Equilibrium Leasing Contracts under Double-sided Asymmetric Information

Thomas Chemmanur*

and

An Yan**

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* Finance Department, Fulton Hall 440, Carroll School of Management, Boston College, Chestnut Hill, MA 02467, Tel: (617) 552-3980, Fax: (617) 552 0431, email: chemmanu@bc.edu.

** Department of Economics, Boston College, Chestnut Hill, MA 02467, Tel: (617) 552-8703, Fax (617) 552 2308, email: yana@bc.edu.

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Abstract

We develop a non-tax rationale for leasing in a double-sided asymmetric information setting, and analyze how various contractual provisions in leasing contracts arise in equilibrium. In our model, a manufacturer of capital goods has private information about their quality; entrepreneurs (users of these capital goods) come to learn this quality only over a period of time. Each unit of the capital goods requires a certain level of maintenance in each period. Entrepreneurs differ in their cost of providing this maintenance; this maintenance cost is information private to each entrepreneur. Leasing emerges as an equilibrium solution to this double-sided adverse selection problem. Various contractual provisions in leasing contracts (e.g., short-term versus long-term leases with non-cancellation provisions, option to buy at lease termination, and service leases) also emerge as equilibrium solutions under alternative settings. Leases with metering provisions emerge in equilibrium when, in addition to maintenance cost, entrepreneurs differ in other dimensions such as their intensity of using the capital good, and their degree of risk aversion. Our model has implications for the lease versus sell decision, the situations under which various leasing contract provisions are appropriate, and for the relative magnitudes of sales prices and the leasing costs for leases with different contractual provisions.

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1 Introduction

Leasing is an important source of external financing for U.S. corporations. It has been estimated that a third of the equipment used by U.S. corporations is leased. However, the motivations for leasing are still not completely understood. While the finance literature has analyzed corporate leasing policy extensively, much of the discussion has been confined to tax-related incentives to lease or buy (see, e.g., Miller and Upton (1976), or Lewellen, Long, and McConnell (1976)). These and other papers assume that the real operating cash flows associated with leasing or owning are invariant to the financial contract chosen, and thus assume that it is primarily the tax-related incentives which lead to a lease or buy decision.

More recently, however, financial economists have come to recognize that, while taxes are important in determining the identity of the lessor and lessee, they may be less crucial in identifying the specific assets to be leased. The co-existence of both leased and purchased assets suggests that the net benefits of leasing may be neither uniformly positive nor negative. The predominance of leasing in certain industries and for certain assets implies wide variations in the benefits from leasing. Equally important is the variety of contractual provisions observed in practice, based on service provisions, option to cancel the lease before the maturity of the contract or to renew it for additional periods, option to buy the asset at the termination date of the lease, metering, etc. Again, tax considerations offer little explanation for the choice of various provisions in leasing contracts.[1] [2]

[1] See, e.g., Smith and Wakeman (1985), who identify several possible non-tax incentives to lease or buy.

[2] McConnel and Schallheim (1983) value various provisions in leasing contracts using the redundant-assets methodology of option pricing models. However, by using the arbitrage-free option pricing methodology, they, by definition, stay away from issues of the optimality of these provisions. Two other papers which take a valuation approach to leasing contracts are those by Grenadier (1995, 1996).

The purpose of this paper is two-fold. First, we develop a non-tax rationale for leasing in an asymmetric information framework and analyze the lease-versus-buy decision in such a setting. Second, we analyze the optimality of many of the leasing contract provisions observed in practice in the above asymmetric information environment. Thus, some of the contracts that arise in equilibrium in our setting are: leases with and without cancellation provisions; leases which grant the lessee an option to buy the asset at a pre-specified price at the termination date; service leases, where the manufacturer agrees to maintain the equipment leased; and leases involving "metering," where the lease payment is a function of an observed measure of the intensity of usage of the asset.

We develop our model in a setting of asymmetric information where the lessor (manufacturer of capital equipment) has private information of the asset he leases to the lessee (entrepreneur). The lessee, however, can learn about the quality of his equipment over time as he uses the asset. Thus, leasing emerges in our model as a way of mitigating the adverse selection problem. However, another problem with leasing in our setting is that, since the lessee does not have ownership rights to the residual value of the asset, he has an incentive to use the asset in such a way that shifts value from the lessor to the lessee. One possibility is that various lessees have different costs of maintaining the capital good. In this case, the higher maintenance cost users have an incentive to devote less care to the maintenance than the lower maintenance cost users. Different contractual provisions (e.g., leases with non-cancellation provisions, option to buy at lease termination, leases with service provisions) in leasing contracts emerge as solutions to this double-sided incentive problem in the capital goods market. A second possibility is that different lessees have different intensities of usage of the capital equipment. Metering contracts emerge to solve this double-sided adverse-selection problem in the capital goods market in this case. A third possibility is that the lessee himself may have uncertainty about the intensity of his usage, but different lessees have different levels of risk-aversion. We show that metering again emerges as a solution to the double-sided adverse-selection problem in this setting. An interesting aspect of our model is that leasing may co-exist with pure sales contract in the market for some capital goods; it may be the sole kind

of financing contract in other cases; and sales contracts may emerge as the only type of contracts offered in yet other settings.

Our research is related to several strands in the finance and economics literature. As mentioned before, there is a large finance literature on leasing focused on the tax-related incentives to lease or buy. However, tax issues alone cannot explain the existence of leasing in many markets: while the tax benefits of leasing were lowered in the tax reform act of 1986, the importance of leasing however has increased. Neither can tax arguments explain the existence of the variety of leasing contracts observed in practice. Smith and Wakeman (1985) provide an informal but insightful analysis of the determinants of corporate leasing policy. They argue that leases can reduce the transaction costs that arise when the physical life of the asset exceeds the economic life of the firm. They have also informally discussed several rationales for some of the common provisions in leasing contracts. Sharpe and Nguyen (1995) hypothesize that firms facing high financial contracting costs can alleviate these costs by leasing, and present evidence indicating that such firms have a high propensity to lease.[3]

Two papers from the economics literature which also analyze leasing in an adverse selection setting are Guha and Waldman (1997) and Hendel and Lizzeri (1998). The focus of Guha and Waldman (1997) is primarily on demonstrating that leasing solves the lemons problem in the used car market. They study a setting where there are two types of used cars, and consumers have heterogeneous valuations for used cars.[4] Hendel and Lizzeri (1998) analyze a setting broadly similar to that in Guha and Waldman (1997). In addition to the welfare effects of leasing, they focus also on how the option price (the price at which leased cars can be purchased at maturity) can be used by car manufacturers to control consumer behavior in an adverse selection setting. They argue that leasing allows the manufacturer to raise the option price, reducing the competitive

[3] Other papers which lend support to the argument that leasing reduces contracting costs in various settings are Krishnan and Moyer (1994) and Barclay and Smith (1995).

[4] Two other arguments for leasing from the economics literature are provided by Bulow (1986), who argues that leasing can be used by a monopolist to overcome the Coasian time-inconsistency problem, and by Waldman (1997), where leasing is used by a durable goods manufacturer with significant market power to eliminate the second-hand goods market.

threat that used cars pose to new cars. However, neither of these papers analyze the rich menu of contractual provisions presenting in the real-world leasing contracts.

The rest of the paper is structured as follows. Section 2 outlines the basic structure of the model. Section 3 characterizes the equilibrium in the basic model. Section 4 extends the basic model by allowing the manufacturer to offer service leases in addition to the leases characterized in the basic model. Section 5 analyzes a variation of the basic model where entrepreneurs differ either in their usage-intensity (section 5.1) or in their degree of risk-aversion (section 5.2) rather than in their maintenance cost; leases with metering emerge in equilibrium in both these cases. Section 6 discusses the implications of the model and section 7 concludes.

2 The Basic Model

The model has four dates (three periods). At time 0, an entrepreneur requires one unit of a capital good to implement a positive net present value project. Capital goods (equipments) are produced by a risk-neutral manufacturer who has private information regarding the quality of these goods. Type G (good) capital goods generate greater cash flow for entrepreneurs than type B (bad) capital goods (details of these cash flows will be discussed later).

The entrepreneur may buy or lease the capital equipment from the manufacturer. And the manufacturer may offer more than one kind of leasing contracts to the entrepreneur (e.g., short-term or long-term). We will discuss the contract structure in more detail below.

The entrepreneur has private information about his own type. In the basic model, we assume that the entrepreneur's private information is about his cost of maintaining the capital equipment per period. The type L (low-cost) entrepreneur has a lower cost c_L of maintaining the equipment in each period than the type H (high-cost) entrepreneur whose maintenance cost per period is c_H,[5] $c_H > c_L$. And the manufacturer has prior information that the entrepreneur has a probability of ϕ to be type H and $1-\phi$ to be type L.

[5] We will change the assumption on the variable about which the entrepreneur has private information in later sections, where we will analyze leasing contracts with service provision and leasing contracts with metering.

Between time 0 and time 1, i.e., in the first period, as the entrepreneur uses the capital equipment, he receives additional information about the type of the capital equipment. For simplicity, we assume this information is not noisy, i.e., the entrepreneur comes to know the true type of the capital equipment without any uncertainty. After the arrival of this information, the entrepreneur decides whether to perform maintenance for the first period. Similarly for the second and third period, i.e., at each date, he makes the maintenance decision for the following period. In addition, the entrepreneur has other choices to make depending on the terms in the leasing contract he accepts. If the entrepreneur chooses a short-term lease, then at time 1, he may choose whether or not to renew his lease, or whether to buy the equipment (if the option is provided) at a pre-specified price, etc. On the other hand, if the entrepreneur chooses a long-term contract, he has the option to buy the equipment at t=2. At t=3, the project ends, and the final cash flows from the project are realized. The sequence of events is summarized in figure 1.

