

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, however. 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 addition to leaving reputational explanations tautological, the inability to assess the effectiveness of reputation independently of observed behavior has potential policy implications. An example involves the motives for leasing of durable-goods manufacturers such as IBM, Xerox, and United Shoe Machinery Corp. The potential for underprovision of quality in the manufacture of durable goods whose attributes are difficult for consumers to determine at the time of purchase is well known: 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. Leasing solves this quality-assurance problem by making manufacturers' revenues contingent on machine performance.[1]

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

The ability of reputation to sustain the sale of high-quality goods is, however, the one of the earliest and best-known applications of the theory of reputation (Klein and Leffler, 1981; and Shapiro, 1983) and poses a challenge to claims that quality-assurance concerns motivated the leasing practices of such prominent durable-goods manufacturers. All three firms — IBM, Xerox, and United — were well-known, served primarily commercial customers and, as the dominant firms in their respective industries, were closely watched by industry analysts. Why would firms with such well-established reputations have to resort to leasing to assure quality when other manufacturers of durable goods, with arguably no greater reputational capital at stake, survived and prospered selling, rather than leasing, their products? Rejection of quality assurance as a motive for leasing lends credence to the charge that the leasing policies of these firms had anticompetitive purposes (e.g., Waldman, 1997).

In this paper, we analyze the effects of post-sale service requirements on the existence of reputational equilibria and, thus, the motives for leasing durable goods. In contrast to the extant literature, which emphasizes ex ante quality decisions, we note that, even at the optimal quality, durable goods often require post-sale service to repair failures or otherwise maintain their efficient operation. As in their choice of quality, manufacturers have an incentive to provide service on previously sold products to the extent that doing so enhances their ability to make future sales — but with one important difference: Whereas the cost of providing ex ante quality is a function of the flow of new machine production, the cost of providing post-sale service depends on the stock of machines outstanding and, thus, on the level of past sales. Under some circumstances, it may not be possible to support the sale of durable goods with post-sale services *at any price* even with a constant flow of new sales indefinitely into the future.

In the next section we provide an overview of the problem. In section 3, we develop a simple model of the firm's service decision and derive a formula that parameterizes the existence of a reputational equilibrium as a function of a good's durability and expected service costs. Section 4 examines incentives under leasing. In section 5, we apply the results to assess the credibility of post-sale service commitments for machinery offered by United Shoe Machinery Corp., IBM, and Xerox. Section 6 discusses alternatives to leasing for dealing with the problem of post-sale service where reputation alone is inadequate to support its efficient provision. Conclusions appear in the final section.

2. The problem of committing to post-sale service

In the now-familiar durable-goods quality model, a durable goods manufacturer has an incentive to represent 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 problem of quality underprovision can be overcome with contractual arrangements such as warranties (e.g., Priest, 1981; Cooper and Ross, 1985) or leasing (see references in fn. 1) that credibly link the seller's profits to its products' realized performance. Contractual solutions to the durable-goods-quality problem, as in other contexts, have their limitations, however. Warranties can be costly to write and ultimately depend on court enforcement for their credibility (Chapman and Meurer, 1989), while leasing forgoes the incentive advantages of user ownership for care and maintenance and entails increased bookkeeping costs (collecting and recording periodic payments) relative to outright sales (Masten and Snyder, 1993).

Such costly and imperfect contractual arrangements may be unnecessary, however, 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, the potential loss of future profits from consistently providing high-quality may be sufficient to deter a manufacturer from misrepresenting low-quality goods as high quality and pocketing the price premium. In the standard model, provision of high-quality goods can be sustained 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 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, 1981, 1983).

A feature of many durable goods not captured in this standard model, however, is their need for various types of post-sale service. Technologically advanced machines — like early computers, copiers, and shoe machines — break down with some frequency and are often in need of repair and other support services. For reasons of both expertise and incentives, it is often the manufacturers themselves that are best suited to provide those services.[2]

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. Manufacturers, for their part, will find it profitable to sell machines accompanied by such services as long as the discounted value of profits on future sales covers expected service costs. The provision of post-sale service alters the standard cheat-versus-cooperate calculation in two ways, however. First, in contrast to ex ante investments in quality, post-sale service represents a future liability for the manufacturer at the time of sale. Second, because a firm's service cost obligations are a function of the stock of machines outstanding, reputation considerations may be unable to sustain the sale of machines with post-sale service even though the price consumers are willing to pay is more than sufficient to cover both production costs and the present value of the expected costs of

[2]The information advantages of manufacturer provision of post-sale service run in both directions: On the one hand, the knowledge and expertise needed to repair complex machines will often arise as a byproduct of their manufacturer; on the other, repair activities provide a source of feedback on machine operations and problems that may aid in the improvement of existing machines and development of new machines. On the incentive side, liability for the cost of repairs gives manufacturers the incentive to produce high-quality machines in the first place. See Masten and Snyder (1993:39) for further discussion. Hodaka and Waldman (2006) present a model in which monopolization of maintenance permits a durable-goods manufacture to solve the time inconsistency problem known as the Coase Conjecture.

servicing machines.[3] Indeed, under some circumstances, there may be no finite price capable of supporting a reputation equilibrium for the sale of durable goods with post-sale service.

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 contingent on the manufacturer providing 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.[4] Under these assumptions, a machine sold with a commitment of perpetual post-sale service will cost the manufacturer c plus

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

Given these costs, a manufacturer would find it profitable to offer a machine for sale with a commitment to provide service as long as $p > c + s/r$. 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

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

Because of 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 $W_0 = wq(1 + r)/r$.

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[3]The problem created by post-sale service analyzed here was, to the best of our knowledge, first suggested by Masten and Snyder (1993, p. 42, fn. 38):

> [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.

[4]Service 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.

