# Does the eye of the master make the horse fat? Maintenance of collateral and asset care under purchase and leasing contracts

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**Abstract**

The paper presents a theory of leasing in which asset *use and maintenance* shape the firm's decision between purchasing or leasing productive assets. When the asset purchase is financed through a secured debt contract and the value of the asset is sensitive to the user's uncontractible maintenance decision, maintenance may be privately unprofitable for the user and cause asset depletion. This jeopardises the return to the financiers and erodes the benefit of collateral pledging, particularly relevant for financially constrained firms. Operating leasing allows to overcome such shortcoming, as the maintenance is delegated to the lessor. However, delegation generates a novel moral hazard problem on the lessee, who, by not paying for maintenance, does not internalise the use incentive and may practice inefficiently low levels of care and asset abuse. The paper characterises circumstances in which it may be optimal to lease rather than buy and rationalises some observed features of leasing contracts.

**Keywords**: Collateral, Financial constraints, Leasing, Maintenance

**JEL classification**: D82, G32

# 1 Introduction

Over the past decade or more, there has been a clear trend among many construction and engineering companies worldwide to rent,[1] rather than buy, major items of equipment for the worksite. This trend is common across all firm sizes, but is especially relevant for SME's. According to a recent survey on the use of leasing amongst European SMEs conducted in 2013 by Leaseurope (2015), 42.5% of the SME's use leasing in 2013, up from 40.3% in 2010, and this proportion is estimated to have risen further to 50.7% in 2014.

Beyond the traditional tax and accounting benefits, many reasons can make cost-efficient renting vs. buying. In this paper we argue that a role in such decision may be played by the incentive problems related to asset use and maintenance. In particular, by buying an asset, a firm not only obtains the right to the use of the same, but can also use it as (inside) collateral. However, pledging the purchased assets to financiers may fail to increase the firm's debt capacity when the second hand asset value is uncertain due to agency problems. Among the factors that affect the asset's residual value, there is the level of maintenance to perform on it (Igawa and Kanatas, 1990). When this cannot be carefully specified as part of the loan agreement, because costly, its level may be privately unprofitable for the user/owner, and jeopardize the return to the financiers in case of default, thus eroding the benefit of collateral pledging. Operating leasing (renting) allows to overcome such shortcoming, as the maintenance is delegated to the lessor, who, by performing preventative maintenance, maintains equipment to manufacturer standards and preserves the asset value.

However, a closer look shows that leasing does not allow to fully overcome the incentive

[1]We will throughout the paper refer to renting or operating leasing as synonyms, although there are differences between them related, for example, to the duration of the contract, the accounting treatment, the redemption option. We abstract however from these features in the paper.

problems related to the maintenance of an asset. Indeed, by not paying for maintenance, the lessee does not internalize the use incentive and may practice inefficiently low levels of care, causing asset depletion. Thus, while leasing preserves the maintenance incentives, it cannot control the "caring" incentive, where by caring incentive we denote all the unverifiable activities or actions that the *user* of an asset exerts in the management of the same and that affect the asset value. The paper aims to identify whether and how the incentive problems related to asset use and maintenance shape the firm's decision between purchasing and/or leasing/renting productive assets.

To this aim, we propose a one-period model in which a firm with an investment project but insufficient resources relies on bank lending to carry it out. The project uses one capital input that can be purchased or leased/rented. The capital input is redeployable, but depreciates in production. The degree of depreciation depends on the intensity of usage in the production process, which in turn depends on the demand conditions, and on the maintenance and care exerted in managing it. When the user of the asset also owns it, maintenance is carried out in house, and is non-contractible. When the asset is leased, maintenance is delegated to the lessor.

The cost of maintenance of the capital good depends on the intensity with which it is used in the production process, which in turn depends on the level of demand. In periods of low demand, the intensity of usage of the capital good is limited (soft usage) and a minimum level of maintenance is required to preserve it to a normal wear-and-tear value (this can be interpreted as the value at which the lessor expects the asset to come back upon expiration of the rental contract when the entrepreneur has managed it with the due diligence). In periods of high demand, the intensity of usage of the capital good is high (hard usage) and more maintenance is required to restore the capital good to its wear and tear value. If maintenance is not carried out at all, irrespective of the level of demand, the good depreciates at a faster pace and has a lower liquidation value.