2.1 Cash Flow Structure

If the entrepreneur performs the maintenance for the first two periods, he will receive a cash flow of x at t=1, kx at t=2, k^2x at t=3 from the type G equipment, or a cash flow of fx, fkx, f k^2x from the type B equipment. Here k is the depreciation factor which is the same for both types of equipment, and f is the cash flow ratio measuring the difference between the type G and the type B equipment given the same maintenance levels in the same time period, where k, $f < 1$.[6] If the entrepreneur does not maintain the equipment, the cash flow generated by the equipment in the next period will decline by $1-\delta$, where $\delta < 1$. We can consider δ as a "damage factor" gauging the damage on the equipment due to a lack of maintenance. For example, if the entrepreneur does not maintain the type G equipment in the first period, the cash flow in the second period will be $k\delta x$ instead of kx. At t=1 or t=2, the entrepreneur has an option to return the equipment to the manufacturer depending on the contract terms. If the entrepreneur returns the equipment,

[6] Here we define the depreciation factor to be the ratio of the cash flow from the equipment in a given period to the cash flow in the previous period.

he can still receive a cash flow of y for each period from some alternative (old) technology, and the manufacturer then owns the residual value of the returned equipment.[7] We assume that this residual value at each date equals to β times the future cash flow value of the equipment to the type H entrepreneur at this date. For example, if at t=1 the type H entrepreneur returns the equipment to the type G manufacturer without performing any maintenance in the first period, the residual value of this returned equipment to the manufacturer would be $\beta(k\delta x + k^2\delta^2 x)$.

2.2 Contract Structure

In the basic model, we allow the following menu of contracts between the manufacturer and the entrepreneur: a sales contract, where the entrepreneur pays the price S upfront (at t=0) and possesses the ownership of the equipment for all three periods; a short-term renewable leasing contract $\{M, R\}$, where the entrepreneur pays the leasing payment M upfront and has an option to renew at t=1 for another two periods by paying a renewal price R; and a long-term leasing contract with an option to buy $\{N, P\}$, where the entrepreneur leases the capital good for two periods (i.e., till t=2) by paying the leasing price N upfront, and has an option to buy the equipment by paying a purchase price P at t=2.[8] We will introduce additional types of contracts (e.g., service leases, and leases with metering provision) in later sections.

Out of the above menu of contracts, the set of contracts actually offered will be determined in equilibrium: i.e., not all contracts will be offered in all situations.[9] We assume that the manufacturer first chooses the set of contracts to be offered to the entrepreneurs from the above

[7] The residual value can arise in many ways. One possibility is that the manufacturer is able to put the capital equipment to some alternative use for himself. Another possibility is that there exists a second hand market for the capital goods which can be used by the manufacturer to dispose of any units of the capital goods which are returned to him by entrepreneurs. In any case, we do not model the determination of this residual value here.

[8] Note that the short-term renewable leasing contract is also equivalent to a short-term contract with an option to buy since the entrepreneur can use the equipment for all the renewing periods after the renewal. Also note that in the long-term leasing contract, no-cancellation is allowed at t=1 (i.e., it is a non-cancelable lease). Finally, it should be obvious that the sales contract is equivalent to a three-period non-cancelable lease (since the capital equipment is worthless after three periods of use). While one can of course come up with other possible specifications of leases (in terms of lease lengths or intermediate options for example), we choose to confine the menu of contracts to the above, since this menu incorporates the commonly observed leases.

[9] We assume that the contracts which are not accepted in equilibrium by either type of the entrepreneurs are never offered by any manufacturer.

menu (at t=0). Then, after observing the contracts offered, the entrepreneur chooses his contract and makes further decisions about the capital equipment over time according to the options specified in the sales or leasing contract he accepts.

2.3 The Manufacturer's Objective

The objective of the manufacturer in choosing the menu of contracts (including contract provisions, as well as prices) to be offered to entrepreneurs is to maximize the expected value of his future cash flows.

2.4 The Entrepreneur's Objective

In the basic model, as well as in section 4 to 5.1, we will assume that the entrepreneur is risk-neutral (we will introduce a risk-averse entrepreneur in section 5.2).

The objective of the entrepreneur at each date is to maximize the expected value of his future cash flow stream. Thus, at time 0, the entrepreneur, facing the menu of contracts offered by the manufacturer, chooses the contract which maximizes the expected value of his cash flows over the following periods. The entrepreneur also makes subsequent choices (e.g., whether or not to perform maintenances, whether or not to renew the lease, or whether or not to buy the equipment from the manufacturer at the end of the lease period) in order to maximize this objective.

2.5 Parametric Assumptions

In this section, we make some additional assumptions about the model parameters to simplify our analysis. We assume:

$$kx - c_H \leq k\delta x, \tag{1}$$

$$k^2x - c_L \geq k^2\delta x, \tag{2}$$

$$fkx - c_L \leq fk\delta x, \tag{3}$$

$$k^3x - c_L \leq k^3\delta x \leq y,\ k^2\delta^2 x \geq y, \tag{4}$$

$$fk^2\delta^2 x \leq y,\ fk\delta x \geq y. \tag{5}$$

Assumption (1) implies that the type H entrepreneur performs no maintenance in any period due to his high cost of maintenance. Assumption (2) and (3) imply that the type L entrepreneur will maintain the type G equipment for two periods and perform no maintenance for the type B equipment. Assumption (4) implies that the type G equipment becomes useless after three periods. And assumption (5) assumes that it is optimal for both types of entrepreneurs to use the alternative technology rather than use the type B equipment in the third period. It will become clear in the next section that the date when the project ends for the type B equipment is not important.[10]

3 Equilibrium in the Basic Model

Definition of equilibrium. An equilibrium in this model consists of (i) the manufacturer's choice at time 0 about the menu of contracts to be offered to the entrepreneur (including the terms of the contract such as prices or fees to be paid, options to renew, cancel or buy at various dates etc.); (ii) a choice by the entrepreneur of the contract to accept at time 0, and other choices at the following times (whether or not to perform maintenance, whether or not to renew or buy). Each of the above choice pairs by the manufacturer and by the entrepreneur satisfies the following conditions: (a) the choice of each party maximizes his objective, given his equilibrium belief about the choice of the other party; (b) the beliefs of both parties are rational, given the equilibrium choice of the other; along the equilibrium path, these beliefs are formed using Bayes' rule; (c) any deviation from equilibrium strategies by any party is met by the other party' belief, which yields

[10] While we make these parametric assumptions to minimize computational complexity, the intuition driving our results goes through unchanged even if these assumptions are relaxed. The crucial requirements here are that the type B equipment has a lower cash flow value to entrepreneurs than the type G, and that the type H entrepreneur has a significantly greater maintenance cost than the type L.

him a lower expected payoff compared to that obtained in the equilibrium.[11] [12]

Define:

$$f_1 \equiv \frac{1}{1+k\delta}, \tag{6}$$

$$\phi_1 \equiv Max(\frac{k\delta x - fx - fk\delta x + y}{k\delta x - y - \beta fk\delta x}, 0), \tag{7}$$

$$\beta_1 \equiv 1 + \frac{fx - 2y}{fk\delta x}. \tag{8}$$

Proposition 1 (Separating Equilibrium) *When $f \leq f_1$, $\phi \geq \phi_1$ and $\beta \leq \beta_1$, the equilibrium in the capital goods market involves the following:*

***The type G manufacturer**: He offers both the short-term leasing contract and the long-term leasing contract.*

***The type B manufacturer**: He offers only a sales contract.*

***The type L entrepreneur**: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the long-term contract, buying it at t=2, and he performs maintenance in the first and the second period. If the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1. He accepts the sales contract, using the equipment for two periods, and he does not, in this case, perform maintenance on the equipment for the first and the second period.*

***The type H entrepreneur**: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the short-term contract, and does not perform maintenance on the equipment for the first period. At t=1, he does not renew his leasing contract. If the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1. He accepts the sales contract, using the equipment for two periods, and he does not, in this case, perform maintenance on the equipment for the first and the second period.*[13]

In the above separating equilibrium, the type G manufacturer utilizes the leasing contracts to distinguish himself from the type B manufacturer. When the cash flows generated by the type G and type B equipment are sufficiently close, the initial leasing period itself is enough for the type G manufacturer to prevent the imitation from the type B. The reason is that in the first leasing

[11] Based on the Perfect Bayesian Equilibrium concept, formally defined for dynamic games with incomplete information by Fudenberg and Tirole (1991).

[12] Given our extremely rich strategy space, one can think of a variety of equilibria, both pooling and separating, involving several combinations of leasing contract lengths and options. Our objective here is primarily to explore the equilibria involving the contracts akin to that observed in practice, and characterizing the conditions under which these occur. Details of some of the other equilibria are available to the interested readers from the authors.