As long as w is positive, a firm would find selling machines with perpetual service commitments to be profitable: The price it 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 though the firm earns enough on each sale to cover the full expected costs of that machine, it must also find it profitable to continue to provide service on those machines it has already sold. In each period after time 0, the firm carries the liability of servicing machines sold in previous 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_t,,into the firm's profit calculation, the present value to the firm of continuing to sell and service machines in period t will be:

$$V_t = W_t - S_t = W_0 - stq(1+r)/r. \tag{1}$$

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 while 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 cost of servicing the accumulated stock of machines previously sold would eventually (here, for $t > \bar{t} = w/s$) 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. And by the usual

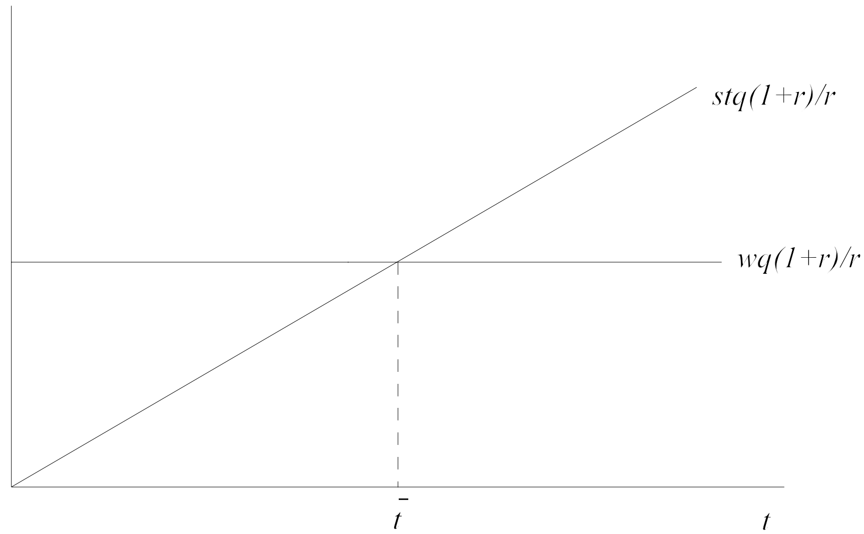

Figure 1. Expected net revenues and service costs over time

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 *for all t*. 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. Reputation with post-sale service

In this section, we offer a somewhat more general model that allows for growth in sales and machine depreciation.[5] 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 discount rate;

p = the (premium) price consumers are willing to pay for the firm's product with a (credible) promise of post-sale service.

As in the previous section, we assume that demand is rectangular, that is, consumers either buy q machines at price p (if they believe that the firm will provide service for the life of the product) or nothing (if they do not consider the firm's service promises credible). In this version of the model, however, we allow the quantity of machines purchased in each period to vary as a function of (i) the stock of machines consumers desire to hold in period t, $Q(t)$, and (ii) the rate of machine depreciation, $\delta \in [0, 1]$. Specifically, we assume

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

that is, the demand for machines in a given period is equal to the change in the desired stock of machines plus enough units to replace depreciated machines.

To model growth in demand, we adopt a limited (or inhibited) growth specification. Specifically, we assume the stock of machines consumers wish to hold in period t, $Q(t)$, equals $M(1-e^{-gt})$, where M represents "market saturation" — a (arbitrarily large) limit on the stock of machines consumers desire —

[5]The example in section 2 corresponds to the special case (in discrete time) of no depreciation and constant sales. In a companion paper (Kosová and Masten, 2006), we analyze an extensive form version of the post-sale service game in which, among other things, we allow for the possibility that consumers discover and communicate cheating on post-sale service commitments with a lag. The model also derives the optimal time for the firm to cheat if consumers followed a strategy of purchasing unless the firm cheated in the previous period.

and g is a growth parameter: Larger g implies $Q(t)$ approaches M more quickly. The rate of change in the desired stock of machines under this demand specification is $\dot{Q}(t) = Mge^{-gt}$; hence, total demand in each period is $q(t) = \delta M + Me^{-gt}(g - \delta)$.

Finally, in addition to affecting per-period sales, $q(t)$, the rate of depreciation affects the manufacturer's expected costs of post-sale service: With machines depreciating, or "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 per-machine present discounted surplus from sale of a machine with service commitment, defined in the preceding section, now becomes

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

We assume that the firm and consumers cannot contract on the provision of post-sale service but are otherwise fully informed about the model. 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 and, because anticipated reneging in the future eliminates the return to service provision today, the condition that discounted profits exceed gains from reneging must hold in every period. Formally, a post-sale service self-enforcing equilibrium (PSSSEE) will exist only if

$$V(t) = W(t) - S(t) \geq 0 \text{ for all } t \in [0, \infty), \tag{2}$$

where

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

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

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 reputational equilibrium with post-sale service will exist only if*

$$(p-c) \geq \frac{s}{\delta}. \tag{3}$$

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

$$W(t') = wM\left[\frac{(g-\delta)}{(g+r)}e^{-gt'} + \frac{\delta}{r}\right]. \tag{4}$$

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

$$S(t') = \frac{s}{r+\delta}M(1-e^{-gt'}). \tag{5}$$

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

$$V(t') \geq 0 \text{ for all } t' \in [0,\infty) \qquad \Leftrightarrow$$

$$\frac{w\delta}{r} - \frac{s}{(\delta+r)} \geq -e^{-gt'}\left[\frac{w(g-\delta)}{(g+r)} + \frac{s}{\delta+r}\right] \quad \text{for all } t' \in [0,\infty). \tag{6}$$

Both the LHS and the expression in squared brackets on the RHS of (6) 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 (6) 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 (6) will be negative. Since $-e^{-gt'}=-1$ at $t'=0$, (6) will be satisfied for all t if

$$\frac{w\delta}{r}-\frac{s}{(\delta+r)}-\left[\frac{w(\delta-g)}{(g+r)}-\frac{s}{(\delta+r)}\right]\geq 0, \tag{7}$$

which reduces to

$$\frac{\delta g+rg}{rg+r^2}\geq 0. \tag{8}$$

Since (8) is always satisfied for δ, g, $r \geq 0$, the condition for a reputation equilibrium to exist is always satisfied if $(p-c)(g-\delta)+s<0$ or, since the latter can hold only if $g<\delta$, if $(p-c) > s/(\delta-g)$.