We assume that the return from maintenance is higher than the cost of maintenance, i.e., the extra value of the capital good that can be ascribed to the maintenance activity is larger than the maintenance cost. This implies that it is always optimal to carry out maintenance.

As regards care, unlike maintenance, it cannot be delegated and is always chosen by the entrepreneur in managing the capital good. Its level is unobservable to third parties and has a fixed non-monetary cost.

Entrepreneurs are opportunistic in that they can exert a suboptimal level of care and, if owners of the capital good, a suboptimal level of maintenance. This may result in credit rationing and underinvestment. In particular, when the entrepreneur has got sufficient resources to finance the project, she can carry out the desired investment and has the right to the returns from production plus the asset residual value in any state of nature. Having the full right to the asset's residual value allows the entrepreneur to internalize maintenance incentives. When her wealth is lower, she has to rely on an external financier to carry out the desired investment. To repay the loan, as well as cash flows, she has to pledge the asset. Having to part with it, the entrepreneur maintenance benefits are lower and a commitment problem arises as she cannot be trusted that she will carry out the due maintenance, jeopardizing the lender's returns. To preserve the maintenance incentive, investment has to be displaced from its first-best level. For decreasing levels of internal wealth, investment has to be further displaced to provide the maintenance incentives. This may become so costly in terms of lost production that it is preferable to stop carrying out the maintenance on the capital good, with a subsequent efficiency loss.

One way out to restore maintenance incentives and avoid underinvestment and capital depletion is to rely on a leasing contract. With such a contract, maintenance is delegated to the lessor, who, being the unconditional owner of the capital good, has the incentive to carry it out. Thus, delegation of maintenance to the lessor mitigates borrowers' opportunism and relaxes firms' financial constraints.

However, this only partly solves the problem as, despite not having the ownership, the lessee still keeps control of the asset, and can exert a suboptimal level of (unobservable) care in managing it. Thus, while the maintenance incentive is controlled by delegating it to the lessor, the caring incentive cannot be controlled. This increases the rental fee, determining a downward distortion in the level of investment. It turns out that the optimality of the leasing contract relative to a purchase contract depends on the severity of each of the aforementioned incentive problems.

The rationales for purchasing/leasing highlighted in our paper are related to some of the reasons firms generally invoke to motivate their reliance on leasing. According to a survey by Leaseurope (2015), one important reason to use leasing is the ability to use assets without bearing the risks of ownership, like the risks on second hand value. This is precisely the prediction we get from our model. When an asset's value is sensitive to the maintenance decision, the risk on its second hand value is high and purchase with a collateralised credit contract may not be a viable option. This problem may be especially severe when the firm is financially constrained and unable to provide further collateral. This is in line with another motivation firms often provide for their reliance on leasing, i.e., the ability to finance up to 100% of the asset purchase price without having to provide guarantees or collateral

(Leaseurope, 2015). In such circumstances, being unable to provide credible (inside and outside) collateral, it is more likely that the asset will be leased, and the maintenance delegated to the lessor.[2] This may in turn explain the commonly observed practices of bundling finance with optional services, e.g., installation, insurance, maintenance and repair of the leased asset, one further motivation for leasing (Leaseurope, 2015).[3]

The remainder of the paper is organized as follows. In Section 2 we present a brief sketch of the literature. In Section 3, we introduce the model. In Section 4, we describe the care and maintenance decision and present the first-best contract under buying. In Section 5, we consider the effects on the maintenance and care decision of the firm having financial constraints. In Section 6 we introduce the possibility for firms to lease rather than buy capital inputs. In Section 7 we compare the two scenarios, while in Section 8 we conclude.