[13] The out-of-equilibrium belief supporting the above equilibrium is that the entrepreneur believes that any manufacturer setting contracts other than these two menus is of type B with probability 1.

period, the entrepreneur can recognize the quality of the equipment, and thus would not renew the contract associated with the type B equipment if the renewal price in that contract is too high. However, when $f \leq \frac{1}{1+k\delta}$, which implies that the expected cash flow from the type G equipment in the first period exceeds the two-period expected cash flow from the type B equipment, the type B manufacturer then could benefit from pooling even if his equipment would be used by the entrepreneur only in the initial leasing period. The type G manufacturer, in this case, has to set the initial leasing prices comparatively low to prevent this mimicking. By doing this, he sacrifices some of his profit in the first period, but avoids the adverse selection problem in the future periods. As a consequence, the type B manufacturer does not pool by offering the same leasing contracts because he knows that, if he pools, the entrepreneur would not renew his leasing contracts, and that the initial leasing price is too low for him to profit from pooling. The following condition on the sales price S incorporates these insights:

$$S \geq \phi M + (1-\phi)N + \phi\beta f k \delta x. \tag{9}$$

When $f \leq \frac{1}{1+k\delta}$, the above inequality is binding.

Further, offering two different leasing contracts allows the type G manufacturer to separate the two types of entrepreneurs. Since the initial leasing prices are under constraint, any incentive scheme using these prices to achieve this separation incurs no cost to the manufacturer. Remember that the type H entrepreneur has a higher maintenance cost than the type L. Hence by setting a significantly higher initial leasing price in the long-term leasing contract than in the short-term contract, the type G manufacturer can ensure that only the type L entrepreneur will accept the long-term leasing contract. In addition, the type G manufacturer can set a high renewal price R in the short-term contract so that the type L entrepreneur, caring about the future usage of the equipment, will prefer the long-term contract to the short-term contract which he would not renew. These intuitions are incorporated in the following incentive compatibility (IC) constraints. These constraints ((10), (11) and (12)) guarantee that the type H entrepreneur accepts only the

short-term leasing contract and that the type L entrepreneur accepts only the long-term leasing contract:

$$-N + x + k\delta x + y \leq -M + x + 2y, \tag{10}$$

$$-N - P + x + kx + k^2 x - 2c_L \geq -M + x + 2y, \tag{11}$$

$$-R + kx + k^2 x - 2c_L \leq 2y. \tag{12}$$

In addition to the IC constraints, the following individual rationality (IR) constraints should be satisfied as well, so that the entrepreneur chooses to lease or buy a piece of capital equipment rather than use the alternative technology available to him.[14]

$$-M + x + 2y \geq 3y, \tag{13}$$

$$-M - R + x + k\delta x + k^2\delta^2 x \leq -M + x + 2y, \tag{14}$$

$$-N - P + x + kx + k^2 x - 2c_L \geq 3y, \tag{15}$$

$$-N - P + x + kx + k^2 x - 2c_L \geq -N + x + kx - c_L + y. \tag{16}$$

These IR constraints take into the consideration that, on the equilibrium path, the type L entrepreneur will exercise the option to purchase the equipment at t=2 and that the type H entrepreneur will not renew the short-term leasing contract at t=1.

The type B manufacturer, however, cannot benefit from separating the different types of entrepreneurs due to the bad quality of his equipment, i.e., his objective is maximized by pooling

[14] We assume throughout that in the first period, the cash flow generated by either type of entrepreneurs using a new piece of equipment (of either type) is always greater than the cash flow that can be generated by the manufacturer himself (e.g., by putting the equipment to alternative uses). This assumption is innocuous since it simply ensures that the manufacturer has the incentive to sell or lease the equipment for at least one period, rather than using it by himself.

the two types of entrepreneurs. Thus, he only offers a sales contract and maximizes his expected cash flow subject to the following IR constraint (17) and IC constraint (18):

$$-S + fx + fk\delta x \geq 2y, \tag{17}$$

$$S \leq \phi M + (1-\phi)(N+P) + \phi\beta(k\delta x + k^2\delta^2 x). \tag{18}$$

Expressions for the various equilibrium prices are derived in the Appendix.

The following numerical example illustrates this separating equilibrium.

Numerical Example 1: Assume the following values for the parameters employed in the basic model: $k = 0.5$, $\delta = 0.65$, $f = 0.4$, $x = 100$, $y = 10$, $c_H = 20$, $c_L = 8$, $\beta = 1.2$ and $\phi = 0.75$. Now the type G manufacturer offers the combination of a short-term contract with $M = 15.7$ and $R = 39$, and a long-term leasing contract with $N = 38.2$ and $P = 7$. These prices and the contract structures allow him to maximize his objective by distinguishing himself from the type B manufacturer and by segmenting the capital goods market. On the other hand, the type B manufacturer, in equilibrium, offers only a sales contract with $S = 33$. He does not mimic the type G manufacturer because his expected cash flow under the sales contract is the same as what he would earn by mimicking. The type G manufacturer prefers to offering the leasing contracts since his expected cash flow from doing so (59.7) exceeds that from offering the sales contract (33). The type L entrepreneur only accepts the long-term contract because he can earn more from the long-term contract (113.8) than from the short-term contact (104.3). And the type H entrepreneur accepts the short-term contract because he is indifferent between the two kinds of contracts (which generate the same expected cash flow of 94.3).

Proposition 2 (Comparative Statics) *For the sales price S and the purchase price in the long-term leasing contract P :*

(i) $\frac{\partial S}{\partial f} > 0, \frac{\partial S}{\partial k} > 0, \frac{\partial S}{\partial y} < 0, \frac{\partial S}{\partial \delta} > 0,$

(ii) $\frac{\partial P}{\partial c_L} < 0, \frac{\partial P}{\partial k} > 0, \frac{\partial P}{\partial y} < 0.$

Assuming $N - M = k\delta x - y$, the lower bound of the range of $N - M$,

(iii) $\frac{\partial M}{\partial f} > 0, \frac{\partial M}{\partial k} < 0, \frac{\partial M}{\partial y} < 0, \frac{\partial M}{\partial \delta} < 0, \frac{\partial M}{\partial \phi} > 0,$

(iv) $\frac{\partial N}{\partial f} > 0, \frac{\partial N}{\partial k} > 0, \frac{\partial N}{\partial y} < 0, \frac{\partial N}{\partial \delta} > 0, \frac{\partial N}{\partial \phi} > 0.$

We discuss the intuition behind the above proposition making use of numerical illustrations. Starting with the values of the model parameters in numerical example 1, first, when f (the cash flow ratio between two types of equipment) increases from 0.4 to 0.42, the initial leasing prices M and N rise to 17.7 and 40.2 respectively. Note that the type G manufacturer utilizes the initial leasing prices to signal his type, so that his initial leasing prices are constrained by the expected cash flow value of the type B equipment. Therefore M and N are increasing with f. The sales price S rises to 35.7 as well since the cash flow value of the type B equipment is larger when f is greater. Second, when k increases from 0.5 to 0.52, which implies a lower depreciation rate. M falls to 15.4 and N rises to 39.2 because the initial leasing prices are also employed by the type G manufacturer to separate the two types of entrepreneurs. In particular, $N-M$ must exceed $k\delta x-y$ so that the type H entrepreneur would not pool with the type L. With a lower depreciation rate, the type H entrepreneur could receive a higher second-period cash flow if he accepted the long-term leasing contract, which provides more incentive for the type H entrepreneur to pool. Hence, the manufacturer must raise N or reduce M to ensure that the type H entrepreneur stays on his equilibrium path. Additionally, S and P rise to 33.5 and 9 respectively due to the increasing cash flow in each period. Third, when δ (the damage factor) increases from 0.65 to 0.67, the consequence to the prices is similar to the case when we increase k: M falls to 15.5; N rises to 39 and S rises to 33.4. Fourth, when the maintenance cost of the type L entrepreneur c_L increases to 8.5, P falls to 6.5 because of the lower profit in the third period. M and N do not change since they are constrained by the expected cash flow value of the type B equipment which is irrelevant to c_L. Fifth, when y (the cash flow to the entrepreneur from the alternative technology) increases from 10 to 10.5, all the prices including M, N, S, P decrease because the manufacturer has to reduce these prices to offset the weaker incentive of the entrepreneur to replace the alternative technology with a unit of the new capital equipment.

We have shown that under certain conditions, a separating equilibrium can be achieved in the capital goods market with double-sided asymmetric information. However it is costly for the type G manufacturer to achieve this double separation. The separating costs are twofold. First, the type G manufacturer cannot fully extract the profit of the entrepreneur during the initial leasing periods due to the constrained leasing prices. Second, the long-term contract offered results in further loss for the type G manufacturer. Specifically, since the prices for the initial leasing period are constrained to prevent mimicking from the type B manufacturer, the type G manufacturer sacrifices more of his expected cash flow when he offers a leasing contract with longer initial leasing period. It can be shown that the per-period charge imposed by the manufacturer to the entrepreneur under the long-term contract is lower than that under the short-term contract.

Thus in certain circumstances, the type G manufacturer will be better off if he does not separate the type H entrepreneur and the type L entrepreneur. This will result in pooling equilibria, two of which are characterized in propositions 3 and 4.

Define:

$$\beta_2 \equiv Max(\frac{k\delta x + k^2\delta^2 x - 2y}{k\delta x + k^2\delta^2 x}, \frac{k^2 x - c_L - y}{k\delta x + k^2\delta^2 x - fk\delta x}), \tag{19}$$

$$\phi_2 \equiv Max(\frac{k\delta x + k^2\delta^2 x - y - \beta fk\delta x - k^2 x + c_L}{\beta(k\delta x + k^2\delta^2 x - fk\delta x) - k^2 x + c_L + y}, \phi_1). \tag{20}$$

Proposition 3 (Equilibrium with only the short-term leasing and sales contract) *When $f \leq f_1$, there exists an equilibrium in the capital goods market involving the following:*

(i) ***The type G manufacturer****: He offers a leasing contract which both the type H and type L entrepreneur will accept and renew at t=1 for two more periods. The type H entrepreneur will perform no maintenance and the type L entrepreneur will perform maintenance for the first two periods.*

The type B manufacturer*: He offers only a sales contract.*

Beliefs*: In equilibrium, both types of entrepreneurs infer a type G manufacturer with probability 1 if a leasing contract is offered, and a type B manufacturer with probability 1 if a sales contract is offered.*[15]

(ii) If $\phi \geq \phi_2$ and $\beta \in [\beta_2, \beta_1]$, the separating equilibrium described in proposition 1 will yield greater cash flows for the type G manufacturer and the same cash flows for the type B manufacturer compared to the equilibrium characterized here.