Consider next the case of $(p-c)(g-\delta)+s\geq 0$: 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 (6) will approach a maximum of 0 as $t'\rightarrow\infty$. Setting the RHS of (6) equal to zero and rearranging terms, we get

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

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 $s/(\delta-g)>s/\delta$), a reputation equilibrium will exist unless $(p-c)<s/\delta$. ■

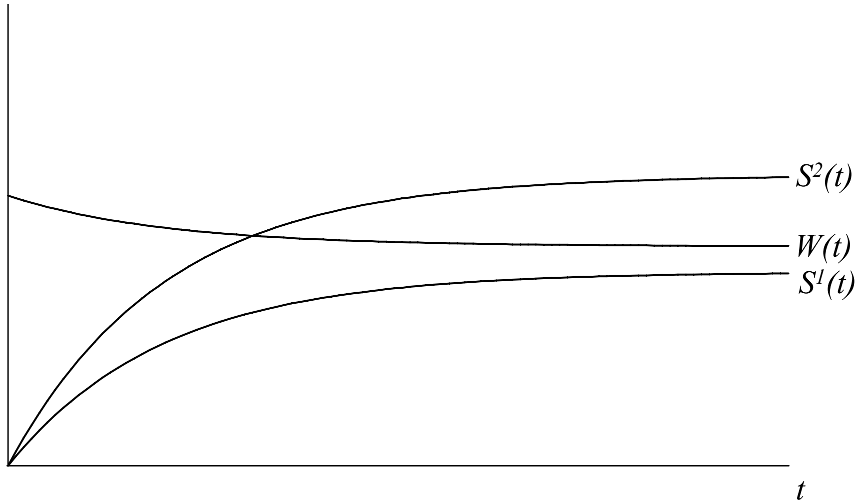

Figure 2. Net revenue and service costs paths with growth and depreciation

Figure 2 plots $W(t)$ and $S(t)$. Graphically, the existence of a post-sale service self-enforcing 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. $W(t)$ lies above $S(t)$ for all t if $(w\delta M)/r \geq sM/(\delta + r)$, which reduces $(p - c) \geq s/\delta$.

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 $(T = 1/\delta)$. 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 $w \geq 0$, condition (3) requires that $w \geq sr/[\delta(r + \delta)]$. The term $sr/[\delta(r + \delta)]$ represents, in effect, a premium by which the present value of a firm's profit on the sale of a machine must exceed break even to make post-sale service provision self-enforcing. This premium is increasing in post-sale service costs

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

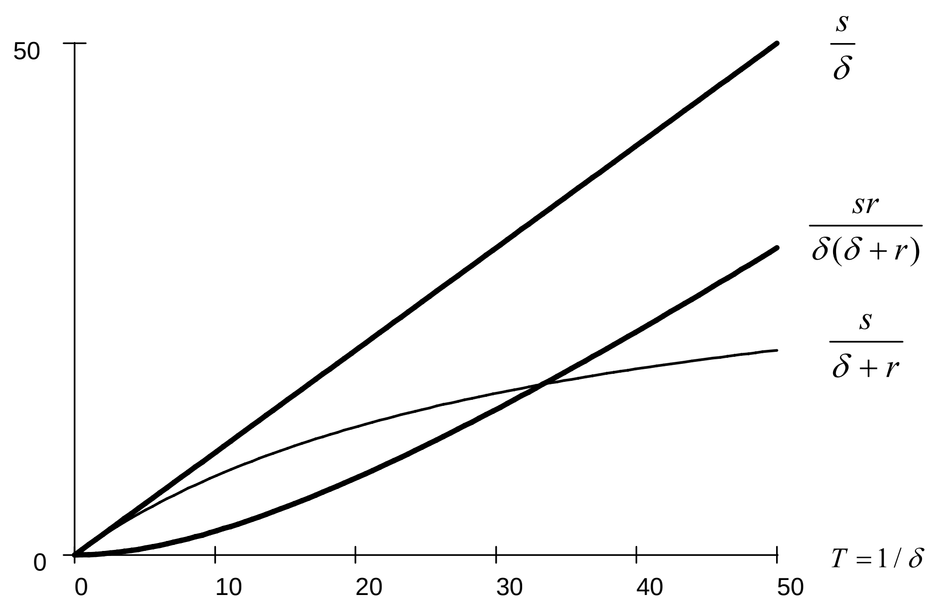

Figure 3. Expected service costs and durability ($s = 1$, $r = .03$)

(s), the discount rate (r), and the durability of machines (T=1/δ).

Figure 3 plots the PSSSEE premium (defined above), the present value of expected post-sale service costs, $s/(r+\delta)$; and their sum, $s/\delta = sT$, as a function of expected machine life, T. Expected service costs increase with average machine life but, because future costs are discounted, rise at a decreasing rate. The PSSSEE premium, by contrast, increases at an increasing rate in machine life. For sales with post-sale service to be profitable, $(p - c)$ must only exceed $s/(r + \delta)$; for provision to post-sale service to be self-enforcing, $(p - c)$ must exceed s/δ.

To provide a sense of the magnitude of the PSSSEE premium, table 1 shows values of $r / [\delta(\delta + r)]$ — the PSSSEE multiplier — for several combinations of discount rates and expected asset lives. For example, with an annual discount rate of five percent, an asset with an expected life of twenty years would require a PSSSEE premium ten times the expected annual cost of post-sale service. Thus, a machine with annual expected service costs equal to five percent of the machine's pre-sale (production and distribution)

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

r	$T = 1/\delta$: 5	10	20	25	30
.03	0.65	2.31	7.50	10.71	14.23
.05	1.00	3.33	10.00	13.89	18.03
.10	1.67	5.00	13.33	17.86	22.53

costs (c in the model), would have expected lifetime service costs (in present value) equal to fifty percent of machine costs ($.05c/(.05+.05)$) and require an *additional* premium of fifty percent of machine costs to make post-sale service provision self enforcing.

4. Leasing

Leasing alters the economics of durable goods transactions in two ways: First, it spreads payments for machines out over the life of the machine, and second, it makes those payments contingent on continued performance.[7] A manufacturer who reneges on promised service under leasing therefore stands to suffer the loss of income from existing leased machinery as well as prospective rentals from future leases. Retain the previous definitions and assumptions, and let φ be the per-period rental rate. A manufacturer will find it profitable to offer machinery for lease with a commitment to provide service without separate charge if

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

Integrating and rearranging terms, we get

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

[7]Strictly speaking, these features of leasing depend on the structure of the lease. A lease that covered the full-life 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. Alternatives to leasing are discussed in section 6.

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) per-period interest on machine production costs (*rc*), and (iii) prorated machine production costs (*c/T*).