# 2 Related literature

The paper is related to two strands of the literature. On one side there is the literature on collateral pledging and the costs related to it. On the other side the literature on moral hazard problems in leasing contracts.

As regards the first, the literature on credit rationing has generally emphasized possible transaction costs attached to collateralisation, such as the lower value that assets may have for lenders than for the borrower (Bester (1985, 1987), Besanko and Thakor (1987), Chan and Kanatas (1985)). In our work, we assume away differences between lenders and borrower in the valuation of the assets, but introduce another reason for the existence of

[2]This argument is different from the one provided by Smith and Wakeman (1985).

[3]Other reasons provided by firms for relying on leasing include the lower price of financing the asset relative to other forms of financing, the better cash flow management, the ability to adapt the contract terms to the company's needs, the predictability and transparency of lease payments or the ability to upgrade and renew assets more frequently than purchasing allows.

a deadweight loss attached to collateralization, namely, a moral hazard problem in the maintenance of the pledged asset. In particular, when it cannot be specified as part of the loan agreement, maintenance can be privately unprofitable for the borrower. This kind of cost attached to collateralisation has been analyzed by Igawa and Kanatas (1990), who show that, when maintenance is costly observable, collateral may fail to play its typical sorting role in asymmetrically informed environments.[4]

Despite the modelling analogy stemming from the incentive problem related to the maintenance of collateral, there are many differences relative to our work. First, while in our paper the firm needs funding to buy the productive asset and uses both cash flows and the asset residual value to repay the loan, in Igawa and Kanatas (1990) the firm already owns the productive asset and pledges it to the lenders to mitigate the asymmetric information problem. Thus, in our setting the firm pledges inside collateral rather than outside collateral.

Another difference between the two papers concerns the sources of asymmetric information. In Igawa and Kanatas, the firm profitability is private information, and the moral hazard in the maintenance of the asset prevents sorting of types. A similar moral hazard problem is present in our paper, but there is no adverse selection. The relevance of the moral hazard problem in maintenance in our setting stems from the cost of capital being large relative to the firm's expected cash flows, which makes maintenance privately unprofitable for the owner. This problem can be overcome by leasing the asset and delegating maintenance to the lessor, who, being the owner of the asset, has the incentive to preserve it to its highest value. However, this delegation can generate a novel moral hazard problem on the lessee,

[4] In particular, firms with privately known success probability own a productive asset and need a fixed size loan to finance a project. They can apply for a secured loand by pledging the asset, for an unsecured loan, or they can self-finance by selling the asset to subsequently rent it. The authors show that high quality firms choose secured contracts, low quality firms choose unsecured contracts and intermediate quality firms choose to self-finance with rental contracts.

who, by not paying for maintenance, does not internalize the use incentive and may practice inefficiently low levels of care in the management of the asset, thereby affecting its residual value and causing the asset depletion.

The distinction between care and maintenance allows us to relate our work also to the literature on moral hazard problems in leasing contracts. This has emphasized the agency problems that arise in the use of an asset when the owner does not coincide with the user. The latter, not having the right to the asset's residual value, has less incentive to care for it (Smith and Wakeman, 1985). This problem has been modelled by Eisfeldt and Rampini (2009), who construct a model in which leasing emerges from the trade-off between the lessor's better ability relative to a secured lender to repossess the asset and the incentive problem generating from the separation between ownership and control.[5][6] The actual existence of a moral hazard problem in leasing contracts has been empirically documented by Schneider (2010) who examines the driving outcomes of long-term lessees and owner-operators of taxis in New York, finding that moral hazard explains a consistent fraction of lessees' accidents, driving violations, and vehicle inspection failures.

Besides this literature, many other contributions have suggested alternative explanations for leasing. In addition to the traditional tax-related incentives to lease or buy (Miller and Upton, 1976; Myers, Dill and Bautista, 1976; Franks and Hodges, 1987), several other factors affect the leasing versus buying decision. Asset characteristics, for example, are important determinants of the leasing versus buy decisions. In particular, leasing is more attractive for

[5] This allows the lessor to extend more credit to a financially constrained firm relative to the case where he makes a loan to the firm and increases the debt capacity of leasing relative to secured lending. The empirical predictions of the model are tested, finding that more financially constrained firms lease more of their capital than less constrained firms do (for similar results, see also Krishnan and Moyer (1994), Sharpe and Nguyen (1995)).