The intuition behind the above proposition is as follows. When the proportion of type H entrepreneurs in the market is high (i.e., ϕ is low) and the residual value of the equipment to the manufacturer is low, it is very expensive for the type G manufacturer to segment the capital goods market by inducing separation between the type L and type H entrepreneur and to repossess the equipment from the type H entrepreneur. Thus, he is better off by setting the lease terms such that the type H entrepreneur renews his lease at t=1, (i.e., he does not return the capital equipment). Consequently, we have a pooling equilibrium, with both the type H and type L entrepreneur choosing the same contract.

Numerical example 2: In numerical example 1, the profit to the type G manufacturer is 61.8 when he offers two separating leasing contracts, which is higher than what he could earn from a pooling leasing contract (40.5). However, if β falls to 0.8 and ϕ falls to 0.3, the type G manufacturer will prefer to offering one pooling leasing contract instead of two separating ones. His expected cash flow will be 45.7 from pooling compared with 45.1 from separating. Thus, when ϕ is low or when β is low, the pooling equilibrium with only a short-term renewable leasing contract and a sales contract will yield a greater expected payoff to the type G manufacturer than the separating equilibrium.

Now we will examine another type of pooling equilibrium. According to the separating equilibrium characterized in proposition 1, it should be clear that the type G manufacturer would never offer the sales contract alone when the quality of the type B equipment is low, (i.e., when $f \leq \frac{1}{1+k\delta}$). This is because, in this situation, he can always benefit from separating himself from the type B manufacturer and from segmenting the market between the type H and type L entrepreneur.[16] But this benefit will diminish when the cash flow ratio f becomes larger and when the residual value factor β becomes smaller.

[15] The out-of-equilibrium belief supporting the above equilibrium is that the entrepreneur believes that any manufacturer offering contracts other than the ones specified here is a type B manufacturer with probability 1.

[16] As shown in the Appendix, the payoff to the type G manufacturer when offering leasing contracts is $fx + (1-\phi\beta)fk\delta x - 2y + (1-\phi)(k^2x - c_L - y) + \phi\beta(k\delta x + k^2\delta^2 x)$ which is higher than the payoff from sales contract $(fx + fk\delta x - 2y)$.

We now relax the assumption (5) and instead assume:

$$fk^2x - c_L \leq fk^3\delta x, \tag{21}$$

$$fk^2\delta^2 x \geq y. \tag{22}$$

These assumptions correspond to the situation when the qualities of the type G and type B equipment are somewhat close.[17] In particular, assumption (21) implies that it is worthwhile for the type L entrepreneur to perform the maintenance on the type B equipment, and assumption (22) implies that even the type H entrepreneur will keep the equipment for three periods. We also define the following:

$$\phi_3 \equiv \frac{kx + k^2x - k\delta x - k^2\delta^2 x - 2c_L}{kx + k^2x - 2c_L - 2y}, \tag{23}$$

$$\beta_3 \equiv \frac{fx + fk\delta x + fk^2\delta^2 x - [x + (1-\phi)(kx + k^2x - 2c_L) + 2\phi y]}{\phi(k\delta x + k^2\delta^2 x)}, \tag{24}$$

$$f_2 \equiv \frac{x + (1-\phi)(kx + k^2x - 2c_L) + 2\phi y}{x + k\delta x + k^2\delta^2 x}. \tag{25}$$

Proposition 4 (Equilibrium with only a Sales Contract) *There exists an equilibrium in the capital goods market involving the following:*

(i) Both the type G manufacturer and the type B manufacturer offer the same sales contract which is accepted by both the type H and type L entrepreneur. The type H entrepreneur will perform no maintenance in any period and the type L entrepreneur will perform maintenance for the first two periods for both types of equipment.

(ii) If $f \geq f_2$, $\phi \geq \phi_3$ and $\beta \leq \beta_3$, this pooling equilibrium here will yield greater cash flows for the type G manufacturer than the separating equilibrium described in proposition 1 and the same cash flow for the type B manufacturer.

We know that when the quality of the type B equipment does not differ too much from that of the type G (i.e., f is large), the benefit from the separation on the manufacturer's side is small.

[17] Remember that so far we have made two crucial assumptions: a large difference between the maintenance costs of the type H and type L entrepreneur and between the productivity of the type G and type B equipment. In this equilibrium, we maintain the assumption on the difference in maintenance costs, but instead assume that the productivity levels of two types of equipment are close.

Moreover, when the returned equipment is of low residual value to the manufacturer (i.e., β is small), it is costly for the manufacturer to separate on entrepreneur's side and to repossess the equipment from the entrepreneur. As a consequence, when $f \geq f_2$ and $\beta \leq \beta_3$, the cost from double separation will eventually exceed the benefit. And the sales contract, in this case, will emerge as the only contract offered in equilibrium in the capital goods market.

Numerical Example 3: Resetting $f = 0.95$ and $\beta = 0.3$ in numerical example 1, we can show that the payoff to the type G manufacturer is 121.2 in the pooling equilibrium with a sales contract, while his payoff in the separating equilibrium is 105.9.

4 Service Leases

A "service" lease refers to a situation where a contractual provision in the lease contract requires the manufacturer (lessor) to provide maintenance to the entrepreneur (lessee).[18] In other words, in the service lease, a service contract is bundled with the lease contract.

In this section, we analyze the rationale for service leases, and investigate the conditions under which they are offered. We maintain essentially the same assumptions here as in the basic model, except that we now expand the menu of contracts: in addition to the contracts characterized in section 2.2, we now allow the manufacturer to offer a short-term (one period) lease with a service (maintenance) contract bundled with it, which requires the manufacturer to perform maintenance for the first period. If the service lease is renewed, the entrepreneur obtains the use of the asset for another two periods, with the manufacturer obligated to maintain the equipment for these two periods.

In the following, we will examine the equilibrium with a sales contract $\{S\}$, a short-term leasing contract without a service provision $\{M_1, R_1\}$, and a short-term service lease $\{M_2, R_2\}$. We denote the manufacturer's maintenance cost by c_p. Also we define:

[18] In contrast, a lease where the entrepreneur (lessee) has the responsibility to maintain the asset is referred to as a "net" lease in the leasing terminology.

$$c^* \equiv \frac{1}{2\phi}[kx - c_L - y - \beta f k\delta x] + \frac{1}{2}[k^2 x - y - \beta(k\delta x + k^2\delta^2 x - fk\delta x) + c_L]. \tag{26}$$

Proposition 5 (Separating Equilibrium with a Service Lease) *When $f \leq f_1$, there exists an equilibrium in the capital goods market involving the following:*

(i) ***The type G manufacturer****: He offers two different leasing contracts: a short-term leasing contract without a service provision and a short-term renewable service lease.*

The type B manufacturer*: He offers a sales contract.*

The type L entrepreneur*: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the short-term leasing contract without the service provision by paying the initial leasing price M_1, and at t=1, he renews his lease contract by paying the renewal price R_1. He performs maintenance for the first two periods. If the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1. He accepts the sales contract, performs no maintenance, and uses the equipment for two periods.*

The type H entrepreneur*: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the service lease by paying the initial leasing price M_2, and at t=1, he renews his lease contract by paying the renewal price R_2. The manufacture performs maintenance in each period as specified by the service lease. If the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1. He accepts the sales contract, and does not, in this case, perform maintenance.*[19]

(ii) If $c_p \leq c^*$, the equilibrium here will yield greater expected cash flows to the type G manufacturer than the separating equilibrium characterized in proposition 1.

The intuition behind the above proposition is as follows. The difference between the lessee's leasing cost for the net lease (i.e., the lease without the service provision) and that for the service lease is such that the type L entrepreneur benefits from taking the net lease, while the type H entrepreneur is better off accepting the service lease. In contrast to the case where no service lease is offered, the type H entrepreneur also chooses to renew the short-term (service) lease, since the properly maintained capital equipment yields him a greater expected cash flow than the alternative technology. Recall that, when the service lease is not offered, the type H entrepreneur would incur a higher cost to perform the maintenance, so he is better off returning the equipment after one period (without performing any maintenance).

[19] The out-of-equilibrium belief supporting the above equilibrium is that the entrepreneur believes that any manufacturer offering contracts other than those specified above is a type B manufacturer with probability 1.

The equilibrium initial leasing prices M_1 and M_2, and the renewal fees R_1 and R_2 are characterized in the Appendix. The difference between R_1 and R_2 is c_p, which implies that, in equilibrium, the type H entrepreneur fully bears the burden of the maintenance cost incurred by the type G manufacturer. As before, M_1 and M_2 are restricted to prevent the type B manufacturer from mimicking the type G.

Part (ii) of proposition 5 states that if his maintenance cost c_p is less than a threshold point c^*, the type G manufacturer would be better off (in terms of the expected cash flows) in the above equilibrium compared to the separating equilibrium in proposition 1. This is because if the equipment could be maintained properly, it will generate the same revenue for both the type H and type L entrepreneur. Thus, given the sufficiently low maintenance cost of the type G manufacturer and the better investment opportunity of the type H entrepreneur, the type G manufacturer desires to provide maintenance to the type H entrepreneur since he can then extract all of the additional cash flows generated in the later periods by the type H entrepreneur.