Promises to service leased machinery will be self enforcing if the loss of future profits exceed the savings from reneging. Define the manufacturer's per-machine expected surplus on a leased machine to 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 be

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

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

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

In contrast to sale, however, a reneging manufacturer also loses the present value of rental revenue over the remaining life of currently leased machines, or

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

Servicing leased machinery will be therefore self enforcing if

$$V_\ell(t) = W_\ell(t) + R_\ell(t) - S(t) \geq 0 \quad \text{for all } t \in [0,\infty), \tag{9}$$

It is straightforward to show that equation (9) is satisfied as long as $\varphi \geq s$. Because leasing machines with service is profitable if $\varphi \geq s + c(r + \delta)$, service provision on leased machines will be self enforcing as long as leasing machinery is profitable, i.e., there is no time inconsistency problem with leasing. Finally, because leasing requires only that the present value of rentals cover machinery costs plus discounted expected lifetime service costs — i.e., $\varphi/(r+\delta) > c + s/(r+\delta)$ — leasing avoids the premium needed with sales to make service provision self enforcing.

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

In this section, we examine the products and services of United Shoe Machinery Corp., IBM, and Xerox, all three of which produced complex durable goods requiring extensive post-sale service and support, which they provided under lease and without separate charges until forced to alter their practices by government intervention.

5.1. United Shoe Machinery Corp.

United Shoe Machinery Corp. was the dominant producer of shoe machines through out the twentieth century. Between its founding in 1899 and 1950, United had produced over eight hundred machine models (Kaysen, 1956: 167-8). At the time of the antitrust case brought in 1947, United offered 343 types of machines. Of these, a little over half (179) were offered for lease only, 42 for sale only, and 122 for optional lease or sale.[8] Sixty-five percent (17,668) of the 27,140 optional term machines outstanding in 1947 were leased.[9] Finally, United "supplied repair service and many kinds of other service useful to shoe manufacturers" without separate charges (District Court Opinion: 142-3).

Service costs. 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 resulting machines were complex and prone to breakdown: "No matter how skillfully designed, these

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[8]Exhibits 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).

[9]Exhibits 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.

complicated machine types will require frequent service."[10] 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 is 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.[11] 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).[12] Kaysen estimated that United's overall expenditures on service accounted for approximately 20% of United's expenses annually, with roughly equal parts of the remainder going to manufacturing, research, distribution, and overhead (Kaysen, 1956: 118). To determine annual per-machine service costs, recall that service costs are a function of outstanding machines (sQ_t), and production (manufacturing and distribution) costs depend on current sales (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, or five percent of manufacturing plus distribution costs (i.e., $s = (11{,}355/115{,}787) \bullet c \cong 0.1\, c$).

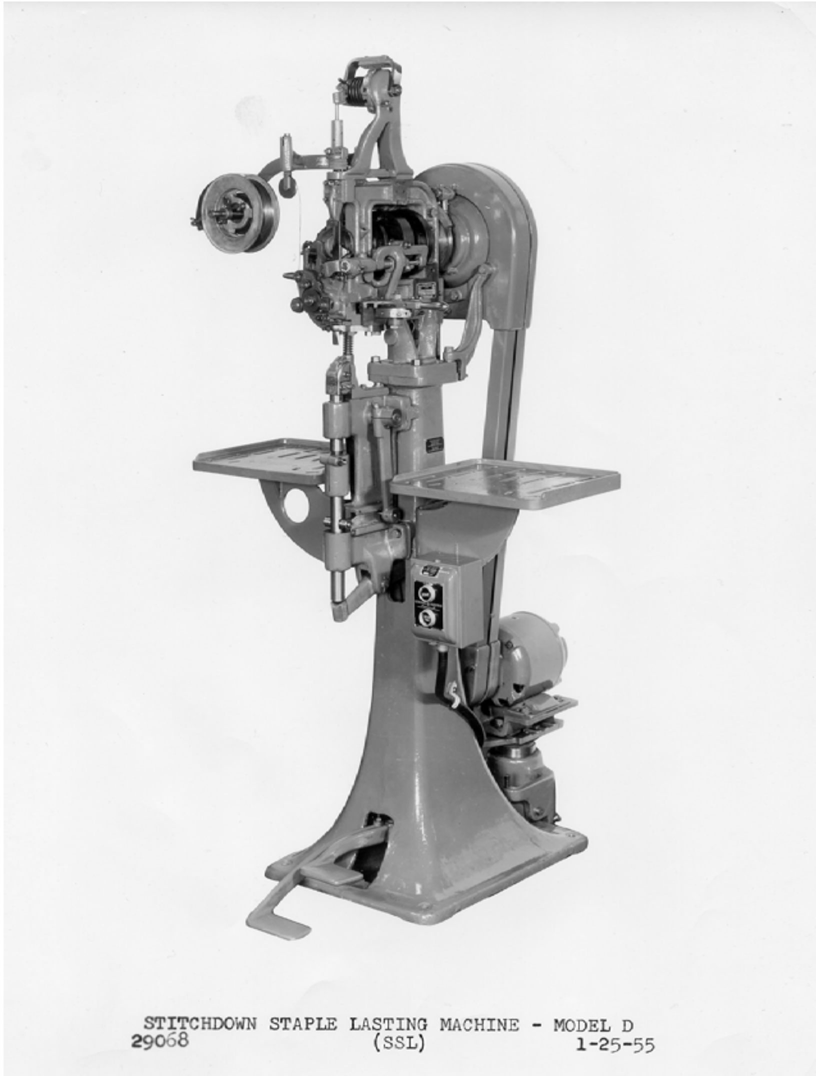
[10]*United States v. United Machinery Corporation*, 110 F. Supp. 295 (D. Mass. 1953): 302 (hereafter cited as District Court Opinion). For a more detailed description of the problems of shoe production and shoe machinery design, see Masten and Snyder, 1993.

[11]Request 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).