[6] Related to the repossession advantage, Gavazza (2011) explores another possible rationale for leasing arising from the lessors transaction cost advantage in redeploying capital.

more liquid and less specific assets, which are more easily redeployable (Klein, Crawford, and Alchian, 1978). Empirical evidence consistent with this is found by Gavazza (2010). Hendel and Lizzeri (2002) and Johnson and Waldman (2003) develop a theoretical analysis of leasing contract in which leasing in the new-car market emerges as a response to the adverse-selection problem in the used-car market.

# 3 The model assumptions

A risk-neutral entrepreneur has an investment project that uses a capital input ($K$). The invested input is converted into a verifiable state-contingent output, $Y \in \{0, y\}$ . Uncertainty affects production through demand (i.e., production is demand-driven). Demand can be high, with probability $p$, or low, with probability $1 - p$. Following a period of high demand, the invested input generates output $Y = y$ according to a strictly concave production function, $y = Af(K)$, with $A > 0$ and $f'(K) \geq 0$ for all $K \geq 0$. Following a period of low demand, the invested input generates zero output $Y = 0$. The characteristics of the technology are common knowledge. The entrepreneur is a price-taker both in the input and in the output markets. The output price is normalized to one, and so is the price of the input.[7]

The entrepreneur has a level of wealth $W$ and has access to external funding $L \geq 0$ from competitive investors to buy or lease the capital inputs $K$ necessary for production. Lending is exclusive, that is, the entrepreneur cannot borrow from multiple investors. Investors and leasing firms play different roles. Investors lend cash that is used by the entrepreneur to buy the capital input. The leasing firm buys the capital input and leases it in exchange for a rental fee $F$ paid upfront. In exchange for the loan $L$, investors receive a repayment $R < Af(K)$

[7]This normalization is without loss of generality because we use a partial equilibrium setting.

in case of success. In case of failure, because output is zero, by limited liability they receive zero.

Investors have an intermediation advantage relative to leasing firms: lower cost of raising funds on the market, $r < r^R$. This assumption is consistent with the investors playing the role of specialized financial intermediaries. Each party is protected by limited liability.

Capital inputs are redeployable. In case in which they are purchased, they can be pledged as collateral to creditors in case of default. Unlike Eisfeldt and Rampini (2009), we assume that pledging collateral is costless and there is no loss in the scrap value of capital due to the transfer from the entrepreneur to the creditors. In case in which capital inputs are leased, they are always repossessed by the lessor upon usage. We assume that the scrap value of capital when repossessed by the lessor cannot be lower than when repossessed by the creditors.

The degree of redeployability of capital inputs is uncertain and is affected by their liquidity and by the intensity with which they have been used in the production process. The input residual value depends on the input depreciation rate. This is partly exogenous and partly endogenous. We denote with $\overline{\delta}$ the exogenous part of the depreciation rate. The endogenous part of the depreciation rate depends only on the level of maintenance that is carried out by the owner of the capital good. This is unobservable by third parties and is denoted by $\mu \in [0, \overline{\mu}]$, with $\overline{\mu} < \overline{\delta}$, and plays the role of slowing down the exogenous depreciation rate. The input liquidity, that we denote with $\gamma \in (0, 1]$, depends on the its exogenous characteristics. More specific inputs tailored to the user's needs are less liquid and cannot be easily resold in the secondary market. Less specific inputs, whose purpose is more general, are more liquid and can be resold at near the purchase price. Thus, the scrap value of capital is $(1 - \delta + \overline{\mu})\,\gamma K$.