The threshold value c^* is decreasing with β. This implies that when β is lower, the manufacturer, even with a higher maintenance cost, would be willing to offer the service contract. The reason for this is that the low residual value of the returned equipment increases the opportunity cost for the manufacturer of repossessing the leased equipment from the type H entrepreneur who chooses not to renew his lease. Therefore as β is smaller, the manufacturer, comparing this opportunity cost with his maintenance cost, has more incentive to provide the maintenance so that the type H entrepreneur will renew the lease at t=1.

Define:

$$\beta_4 = \frac{kx - c_L - y + \phi(k^2 x - c_L - y) - 2\phi(c_H - c_L)}{fk\delta x + \phi(k\delta x + k^2\delta^2 x - fk\delta x)}. \tag{27}$$

Proposition 6 *When $\beta \leq \beta_4$, the type G manufacturer will prefer to offering the combination of a service lease and a net lease rather than offering the leasing contracts characterized in proposition 1 even if $c_P \geq c_H$.*

This proposition shows that in certain circumstances, the manufacturer may provide the service contract to the type H entrepreneur even if his maintenance cost is higher than that of the type H entrepreneur's. The intuition here is that the service contract allows the manufacturer to minimize the loss arising from the type H entrepreneur not renewing the short-term lease. When the residual value of the returned equipment to the manufacturer is low, the benefit to the manufacturer from motivating the entrepreneur to renew his lease and keep using the equipment outweights even a high maintenance cost incurred by the manufacturer.

Numerical Example 4: If the maintenance cost of the manufacturer c_p is below 4.4, the type G manufacturer will receive a higher profit from offering service leases than from offering only leases without service provision. And when $\beta \leq 0.54$, the type G manufacturer will prefer the service lease even if $c_p > c_H = 20$. For example, when $\beta = 0.4$ and $c_p = 22$, the type G manufacturer can earn 45.8, which is higher than 43.8 that he would earn by offering the menu of contracts characterized in proposition 1.

5 Leases with Metering

"Metering" refers to a contractual provision in leasing contracts which links the lease payments to some measure of the intensity of the asset's usage by the lessor (e.g., computer lease payments may be linked to CPU cycles; automobile lease payments to odometer mileage, etc.). Two informal arguments often advanced as rationales for including metering provisions are the control of asset abuse and the reduction in the volatility of the lessee's net cash flows. We analyze each rationale in turn in sections 5.1 and 5.2 respectively.

5.1 Equilibrium with Private Information about Usage Intensity

In this section, we modify some of the assumptions in the basic model (section 2 and 3) and investigate the rationale behind the metering provision found in many leasing contracts.

We now assume that entrepreneurs differ in usage intensity rather than in maintenance cost. The high-intensity entrepreneur (type II, in this section) uses the capital equipment more intensely

(for instance, for more hours per period) than the low intensity (type I) entrepreneur. We assume that high intensity use yields the entrepreneur a greater expected cash flow than low intensity use (denote the cash flow ratio between high and low intensity use by l, $l \geq 1$). We also assume the depreciation factor k for both the low-intensity use and the high-intensity use. Therefore, for the type G equipment, the type I (low-intensity) entrepreneur receives cash flows of x at t=1, kx at t=2, k^2x at t=3, and the type II (high-intensity) entrepreneur receives cash flows of lx, lkx, lk^2x for the same three periods respectively. For the type B equipment, both types of entrepreneurs receive the expected cash flows of fx at t=1, and fkx at t=2.[20] The manufacturer has the ability to meter the intensity of usage of the equipment using a costly metering technology. The cost of metering is m. Moreover, we set the maintenance costs equal to zero ($c_H = c_L = 0$) to simplify our analysis. Other assumptions remain the same as in the basic model.

At time 0, the manufacturer can choose among three contracts: a sales contract $\{S\}$, a leasing contract with limited usage and metering $\{M_1, R_1, V, \bar{u}\}$, or a leasing contract with unlimited usage and no metering $\{M_2, R_2\}$. If the entrepreneur accepts the sales contract, he pays the sales price S upfront at time 0, and gains the ownership of the equipment for the following periods. If he accepts the leasing contract with limited usage, he uses the equipment for one period by paying an initial lease payment M_1 upfront at t=0, with a penalty V at t=1 if he over-uses the equipment. In other words, the initial lease payment is a function of the usage: it is M_1 if the usage is below a threshold usage u, and it is $M_1 + V$ if the usage exceeds u, where V is the penalty assessed for the over-use. The usage of the equipment is measured by the manufacturer through metering. At t=1, the entrepreneur has an option to renew the contract for another two periods by paying R_1. On the other hand, if the entrepreneur accepts the leasing contract with unlimited usage, he can use the equipment for one period without any constraint on usage by paying M_2 upfront at time 0, and have an option to renew for two more periods by paying R_2 at t=1.

[20] This assumption is for simplicity and for consistency with that in the basic model. Recall our assumption in the basic model that the project will end at t=2 with the type B equipment.

In the following proposition, we define:

$$f_3 \equiv \frac{1}{1+k}, \tag{28}$$

$$m_1 \equiv \frac{-\beta f k x + \phi(lkx + lk^2x - 2y)}{1-\phi} + kx + k^2x - 2y. \tag{29}$$

Proposition 7 (Metering under Private Information about Usage Intensity) *When $f \leq f_3$ and $m \leq m_1$, the equilibrium in the capital goods market involves the following:*

***The type G manufacturer**: He offers two different leasing contracts: a leasing contract with metering and limited usage; and a leasing contract with unlimited usage and no metering.*

***The type B manufacturer**: He offers only a sales contract.*

***The type I entrepreneur**: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the leasing contract with limited usage and metering, uses the equipment within the threshold level u, and buys the equipment at t=1. If, however, the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1, and he accepts the sales contract.*

***The type II entrepreneur**: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the leasing contract with unlimited usage and no metering, and buys the equipment at t=1. If, however, the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1, and he accepts the sales contract.*

In the above setting, metering allows the type G manufacturer to increase his expected profits by segmenting the market between the high-intensity and low-intensity entrepreneur. Under the contract with metering, the manufacturer sets a high penalty for high intensity usage, so that the high intensity entrepreneur does not accept this contract. At the same time, he sets a comparatively high initial leasing price in the leasing contract without metering (and with unlimited usage), which ensures that the low-intensity entrepreneur is better off choosing the metering contract.[21] The high penalty for the high intensity usage in the metering contract is a cheap threat because the penalty will never be incurred in equilibrium. Thus, the only additional cost incurred in the equilibrium with metering is the metering cost. When this cost is low enough, the type G manufacturer has the incentive to offer the menu of contracts characterized in this proposition.

Numerical Example 5: Set $k = 0.4$, $x = 100$, $y = 10$, $f = 0.3$, $\beta = 1.2$, $\phi = .35$, $l = 1.4$, and $m = 20$, with low-intensity usage equaling to 20 units per period and high-intensity usage

[21] The initial leasing prices in the leasing contracts are constrained as well by the need to prevent mimicking by the type B manufacturer, similar to the IC constraint in proposition 1.

equaling to 40 units per period. In this case, the type G manufacturer offers a short-term leasing contract with limited usage and metering $\{M_1 = 3.7,\ R_1 = 36,\ V \geq 33.5$, and u =30 units per period$\}$ which will be accepted by the type I (low-intensity) entrepreneur, and a short-term leasing contract with unlimited usage $\{M_2 = 14.8,\ R_2 = 58.4\}$ which will be accepted by the type II (high-intensity) entrepreneur. These prices, together with the over-usage penalty (supported by ascertaining the level of usage by incurring the metering cost m) allow him to achieve the market segmentation on the entrepreneur's side, as well as to distinguish himself from the type B manufacturer. In equilibrium, the type B manufacturer offers only a sales contract with $S = 22$. He does not mimic the type G manufacturer because he cannot increase his expected cash flows from doing so. The type G manufacturer prefers to offering leasing contracts since his expected profit from leasing contracts (38.4) is higher than that from the sales contract (22). The type II entrepreneur only accepts the contract with unlimited usage because, when $V \geq 33.5$, he is better off by doing so; the type I entrepreneur accepts the metering contract with limited usage because he can earn more (116.3) by doing so than by taking the contract with unlimited usage (105.2).

5.2 Equilibrium with Entrepreneurial Risk-Aversion and Uncertainty about Usage Intensity

In this section, we slightly modify the assumptions in section 5.1 by assuming that the entrepreneur is uncertain about his own usage intensity in any given period: the entrepreneur assesses a probability α of his being a low-intensity user in each period and probability of $1 - \alpha$ being a high-intensity user. The entrepreneur comes to realize his usage intensity in any period with probability 1 only at the end of that period. Further, we assume that entrepreneurs are risk-averse with the degrees of risk-aversion varying across entrepreneurs. We will refer to the more risk-averse entrepreneur as the type I entrepreneur in this section, and the less risk-averse entrepreneur as the type II. For simplicity, we assume that the type II entrepreneur is risk-neutral (so that his utility function is linear), and assume a concave von Neumann-Morgenstern expected utility func-

tion $U(.)$ for the type I (risk-averse) entrepreneur.[22] We assume that, while each entrepreneur knows his own type, the manufacturer cannot distinguish between the two types of entrepreneurs before observing the entrepreneurs' contract choices; the manufacturer only observes the prior probability ϕ of any given entrepreneur being of type I.