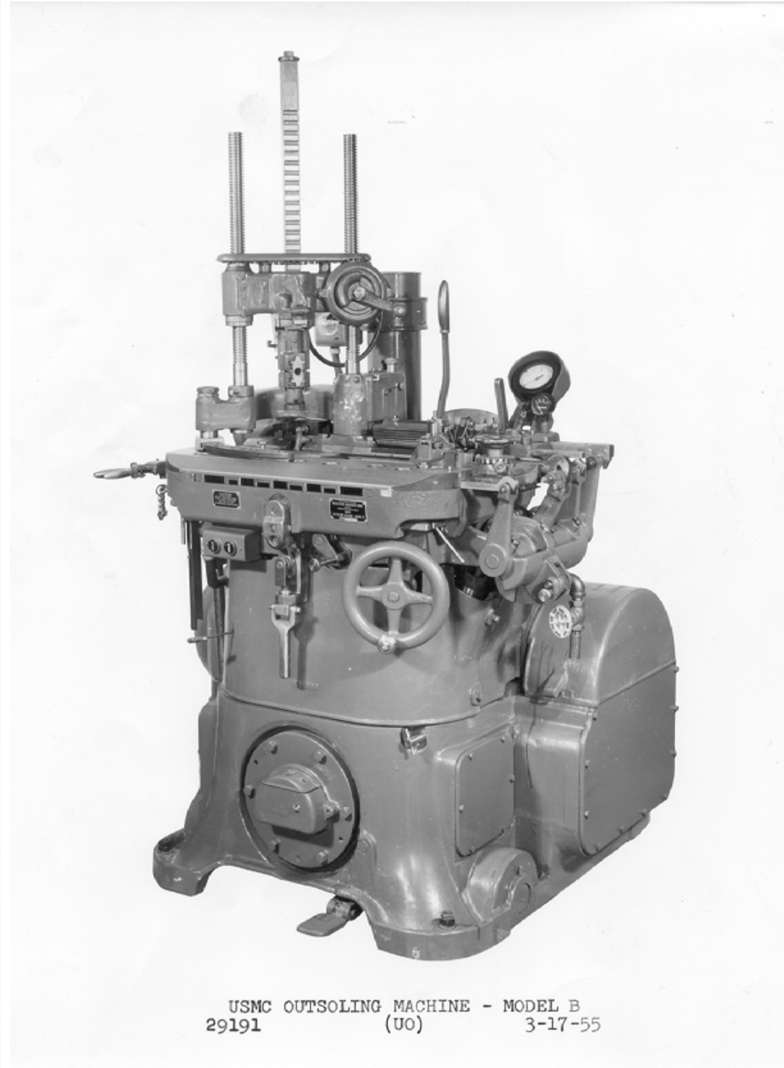
[12]"Memorandum to Mr. A.W. Todd, President, USMC Universal Heat Activating Machine – Model A," May 5, 1947, (Plaintiff Exhibit S-247.A). This machine had 506 parts, compared to an average of 542 (see table 1 below).

PSSSEE multiplier. The premium needed to make provision of post-sale service self enforcing depends on machine durability (*T*) and the discount rate (*r*) as well as service costs (*s*). 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, shoe 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 1914 (Dean [2]). Of course, technological progress could make an otherwise functional machine economically obsolete. In the respect, too, United's shoe machinery exhibited considerable longevity: Kaysen (1956) calculated the median age (i.e., 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 machines (as on 1947) was thirty-two years.

The historical record contains a number of estimates of the economic life of individual shoe machine types and models. 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 concludes "the average composite life of shoemaking machinery is approximately 15



Estimated life, 12 years (Dean), 20 years (AAC)



Estimated life, 17 years (Dean), 12 years (AAC); parts, 699

Figure 4. United Shoe Machinery Corp. shoe machines

Table 2. Economic Life (*T*) Estimates of United Shoe Machinery Models

	Mean	Std. Dev.	Min	Max	Obs
T (Dean)	13.0	3.60	6	25	266
T (AAC)	17.1	3.21	12	20	170

years."[13] At least two additional 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).[14] 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.[15] 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). Tabe 2 reports descriptive statistics for the Dean and ACC estimates.[16] The Dean economic life estimates are significantly lower than those of American Appraisal Company. Closer examination shows remarkably little agreement between the Dean and AAC sets of estimates. (See figure 5.) The simple correlation between the

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[13]U.S. Bureau of Internal Revenue Bulletin F, as quoted in Coles (1955). Coles does not provide the date that the bulletin was issued.

[14]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).

[15]Two 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 the 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 for across machine types for the Internal Revenue Service estimates was seventeen years compared to fourteen years for the Dean estimates.

[16]The 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 for sale only had shorter economic lives than leased machines, both Dean's and the AAC's estimates would overstate average durability.

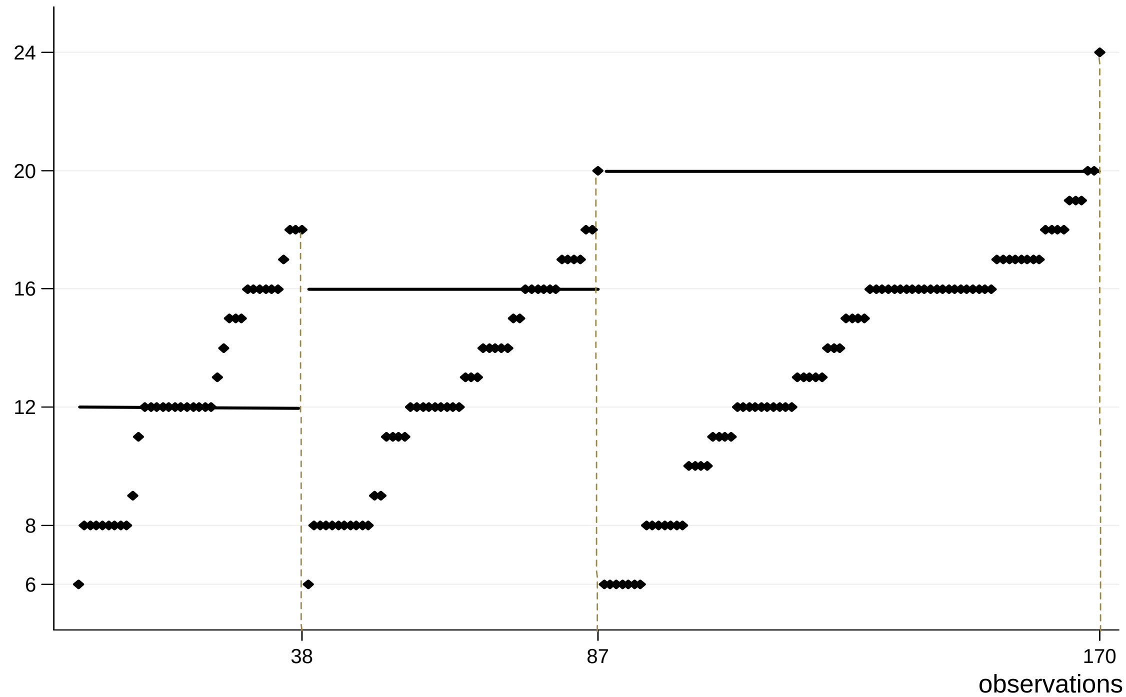

Figure 5. Comparison of AAC (—) and Dean (♦)economic life estimates for USMC machinery

two sets of estimates for the 170 machinery models in common is only 0.14 (albeit significant at the 0.06 level). Notwithstanding the lack of consistency in the Dean and AAC estimates, it is evident that United's machines had substantial economic lives, with an average life (across models) likely to fall in the range of thirteen to seventeen years.[17]