Maintenance is carried out by the party who owns the capital good and has both a pecuniary and non-pecuniary cost. The non-pecuniary cost is constant and equal to $\eta > 0$. The pecuniary cost depends on the level of demand. When this is high, inputs are intensively used in the production process and this further depletes the capital good. In this case, the cost of maintenance depends on the level maintenance, $\mu$, on the level of capital input invested, $K$, and on the care, $a \in \{a_0, a_1\}$, deployed by the user in the management of the capital good . In particular, under low care $(a = a_0)$, the pecuniary cost of maintenance is described by the function $m(\mu) K$, with $m'(\mu) > 0$, $m''(\mu) > 0$ and $m(0) = m'(0) = 0$, and $m'(\overline{\mu}) = 1$, while, under high care $(a = a_1)$, the pecuniary cost of maintenance is equal to $\beta m(\mu) K$, with $\beta = \beta_1 < 1$ with probability $q$, and $\beta = 1$ with probability $1 - q$.

The care to exert in the management of the asset is always chosen by the entrepreneur and has a non-pecuniary cost, $\phi > 0$. It is unobservable, in the sense that, upon observing a high maintenance cost, $m(\mu) K$, it is not possible to say with certainty whether it is due to carelessness.

The sequence of events is as follows.

At $t = 0$, the entrepreneur makes contract offers to competitive banks/rental firms specifying the size of the loans, $L$, the repayment obligations, $R$, the amount of capital input to be purchased/rented, $K$. If they accept, at $t = 1$, uncertainty resolves and production takes place. At $t = 2$, the care decision, if any, is taken. If the demand is high, the capital good is intensively used in the production process and the entrepreneur has to decide the care to undertake in managing it. If the demand is low, there is no care decision to take since the use of the good is limited. At $t = 3$, the party who owns the good has to decide the level of maintenance. Under buying, the care and maintenance decision are simultaneously taken by the entrepreneur. Under renting, the entrepreneur takes the care decision and, without observing it, the rental firm takes the maintenance decision. At $t = 4$, repayments are made.

# 4 The benchmark

In this section, we establish the benchmark outcome to evaluate the efficiency of various equilibria that we characterize in the following sections. We will refer to this as the first-best outcome. We define the first-best as the situation where there is symmetric information, maintenance and care are both observable and verifiable by a third party and can be included in an enforceable contract. In this setting, the entrepreneur can costlessly finance the investment that maximizes the firm's value. Moreover, because of the bank's intermediation advantage relative to leasing firms ($r^R > r$), she always prefers to borrow on the market to buy the capital good and never lease it. Finally, in each state of the world maintenance and care are set to the level which produces the largest residual asset value net of maintenance and care costs. To characterize the first-best equilibrium, we proceed by backward induction. We first define the optimal care and maintenance decisions for any level of capital, then we determine the first-best outcome.

## 4.1 The optimal care and maintenance decision

The entrepreneur needs a capital input to carry out production. The value of the input is not exhausted in the production process but can be partly preserved depending on the intensity with which it is used in production, i.e., the level of demand, and the levels of maintenance and care.

The value of maintenance is given by the difference between its benefit and the costs. It depends on the state of the world, on the level of capital good and, eventually, on the care exerted in the management of the capital good.

In the bad state of the world, the capital usage is soft because the demand in the product market is low, no care is required, and maintenance has zero monetary cost. Since the benefit from maintenance is $\mu\gamma K$, which is increasing in $\mu$, while its non pecuniary cost is constant and equal to $\eta$, the first-best level of maintenance is $\mu_L = \overline{\mu}$ for all $K \geq \frac{\eta}{\overline{\mu}\gamma}$ and $\mu_L = 0$ otherwise.