We assume the same menu of contracts as in the previous section: a sales contract $\{S\}$, a leasing contract with limited usage and metering $\{M_1, R_1, V, u\}$, and a leasing contract with unlimited usage and no metering $\{M_2, R_2\}$.[23] The definitions of these three contracts, as well as all other assumptions, remain the same as in section 5.1. We also define:

$$m_2 = \frac{1}{\phi}[(1-\phi)R_2 + \phi R_1 - \beta f k x] \tag{30}$$

Proposition 8 (Metering under Uncertainty about Usage Intensity) *When $f \leq f_3$, $m \leq m_2$, and $\alpha \geq \frac{1}{2}$, the separating equilibrium in the capital goods market involves the following:*

***The type G manufacturer**: He offers two different leasing contracts: a leasing contract with metering and limited usage; and a leasing contract with unlimited usage and no metering.*

***The type B manufacturer**: He offers only a sales contract.*

***The type I entrepreneur**: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He pays an initial leasing fee M_1 upfront, with a penalty V if his intensity of usage in the first period (as measured through metering) turns out to be high; he pays no penalty if his first-period intensity of usage is low. At t=1, he renews the contract by paying the renewal price R_1. If, however, the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1, and he accepts the sales contract.*

***The type II entrepreneur**: If the manufacturer offers leasing contracts, he infers that the manufacturer is of type G with probability 1. He accepts the leasing contract with unlimited usage and no metering by paying a lump sum initial leasing payment M_2 upfront at t=0, and renews the contract by paying R_2 at t=1. If, however, the manufacturer offers only a sales contract, he infers that the manufacturer is of type B with probability 1, and he accepts the sales contract.*

The incentive mechanism constructed in the first leasing period utilizes the different degrees of risk aversion of the entrepreneurs. When the entrepreneur is risk-averse, he values not only the amount of expected cash flows but also the low volatility of cash flows. Thus the manufacturer can

[22] Clearly, this analysis can be generalized, at the cost of some additional computational complexity, to the case where both types of entrepreneurs are risk-averse, with the type I having a greater degree of risk-aversion than the type II entrepreneur.

[23] For simplicity, we allow only for contracts with metering of first-period usage only. However, the intuition behind our analysis extends to the case where metering is done every period, thus following the risk-averse entrepreneur to hedge his cash flow volatility in the subsequent periods as well.

require a higher price from the type I (risk-averse) entrepreneur and compensate him for this with a payment schedule that reduces the volatility of his future profits. Specifically, the manufacturer can use the metering contract to charge the risk-averse entrepreneur different prices corresponding to the different cash flows under the different usage intensities. This price schedule with a high mean value prevents the type II (risk neutral) entrepreneur from mimicking since the risk neutral entrepreneur does not value the decreased cash flow volatility offered in the metering contract.

However such an incentive scheme in the initial leasing period is costly although it benefits the manufacturer in the following periods by segmenting the market. If no hidden information exists on the manufacturer's side or if the qualities of two types of equipment are close so that no constraint exists on the initial leasing prices, the loss to the type G manufacturer in the initial leasing period in order to construct such an incentive scheme will exactly offset the benefit he can receive in the following periods. But when the initial leasing prices are restricted to prevent the mimicking of the type B manufacturer, the incentive scheme under metering in the initial leasing periods is cost-free, and the type G manufacturer can then appropriate the net benefit from the market segmentation. The condition $f \leq f_3$ ensures that the initial leasing prices set by the type G manufacturer to be bound by the non-mimicking constraint.

Numerical Example 6: Set $k = 0.3$, $x = 20$, $y = 1.5$, $f = 0.6$, $\beta = 1.2$, $\phi = .35$, $l = 2$, $m = 5$, $\alpha = 0.5$ and $U(x) = \sqrt{x}$ with low-intensity usage equaling to 20 units per period and high-intensity usage equaling to 40 units per period. In this case, the type G manufacturer will offer two leasing contracts from which the type I entrepreneur will accept the leasing contract with limited usage and metering $\{M_1 = 7.1,\ R_1 = 5.9,\ V = 8$ and $u =$30 units per period$\}$, and the type II entrepreneur will accept the leasing contract with unlimited usage $\{M_2 = 8.1,\ R_2 = 6.4\}$. The type G manufacturer does not offer the sales contract since doing so, he would earn 12.6 which is lower than what he can earn (12.7) from offering the leasing contracts. In equilibrium, the type B manufacturer offers only a sales contract with $S = 12.6$. He does not mimic the type G manufacturer because he can not benefit from imitation in terms of his expected cash flow.

The type II entrepreneur accepts the contract with unlimited usage since he is better off by doing so (18.9) than by accepting the other contract (18.3); and the type I entrepreneur accepts the contract with limited usage and metering because his utility is higher (4.29) from this contract than from the contract with unlimited usage (4.27).

6 Implications of the model

We now discuss some of the implications of our model.

(i) Non-tax determinants of lease versus buy:[24] The first implication of our model relates to the kinds of equipment that will be leased rather than sold outright. Our model predicts that in a situation where there is asymmetric information about the quality of the capital equipment, the higher quality equipment will be leased, while the lower quality equipment will be sold outright. In some cases, the asymmetric information may be about the nature of the technology, rather than about the quality of the capital good itself: manufacturers of capital equipment may have information superior to users about how suitable the technology underlying the capital good is for the application at hand. In this case, manufacturers having better technologies will signal their type by leasing the equipment cheaply to users in the initial periods. Thus, capital equipment making use of newer technologies (and therefore characterized by asymmetric information) are likely to be leased, while those involving older technologies are primarily sold (for example, many models of the new electric-gasoline hybrid cars are primarily leased).[25]

(ii) Implications for contractual provisions in leases: Our model has several implications for the provisions in leasing contracts, and the relationship of these provisions to various characteristics of the lessor and the lessee. The first implication is that lessees with a comparative advantage in providing maintenance will take long-term (non-cancelable) leases, while lessees with a high opportunity cost of providing maintenance will take short-term leases (e.g., automobile leases

[24] Of course, in many cases, the lease versus buy decision may be driven simply by tax considerations.

[25] Such strategies are found in practice in many markets for newer technologies: e.g., internet service providers (e.g., AOL or Microsoft Network) allowing free usage for the first month.

for senior corporate executives are usually short-term, and the automobiles are returned to the lessors after the initial leasing period).[26] Of course, such short-term leases will be offered only if the manufacturer has a comparative advantage in disposing of off-lease goods returned by the short-term lessees, which seems to be the case for cars (as a result of continuous dealings in the secondary market, vehicle leasing companies have an advantage relative to short-term users in finding secondary buyers).

The second implication deals with the existence of service leases (leases bundled with service contracts). Our model predicts that service leases will occur in situations where the manufacturer either has a lower cost of providing maintenance compared to certain users, or the equipment is particularly sensitive to the provision of appropriate maintenance (so that the value of the equipment deteriorates dramatically due to lack of maintenance, and the value to the manufacturer of any equipment returned to him is low if the equipment has not been maintained properly) or both. Thus, complex, specialized assets like mainframe computers and medical equipment are provided under a service lease, since typically the manufacturer has a significant comparative advantage in the provision of maintenance in these cases, and the equipment value is very sensitive to the provision of maintenance.

The third implication relates to the presence of metering provisions. If it is relatively inexpensive to ascertain the intensity of usage, leases will contain metering provisions allowing the lessor to distinguish between lessees of different usage intensities, and to charge higher intensity lessees a greater amount (e.g., rental rates for farm equipment are often based on the number of hours of usage per day; also truck and automobile leases containing mileage provisions). Another advantage of leases with metering is that they allow the lessee to hedge against uncertain demand for his products, and thus to reduce the volatility of his net cash flows. Therefore, if the lessee is uncertain about his own future usage, and wants to reduce the volatility of his net cash flows, he

[26] Consistent with this, it has been documented that roughly two-thirds of short-term (two and three years) car leases are not renewed in practice.

can opt for a lease with a metering provision, under which he will be charged more if this usage (and therefore revenue) is high, and less if his usage is low. Such lessees, who value the reduction in cash flow volatility, will also be willing to pay a greater expected leasing price than those who do not value such volatility reduction. Thus, leases with such metering provisions also allow the lessor to maximize profit by segmenting the market between these two types of lessees.