The remaining datum needed to calculate the PSSSEE multiplier is the discount rate. For 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).[18] United, meanwhile,

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[17]Economic life averaged over machines, rather than models, is 15.2 years (Dean) and 18.7 years (AAC). Inasmuch 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 the life of the 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).

[18]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).

used an interest rate of 6% internally for purposes of setting machine prices and rentals (United Request for Findings of Fact, Vol. III:. 481). Taking $r \in [0.06, 0.106]$ and $T \in [13, 17]$ implies a range of potential values for the PSSSEE multiplier of 5.7 to 10.9.[19] Applying our earlier estimate of United's average annual service costs yields an estimated average PSSSEE premium for United machine models between 57 and 109 percent of United's manufacturing costs (or 26 to 54 percent of manufacturing plus distribution costs).

Comparative analysis. The preceding numbers represent averages for United's machinery offerings. Differences in service requirements and durability would cause the PSSSEE premium to vary among machines accordingly. 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 will be its overall temptation to renege. Put differently, leasing machines with high lifetime expected service liabilities reduces the size of the cumulative premium the firm must charge to make post-sale service commitments on the sale machines credible. Accordingly, leasing should be more prevalent for machines with larger lifetime expected service costs.

The frequency and cost of repairs, maintenance, and adjustments will generally be related to a machine's complexity, which, in turn is likely to be reflected in the number components or parts making up the machine (Masten and Snyder, 1993: 52). In addition, shoe machines that employ accessory materials such as thread, staples, tacks, or nails have a greater tendency to malfunction and require more frequent adjustment and repair (McCarthy, 1991). Table 3 presents descriptive statistics for the number of parts in a machine (Parts); whether a machine uses 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

[19]Inflation averaged 5.6 percent during the 1940s, which included World War II, and 2.05 percent during the 1950s. Using real interest rates of 4 and 8.6 percent, the corresponding multiplier range would be 4.4 to 10.1.

Table 3. USMC machinery characteristics descriptive statistics

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	–	–	–	–

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

Table 4. Probit estimates of the probability a machine model is offered for sale

	Constant	Parts/100	Material	T(Dean)	T(AAC)	*n*	%=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

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

sale or lease, or sale only.[20] On average, United's lease-only machines both had more parts and were more likely to employ accessory materials than the machines United offered for sale; and optional term machines contained more parts than machine offered only for sale. No significant difference exists in the economic lives of United's lease-only machines and optional term machines using either the Dean or AAC estimates.[21]

Table 4 reports results of probit estimations of the probability that a machine model is offered for sale (either exclusively or on optional sale or lease terms) if either the machine is for a variety of specifications. Parts is significant 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

[20]Masten 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.

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

Table 5. Grouped probit estimates of the probability a machine sold

	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

t-statistics calculated using bootstrap standard errors with 1000 repetitions
† *m* = total number of machines; *n* = number of independent observations.
* indicates significance at the .01 level

specifications (4) and (5) are seven and five percentage points. Machines the 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).[22] Neither *T*(Dean) nor *T*(AAC) have any significant in any of the specifications in which they are included.

Finally, we re-estimated the regressions reported in table 4 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.[23] Results are reported in table 5. Results for Part 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

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

[23]Approximately, 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).

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 may account for the latter. Whereas a machine's complexity — and a sense, thereby, of 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 some other number of years out in the future.[24]

5.2. IBM

IBM, like United Shoe Machinery Corp. as well as other early computer manufacturers, originally offered its systems for lease only (see, e.g., Fisher, et al., 1983: 17, 21, 172). And like United, IBM was forced by antitrust authorities to sell its computers. Under a consent decree with the Justice Department in 1956, IBM agreed, among other things, 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

[24]Machine 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.")

machines."[25] Leasing nevertheless remained the predominant means by which IBM placed mainframe computers throughout the 1950s and '60s.[26]

Service Costs. 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 accomplish repairs, IBM needed to maintain a staff of highly trained engineers and an inventory of spare parts.

The operation of computers also depended, of course, on software, 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.

The service costs associated with mainframe computer systems varied over time and between systems. A detailed analysis of the life-cycle costs of a representative IBM computer system by Phister (1974) provides

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[25](Fisher et al., 1983: 34). The decree also set a maximum lease term of one year and required IBM "to offer to render, without separate charge, to purchasers...the same type of services, other than maintenance and repair services, which it renders without separate charge to lessees of the same types of machines" and "to offer...to maintain and repair at reasonable and nondiscriminatory prices and terms" purchased machines (id.: 34).

[26]Fisher at al. (1983: 174). Post-decree sales of IBM computers were often to computer leasing companies, i.e., firms that leased the equipment to final users (id.: 406).

Table 6. Hardware service costs for a representative IBM computer system over time

	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

a sense of their magnitude.[27] Table 6 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 different points in time (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).[28]

Finally, Table 7 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"[29] costs combined account for over 28% of (undiscounted) costs over the life of machine (i.e., $sT/(c + sT)$).[30]

[27]Phister 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: 235, 506-510.

[28]Phister, 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). He estimated manufacturing costs for other computer system manufacturers to be in the range of 25 to 35% (id.).

[29] Hardware "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).

[30]Phister's figures include only maintenance and sustaining costs for hardware and thus exclude costs associated with service on associated software.