(iii) Implications for leasing costs and sales prices: The first implication in this regard is that the cost per period will be greater on average for short-term leases rather than for long-term leases. Recall that, in equilibrium, short-term leases are entered into by users who have a high cost of providing maintenance (and who return the equipment to the lessor after the initial period). The high cost of short-term leases therefore reflects the costs imposed on the lessor arising from the lack of appropriate maintenance by high-cost users. The second implication is for sales prices versus leasing costs: our model predicts that the equilibrium sales price will be lower on average than the leasing price for an a priori indistinguishable piece of equipment (since the average quality of leased equipment is better than that sold outright).[27]

7 Conclusion

Leasing is an important source of external financing for U.S. corporations: it has been estimated that about a third of the capital equipment used by the corporations is leased. However, the motivations for leasing, and for the various contractual provisions in lease contracts, are not yet fully understood. In this paper, we developed a non-tax rationale for leasing in a double-sided asymmetric information setting, and analyzed how various contractual provisions in leasing contracts arise in equilibrium. We assumed a capital goods market where the manufacturer of capital goods has private information about the quality of goods he produces; entrepreneurs (users

[27] This is easily borne out for automobiles: see, e.g., the Complete Car Cost Guide, which lists the lease cost for a mid-price sedan at $28,535, compared to the loan cost of $25,535. Also, there is some empirical evidence indicating that the quality of off-lease cars is greater than sold cars of a similar age: Desai and Purohit (1998), using auction data for a popular car model, provide evidence that the price decline for off-lease cars is slower than that for sold cars.

of these capital goods) come to learn this quality only over a period of time. Each unit of the capital goods requires a certain level of maintenance in each period. Entrepreneurs differ in their cost of providing this maintenance; this maintenance cost is information private to each entrepreneur. Leasing emerged as an equilibrium solution to this double-sided adverse selection problem. Various contractual provisions in leasing contracts (e.g., short-term versus long-term leases with non-cancellation provisions, option to buy at lease termination, and service leases) also emerged as equilibrium solutions under various alternative settings. Finally, leases with metering provisions emerged in equilibrium when, in addition to maintenance cost, entrepreneurs differ in other dimensions such as their intensity of using the capital good, and their degree of risk-aversion. An interesting aspect of our model is that, in equilibrium, leasing co-existed with a sales contract in some cases; it was the sole kind of financing contract in other cases; and the sales contract emerged as the only kind of contracts offered in yet other settings. We developed the implications of our model for the lease-versus-sell decision, the situations under which various leasing contract provisions are appropriate, and for the relative magnitudes of sales prices and the leasing costs for leases with different contractual provisions.

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Appendix

Proof of Proposition 1. In this proof, we will first determine the equilibrium prices for each contract and then show that a separating equilibrium exists when $f \leq f_1$, $\phi \geq \phi_1$ and $\beta \leq \beta_1$.

At time 0, the manufacturer maximizes his expected profits based on his own type and his belief about the entrepreneurs. The type G manufacturer believes that, by his contract design, the type L entrepreneur will accept the long-term lease contract and exercise the buy option at t=2, and that the type H entrepreneur will accept the short-term contract and not renew the contract at t=1. He, thus, maximizes:

$$\phi M + (1-\phi)(N+P) + \phi\beta(k\delta x + k^2\delta^2 x), \tag{A1}$$

subject to constraint (9), (10), (11), (12), (13), (14), (15) and (16). The last term in (A1) is the residual value of the returned equipment to the manufacturer.

The type B manufacturer, knowing that both types of entrepreneurs will take the sales contract, maximizes S subject to constraint (18) and (17).

1. IR constraint (14) and (15) are redundant because they are implicitly implied by constraint (11), (12) and (13).

2. Constraint (13) is not binding because if so, we can show that $\phi M + (1-\phi)N \geq x - y + (1-\phi)(k\delta x - y)$. However, we know from constraint (9) and (17) that $\phi M + (1-\phi)N \leq fx + fk\delta x - 2y - \phi\beta fk\delta x < x - y + (1-\phi)(k\delta x - y)$ since $f \leq f_1$.

3. Constraint (9) must hold equality because otherwise there exists a new contract $\{M^*, N^*, R, P\}$ with $M^* = M + \epsilon$ and $N^* = N + \epsilon$ where $\epsilon \leq x - y - M$, which would generate a higher payoff to the type G manufacturer than the old contract $\{M, N, R, P\}$ and yield the same cash flow to the type B manufacturer.[28] As a consequence, constraint (18) is automatically satisfied. Following the same logic, we can show that $S = fx + fk\delta x - 2y$.

[28] Under the new contract setting, all the inequality and equality constraints are still satisfied.

4. The inequality constraints on P are:

$$\begin{aligned} P &\leq kx + k^2x - 2c_L - 2y - (N - M) = T_1, \\ P &\leq k^2x - c_L - y = T_2. \end{aligned} \tag{A2}$$

Because $N - M \leq kx - c_L - y$, (A2) implies $T_1 \geq T_2$, and further $P \leq T_2 = k^2x - c_L - y$. Hence, the type G manufacturer will choose $P = k^2x - c_L - y$ to maximize the expected profit.

Now the equilibrium prices are that $S = fx + fk\delta x - 2y$, $P = k^2x - c_L - y$, $R \geq kx + k^2x - 2c_L - 2y$ and M & N satisfy:

$$\begin{aligned} &\phi M + (1-\phi)N = fx + fk\delta x - 2y - \phi\beta fk\delta x, \\ &N - M \in [k\delta x - y, kx - c_L - y],\ M \in [0, x - y). \end{aligned} \tag{A3}$$

From (A3),

$$\begin{aligned} M \in [l^*, u^*] = [&fx + fk\delta x - 2y - \phi\beta fk\delta x - (1-\phi)(kx - c_L - y), \\ &fx + fk\delta x - 2y - \phi\beta fk\delta x - (1-\phi)(k\delta x - y)]. \end{aligned} \tag{A4}$$

It is easy to show that $l^* \leq x - y$, and when $\phi \geq \phi_1$ and $\beta \leq \beta_1$, $u^* \geq 0$, which implies that there exists at lease one solution $\{M, N\}$ to (A3). ■

Proof of proposition 2. It is straightforward to derive with a little bit of algebra these comparative statics from the equilibrium prices characterized in the proof of proposition 1. ■

Proof of proposition 3. The type G manufacturer, under the belief that both types of entrepreneurs will accept the short-term leasing contract $\{M, R\}$ and exercise the purchase option at t=1, maximizes his expected profit $M + R$ satisfying the following non-mimicking conditions:

$$\begin{aligned} M + \beta fk\delta x &\leq S, \\ -R + fk\delta x &\leq y. \end{aligned} \tag{A5}$$

He sets the prices to satisfy the following IR constraints as well:

$$\begin{aligned} -M - R + x + k\delta x + k^2\delta^2 x &\geq 3y, \\ -R + k\delta x + k^2\delta^2 x &\geq 2y. \end{aligned} \tag{A6}$$

The type B maximizes his expected payoff S, satisfying the following IR and IC constraint:

$$\begin{aligned} -S + fx + fk\delta x &\geq 2y, \\ M + R &\geq S. \end{aligned} \tag{A7}$$

With the same logic provided in the first proof, we can show that the equilibrium prices are $S = fx + fk\delta x - 2y$, $M = fx + fk\delta x - 2y - \beta fk\delta x$ and $R = k\delta x + k^2\delta^2 x - 2y$.

The type G manufacturer's expected payoff then equals to $fx + fk\delta x - 2y - \beta fk\delta x + k\delta x + k^2\delta^2 x - 2y$. By contrast, the type G manufacturer, by offering separating leasing contracts, can earn $fx + (1 - \phi\beta)fk\delta x - 2y + (1 - \phi)(k^2 x - c_L - y) + \phi\beta(k\delta x + k^2\delta^2 x)$. Therefore, when $\phi \geq \phi_2$ and $\beta \in [\beta_2, \beta_1]$, the expected payoff to the type G manufacturer is higher from the separating equilibrium than from the pooling equilibrium. ■

Proof of proposition 4. The manufacturer must provide a sales contract accepted by both types of entrepreneurs. Thus the sales price equals to $fx + fk\delta x + fk^2\delta^2 x - 3y$.

Following the same logic as before, the equilibrium prices are that $M = x - y$, $R \geq kx + k^2 x - 2c_L - 2y$, $N = x + kx - c_L - 2y$ and $P = k^2 x - c_L - y$. The expected payoff to the type G manufacturer then is $x - y + (1 - \phi)(kx + k^2 x - 2c_L - 2y) + \phi\beta(k\delta x + k^2\delta^2 x)$. When $f \geq f_2$, $\phi \geq \phi_3$ and $\beta \leq \beta_3$, the pooling equilibrium with only a sales contract would be preferred by the type G manufacturer compared with the separating equilibrium characterized in proposition 1. ■

Proof of proposition 5. Now the beliefs of the type G manufacturer, given the contracts offered, are that (1) the type H entrepreneur will accept the short-term service lease and renew the contract at t=1; (2) the type L entrepreneur will accept the short-term contract without service term and buy the equipment at t=1. Under these beliefs, he, at t=0, maximizes his expected

profit $\phi(M_2+R_2)+(1-\phi)(M_1+R_1)-\phi(2c_P)$ subject to the following IC constraints:

$$\begin{aligned} -M_1-R_1+x+kx+k^2x-2c_L &\geq -M_2-R_2+x+kx+k^2x, \\ -M_2-R_2+x+kx+k^2x &\geq -M_1+x+2y, \\ -R_1+k\delta x+k^2\delta^2 x &\leq y, \\ \phi M_2+(1-\phi)M_1+\beta f k\delta x &\leq S, \end{aligned} \tag{A8}$$

and IR constraints:

$$\begin{aligned} -M_1-R_1+x+kx+k^2x-2c_L &\geq 3y, \\ -R_1+x+kx+k^2x-2c_L &\geq x+2y, \\ -M_2-R_2+x+kx+k^2x &\geq 3y, \\ -R_2+kx+k^2x &\geq 2y. \end{aligned} \tag{A9}$$

The type B manufacturer maximizes his sales revenue S subject to:

$$\begin{aligned} -S+fx+fk\delta x &\geq 2y, \\ \phi(M_2+R_2)+(1-\phi)(M_1+R_1)-\phi(2c_P) &\geq S. \end{aligned} \tag{A10}$$

It is easy to show under the same logic before that $S=fx+fk\delta x-2y$, $R_2=kx+k^2x-2y$, $R_1=kx+k^2x-2c_L-2y$ and $M_1=M_2=fx+fk\delta x-2y-\beta fk\delta x$.