Table 7. Cost breakdown for a \$100K processor

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

PSSSEE multiplier. For an estimate of the economic life of computer systems (T), we make use of the relation $Q(t) = Q(t-1) + q(t) - \delta Q(t-1)$, i.e., the stock of machines today equals last period's stock plus last period's shipments minus the fraction of last period's stock going out of service (δ). Rewriting this expression, we get the number of machines retired in period $t-1$ equals

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

Using annual data on the number and value of computer systems shipped and in use for the years 1955-1974 (from Phister, 1974: 251), we obtained the following estimates of depreciation for computer systems[31]:

Table 8. Estimated economic lives of computers

	$\hat{\delta}$	s.e.	R^2	T
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

[31]The estimates of δ reported in table 8 are from regressions that did not include 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 calculates the average age at retirement of general purpose computers (U.S. only) to be a little over 6 years (see Phister, 1974: 254).

Hence, depending on which measure is used, we estimate the rate at which computers go out of service to be between approximately 7 and 11% per year, which would imply expected asset lives between 9 and 14 years. Assuming a discount rate of five percent yields a PSSSEE multiplier of 2.9 to 5.8 or a PSSSEE premium of 29 to 58 percent of manufacturing costs if annual post-sale service costs are ten percent of manufacturing costs.

5.3. XEROX (incomplete)

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). With 1,260 parts, machine breakdowns, the cost of which were born by Xerox, were frequent (Dessauer, 1971: 130, 132):

> "We own the machines we lease," he [Joe Wilson] explained. "We bear the cost of repairs or of replacing parts. That's written into the contracts we sign with our customers. 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!"

6. Alternatives to Leasing

The preceding analysis is premised on manufacturers offering post-sale services as an appendage to machine sales. A potential solution to the problem of manufacturer reneging on post-sale service commitments, therefore, is to unbundle service from machine sales and price each separately. Machinery and service bundling may be desirable for two reasons, however. The first relates to information economies associated with their joint production. Especially on technologically advanced machines, manufacturers may have superior knowledge, acquired through development and manufacture, about how to repair complex machinery. Manufacturer servicing of its own machines also provides a potentially valuable source of feedback on machine problems and operations that can suggest improvements on existing machines and advance development of new models. [add refs.]

Second, even in the absence of such information economies, manufacturer liability for service has potential incentive advantages: Assigning responsibility for product failures to manufacturers provides manufacturers incentives to produce reliable machines in the first place. Discussing the high cost of maintaining computer systems, Phister observed:[32]

> The implications [of the high cost of maintenance] for the system manufacturer are clear. It is extraordinarily important to pay careful attention to reliability and maintainability when planning and developing products; and there are likely to be many features that can be added to hardware and software at some slight initial cost, which will pay off many times over in reduced maintenance cost. It is also very important to build a competent, well-managed maintenance organization, to keep these costs under control and to respond promptly and ably to customer problems.

Where information economies or incentives make manufacturers the efficient provider of post-sale service, solutions other than leasing to the post-sale service problem are still possible. Rather than relying on self enforcement, parties could attempt to make manufacturers' service commitments legally binding using warranties. The difficulty of courts determining what constitutes effective and timely performance of contractual guarantees are likely to be especially ineffective in the settings involving highly complex and inherently fallible machinery, however (see Masten and Snyder, 1993: 42).

Finally, as Masten and Snyder (1993) discuss, the self-enforcing incentives of leasing are difficult to replicate fully using contracts (43):

> 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.

[32]Phister (1974: 236. See also Masten and Sndyer (1993), and Dessauer (1971: 132).

Ultimately, reliability improvements and associated service cost reductions will eliminate the problem of post-sale service provision. Until that point, leasing offers numerous advantages over the alternatives.

6. Conclusion

In this paper, we have addressed the question 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: While 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. Leasing eliminates this problem by tying revenues, as well as costs, to the stock of outstanding machines.

Using historical data, we calculated the size of the premium United Shoe Machinery Corp. and IBM 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 and found values in the range of thirty to one hundred percent of manufacturing costs. Since 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 manufacturers 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):[33]

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

> 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.

Finally, 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 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 post-sale considerations analyzed in this paper.

USMC Primary Sources

American Appraisal Company, "Schedule of Machines by Life Groups as Estimated by the American Appraisal Company" (Study #29), Joel Dean Papers, Carton 58, File 133, Baker Library, Harvard Business School.

Andrews, Anthony, & McLean, "Sales Prices for Outstanding Shoe Machinery: A Basis for Negotiation, Prepared for National Shoe Manufacturers Association by Andrews, Anthony & McLean in Association with the American Appraisal Co." April 27, 1955. U.S. National Archives and Records Administration, Enclosure File 60-137-1, Serial No. 5770.

Andrews, Anthony, & McLean, "The Theoretical Time Pattern of the Value of Machinery," Annex V of "Sale Prices for Outstanding She Machinery: A Basis for Negotiation." U.S. National Archives and Records Administration, Enclosure File No. 60-137-1, Serial No. 5768.

Andrews, Anthony, & McLean, "An Appraisal of the Estimating Techniques for Economic Lives of the 30 Major Shoe Machine Types Used in the Dean Report," Annex III of "Sale Prices for Outstanding She Machinery: A Basis for Negotiation," U.S. National Archives and Records Administration, Enclosure File No. 60-137-1, Serial No. 5766.

Coles, C.R., "Sale Life vs. Lease Life (Study #28)," May 11, 1955, Joel Dean Papers, Carton 58, File 133, Baker Library, Harvard Business School.

Committee on Machine Life for the National Shoe Manufacturers Association, "Life Data on 30 Machines in Anthony Sample," Joel Dean Papers, Carton 58, File 133, Baker Library, Harvard Business School.

Dean, Joel [1], Customer Equivalency tables, Joel Dean Papers, Carton 60, File 183, Baker Library, Harvard Business School.

Dean, Joel [2], "United Shoe Machinery Corporation Lease Machines Outstanding, 1/1/54," Joel Dean Papers, Carton 57, File 41, Baker Library, Harvard Business School.

Dean, Joel [3], "Determination of Customer-Equivalent Optional Sale Prices for New Machinery," April 1, 1956. (Reproduced in Dean, *Decision Economics*, Vol. 8)

Dean, Joel [4], "Determination of Customer-Equivalent Optional Sale Prices for Machines Outstanding on Form B Leases," (reproduced in J. Dean, *Decision Economics*, Vol. 8, Ch. 3).

Dean, Joel [5],"Economic Life-Expectancy and Customer-Equivalent Lease-Pricing," *Decision Economics*, Vol. 8, Ch. 5).

McCarthy, Edward F., Letter and attachment, Feb. 8, 1991.

"Request for Findings of Fact of the United Shoe Machinery Corporation in the District Court of the United States for the District of Massachusetts," Civil Action No. 7198, In the District Court of the United States for the District of Massachusetts, April 21, 1952.

Lybrand, Ross Bros. & Montgomery, "United Shoe Machinery Corporation: Report of Work Done by Lybrand, Ross Bros. & Montgomery on the Computations of New Machine Ceiling Sales Prices, 1955," April 26, 1956.

United Shoe Machinery Corp. Terms Committee Memorandum, "USMC Universal Heat Activating Machine – Model A," May 5, 1947. (Plaintiff Exhibit S-247.A)

Secondary Sources and References

Aghion, Phillipe, and Patrick Bolton, "Contracts as a Barrier to Entry," American Economic Review, 77, 1987, pp. 388-401.

Cooper, Russell, and Ross, Thomas W., "Product Warranties and Double Moral Hazard," Rand Journal of Economics, 16, Spring 1985, pp. 103-113.

DeLamarter, Richard T., *Big Blue: IBM's Use and Abuse of Power*. New York: Dodd, Mead & Company, 1986.

Dessauer, John H., *My Years with Xerox: The Billions Nobody Wanted*. Garden City, NY: Double Day, 1971.

Dybvig, Phillip H., and Nancy A. Lutz, "Warranties, Durability, and Maintenance: Two sided Moral Hazard in a Continuous-Time Model," *Review of Economic Studies*, 60, 1993, pp. 575-597.

Fisher, Franklin M., J.W. McKie, and Richard B Mancke, *IBM and the US Data Processing Industry-An Economic History*. Praeger Publishers, New York, 1983.

Flath, David, "The Economics of Short-Term Leasing," *Economic Inquiry*, Vol.18, April, 1980, pp. 247-259.

Hodaka, Morita and Michael Waldman, "Durable Goods, Monopoly Maintenance, and Time Inconsistency," *Journal of Economics & Management Strategy*, 13, Summer 2004, 273-302.

Houthakker. Hendrik S., "Uncle Sam v. IBM: Why?" *Wall Street Journal*, Feb. 5, 1979. p. 18.

Kaysen, Carl, *United States v. United Shoe Machinery Corporation: An Economic Analysis of an Antitrust Case*. Cambridge, MA: Harvard University Press, 1956.

Klein, Benjamin and Keith B. Leffler, "The Role of Market Forces in Assuring Contractual Performance," *Journal of Political Economy*, 890 (4), 1981, 615-641.

Kosová, Renáta and Scott E. Masten, "Reputational Equilibria with Post-Sale Service" (mimeo, 2005).

Levy, David T., "Short-term Leasing and Monopoly Power: The Case of IBM," *Journal of Institutional and Theoretical Economics*, 144, September, 1988, pp. 611-634.

Marcom, John, "IBM Service Strategy Changes With the Times," *Wall Street Journal*, Aug. 25, 1986. p. 6.

Masten, Scott E., and Edward Snyder: "United States versus United Shoe Machines Corporation: On the Merits", *Journal of Law and Economics*, 36 (1), April, 1993, pp. 33-70.

Mercer, D., *IBM: How the World's Most Successful Corporation is Managed*. London: Kogan Page Ltd., 1987.

Phister, Montgomery, Jr., *Data Processing Technology and Economics*. Santa Monica Publishing Company, 1974.

Priest, George L., "A Theory of the Consumer Product Warranty," *Yale Law Journal,* 90, May 1981, pp. 1297-1352.

Pugh, E. W., *Building IBM: Shaping an Industry and Its Technology.* Cambridge, MA: MIT Press, 1995.

Schmedel, Scott R., "Control Data Sues IBM for Damages In Antitrust Case," *Wall Street Journal*, Dec. 12, 1968.

Schmedel, Scott R., "IBM, Justice Agency Lawyers Meet Today To Define Aims of 1969 Antitrust Case," *Wall Street Journal*, Oct. 6, 1972. p. 4.

Shapiro, Carl, "Consumer Information, Product Quality and Seller Reputation," *The Bell Journal of Economics*, 1981, pp. 20-35.

Shapiro, Carl, "Premiums for High Quality Products as Rents to Reputation," *Quarterly Journal of Economics*, November, 1983, pp. 659-680.

Sharpe, William F., *The Economics of Computers*. New York: Columbia University Press, 1969.

Telser, Lester G., "A Theory of Self-Enforcing Agreements," *Journal of Business*, 53, 1, 1980, pp. 27-44.

Tirole, Jean, *The Theory of Industrial Organization*. Cambridge Massachusetts, The MIT Press, 1998.

Waldman, Michael, "Eliminating the Market for Secondhand Goods: An Alternative Explanation for Leasing," *Journal of Law and Economics*, 40, April 1997, pp. 61-92.

Wall Street Journal, "IBM to Serve All Customers Of Leasing Firms," May 28, 1968. p. 3.

Wall Street Journal, "IBM Raises Charges To Maintain 101 Types Of Computing Devices," Oct. 21, 1968. p. 23.

Wall Street Journal, "IBM Heeds Protests, Drops Certain Changes In Maintenance Fees," Oct. 25, 1968. p. 10.

Wall Street Journal, "IBM Net Would Be Hurt By Computer Leasing Lull,"Oct. 31, 1968. p. 34.

Wall Street Journal, "IBM Says Its Business Continues to Be Hurt By Trend to Leasing," Sept. 21, 1979. p. 7.

Wall Street Journal, "IBM Studying Separate Prices For Servicing,"Dec. 9, 1968. p. 3.

Wiley, John S., Eric Rasmusen, and Mark J. Ramseyer, "The Monopolist that Leases," *UCLA Law Review*, 37, June, 1990, pp. 693-731.

Yourdon, E., "Reliability Measurements for Third Generation Systems," *Proceedings of the 1972 Annual Reliability and Maintainability Symposium*, IEEE Catolog No. 72CH0577-7R: 174-82.