The expected payoff to the type G manufacturer then is $fx+fk\delta x-2y-\beta fk\delta x+kx+k^2x-2y-2c_L+\phi(2c_L-2c_P)$. Thus when $c_P\leq c^*$, the type G manufacturer can benefit from providing service to the high-maintenance-cost entrepreneur. ■

Proof of propostion 6. It is straightforward to show that when $\beta\leq\beta_4$, $c^*\geq c_H$. ■

Proof of proposition 7. The type G manufacturer has the following beliefs: (1) the type I entrepreneur will accept short-term leasing contract with limited usage and metering, and buy the machine at t=1; (2) the type II entrepreneur will accept short-term contract without limitation on usage and renew the contract at t=1. With these beliefs, he maximizes his expected profit

$\phi(M_2 + R_2) + (1-\phi)(M_1 + R_1 - m)$ subject to the following IC constraints:

$$\begin{aligned}
-M_2 - R_2 + lx + lkx + lk^2x &\geq -M_1 - R_1 - V + lx + lkx + lk^2x, \\
-R_1 + lkx + lk^2x &\geq 2y, \\
-M_1 - R_1 + x + kx + k^2x &\geq -M_2 - R_2 + x + kx + k^2x, \\
-R_2 + kx + k^2x &\leq 2y, \\
\phi M_2 + (1-\phi)M_1 + \beta fkx &\leq S,
\end{aligned} \tag{A11}$$

and IR constraints:

$$\begin{aligned}
-M_2 - R_2 + lx + lkx + lk^2x &\geq 3y, \\
-R_2 + lkx + lk^2x &\geq 2y, \\
-M_1 - R_1 + x + kx + k^2x &\geq 3y, \\
-R_1 + kx + k^2x &\geq 2y.
\end{aligned} \tag{A12}$$

The type B manufacturer maximizes his sales revenue S subject to:

$$\begin{aligned}
-S + fx + fkx &\geq 2y \\
\phi(M_2 + R_2) + (1-\phi)(M_1 + R_1 - m) &\geq S
\end{aligned} \tag{A13}$$

Under the same logic, the equilibrium prices can be derived as that $R_2 = lkx + lk^2x - 2y$, $R_1 = kx + k^2x - 2y$, $S = fx + fkx - 2y$ and other prices satisfy:

$$\begin{aligned}
\phi M_2 + (1-\phi)M_1 &= fx + fkx - 2y - \beta fkx, \\
0 \leq M_2 - M_1 &\leq V + (R_1 - R_2), \\
\text{and } M_1 \in [0, x-y],\ & M_2 \in [0, lx-y].
\end{aligned} \tag{A14}$$

(A14) can be further rewritten as:

$$M_1 \leq fx + fkx - 2y - \beta fkx, \text{ and } M_2 \geq fx + fkx - 2y - \beta fkx. \tag{A15}$$

$0 \leq fx + fkx - 2y - \beta fkx \leq x$, which implies that there exist solutions to (A14). When $m \leq m_1$, constraint (A13) is also satisfied. ■

Proof of proposition 8. The type G manufacturer maximizes $(1-\phi)(M_2+R_2)+\phi[M_1+R_1+(1-\alpha)V]-\phi m$. Define:

$$\begin{aligned} F_1 &= x+kx+k^2x, \qquad & F_2 &= x+lkx+lk^2x, \\ F_3 &= lx+kx+k^2x, \qquad & F_4 &= lx+lkx+lk^2x. \end{aligned} \tag{A16}$$

The IR constraints for the entrepreneurs are:

$$\begin{aligned} &\alpha^2(F_1-M_2-R_2)+\alpha(1-\alpha)(F_2-M_2-R_2)+(1-\alpha) \\ &\alpha(F_3-M_2-R_2)+(1-\alpha)^2(F_4-M_2-R_2) \ \geq \ 3y, \end{aligned} \tag{A17}$$

$$\alpha(kx+k^2x-R_2)+(1-\alpha)(lkx+lk^2x-R_2) \ \geq \ 2y, \tag{A18}$$

$$\begin{aligned} &\alpha^2U(F_1-M_1-R_1)+(1-\alpha)\alpha U(F_3-M_1-R_1-V)+(1-\alpha) \\ &\alpha U(F_2-M_1-R_1)+(1-\alpha)^2U(F_4-M_1-R_1-V) \ \geq \ U(3y), \end{aligned} \tag{A19}$$

$$\alpha U(kx+k^2x-R_1)+(1-\alpha)U(lkx+lk^2x-R_1) \ \geq \ U(2y), \tag{A20}$$

where the expected utility of the entrepreneur arises from four possible outcomes: low-intensity in both the first and the second periods, low-intensity in the first period and high-intensity in the second period, high-intensity in the first period and low-intensity in the second period, high-intensity in both periods.

The IC constraints for the type I and type II entrepreneur are:

$$-M_2-R_2 \ \geq \ -M_1-R_1-(1-\alpha)V, \tag{A21}$$

$$\alpha(kx+k^2x-R_1)+(1-\alpha)(lkx+lk^2x-R_1) \ \geq \ 2y, \tag{A22}$$

$$\begin{aligned} &\textit{L.H.S.} \text{ of (A19)} \ \geq \ \alpha^2U(F_1-M_2+2y)+(1-\alpha)\alpha U(F_2-M_2+2y) \\ &+ \ (1-\alpha)U(F_3-M_2+2y)+(1-\alpha)^2U(F_4-M_2+2y), \end{aligned} \tag{A23}$$

$$\alpha U(kx + k^2x - R_2) + (1-\alpha)U(lkx + lk^2x - R_2) \ \leq \ 2y \tag{A24}$$

The IC constraint for the type B manufacturer is:

$$(1-\phi)M_2 + \phi[M_1 + (1-\alpha)V] + \beta fkx \ \leq \ S. \tag{A25}$$

The type B manufacturer maximizes S facing the following IC and IR constraint:

$$fx + fkx - S \ \geq \ 2y, \tag{A26}$$

$$(1-\phi)(M_2 + R_2) + \phi[M_1 + R_1 + (1-\alpha)V] - \phi m \ \leq \ S. \tag{A27}$$

Constraint (A17) and (A22) are satisfied automatically. (A18), (A25) and (A26) hold equality. So does (A20) when $\alpha \geq \frac{1}{2}$. Thus $R_2 \geq R_1$ and $M_1 + (1-\alpha)R_1 \geq M_2$.

Constraint (A19) is satisfied as well if $x > fx + fkx$ since (from (A23) and (A25)):

$$\begin{aligned} L.H.S. \text{ of (A19)} \ &\geq \ \alpha U(x - M_2 + 2y) + (1-\alpha)U(lx - M_2 + 2y) \\ &\geq \ U(x - M_2 + 2y) \ \geq \ U(x - S + 2y) \ > \ U(3y). \end{aligned} \tag{A28}$$

Finally the equilibrium contract prices are $S = fx + fkx - 2y$, $R_2 = \alpha(kx + k^2x) + (1-\alpha)(lkx + lk^2x) - 2y$, R_1 solves $\alpha U(kx + k^2x - R_1) + (1-\alpha)U(lkx + lk^2x - R_1) = U(2y)$, and $\{M_1, M_2, V\}$ satisfies:

$$\begin{aligned} (1-\phi)M_2 + \phi[M_1 + (1-\alpha)V] &= fx + fkx - 2y - \beta fkx, \\ M_1 + (1-\alpha)V - M_2 \ &\geq \ R_2 - R_1 \text{ and constraint (A23).} \end{aligned} \tag{A29}$$

When $m \leq m_2 = \frac{1}{\phi}[(1-\phi)R_2 + \phi R_1 - \beta fkx]$, (A27) is satisfied. ■

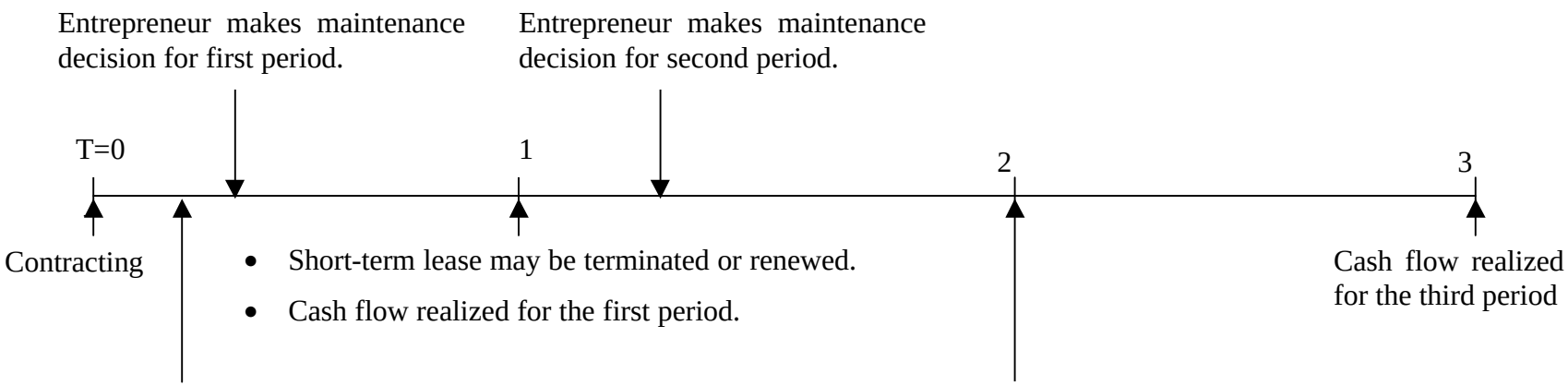

Figure 1: Timeline