In the good state of the world, the capital usage is hard because the demand in the product market is high and care becomes relevant in determining the total cost of maintenance. In particular, it is $\overline{\beta}m(\mu)K+\eta$, with $\overline{\beta} = 1-q(1-\beta_1) < 1$, under high care, and $m(\mu)K+\eta$ under low care. Since the monetary cost of maintenance depends on the level of care, it follows that the first-best maintenance is affected by the care decision. If high care is performed, the value of maintenance is $\mu\gamma K - \overline{\beta}m(\mu)K - \eta$, while, if low care is performed, it is $\mu\gamma K - m(\mu)K - \eta$. Denote by $\mu_1$ and $\mu_0$ the levels of $\mu$ that maximize the maintenance value when $\eta = 0$, given high and low care, respectively.[8] Since $m(\mu)$ is convex and $\overline{\beta} < 1$, then $\mu_1 > \mu_0$ and $\mu_1\gamma - \overline{\beta}m(\mu_1) > \mu_0\gamma - m(\mu_0)$. Thus, in our setting, maintenance and care are complements and the best combination of care and maintenance in the good state of the world would be $a = a_1$ and $\mu_H = \mu_1$ in the absence of fixed non-pecuniary costs. However, because of the fixed non pecuniary costs $\phi$ and $\eta$, a different combination of care and maintenance could be preferred if the investment level is low. More precisely, for $a = a_1$ and $\mu_H = \mu_1$ to be the first-best care and maintenance combination under high demand in the product market, the maintenance value has to satisfy two conditions. It has to be greater than the cost of care, $\phi$, and greater than the maintenance value given $a = a_0$ and $\mu_H = \mu_0$. The first condition requires $K \geq \frac{\phi+\eta}{\mu_1\gamma - \overline{\beta}m(\mu_1)}$, and the second condition requires $K \geq \frac{\phi}{\Delta\mu\gamma + q(1-\beta_1)m(\mu_1) - (m(\mu_1)-m(\mu_0))}$.

[8] $\mu_1$ is such that $\overline{\beta}m'(\mu_1) = \gamma$ and $\mu_0$ is such that $m'(\mu_o) = \gamma$.

Let be $\underline{K} \equiv \max\{\frac{\phi+\eta}{\mu_1\gamma-\overline{\beta}m(\mu_1)}, \frac{\phi}{\Delta\mu\gamma+q(1-\beta_1)m(\mu_1)-(m(\mu_1)-m(\mu_0))}\}$. The following proposition holds.

**Proposition 1** *For any level of capital $K \geq \underline{K}$, the optimal choice of care and maintenance upon high demand in the product market is $a = a_1$ and $\mu_H = \mu_1$, and the optimal choice of maintenance upon low demand in the product market is $\mu_L = \overline{\mu}$.*

Proposition 1 implies that if the non-pecuniary costs of care and maintenance are sufficiently small with respect to the investment in capital good, then the optimal care and maintenance choice entails $a = a_1$, $\mu_H = \mu_1$, and $\mu_L = \overline{\mu}$.

## 4.2 The first-best outcome

The first-best outcome will vary depending on the maintenance and care costs.

By assuming that both maintenance and care are enforceable, the entrepreneur can implement the level of investment that maximizes her expected payoff, conditional on any maintenance and choice. Under low care and maintenance equal to $\mu_0$ in the case of high demand in the product market, and high maintenance in the case of low demand, the entrepreneur's expected payoff is

$$\Pi_{\mu_0\overline{\mu}}(K) = pAf(K) - [r - (1 - \overline{\delta} + \mu_0 + (1-p)(\overline{\mu} - \mu_0))\gamma + p\,m(\mu_0)]K - \eta$$

Denote by $K_{\mu_0\overline{\mu}}$ the level of capital input that maximizes $\Pi_{\mu_0\overline{\mu}}(K)$. If strictly positive, $K_{\mu_0\overline{\mu}}$ solves the following first-order condition:

$$pAf'(K) = r - (1 - \overline{\delta} + \mu_0 + (1-p)(\overline{\mu} - \mu_0))\gamma + p\,m(\mu_0). \quad (1)$$

As discussed in the previous section, maintenance is Pareto improving with respect to no maintenance at all only if its cost is not too high. This situation, for the case of strong capital usage without care is characterized in the following proposition.

**Proposition 2** *When the capital usage is strong, maintenance is valuable regardless of care if and only if* $\eta \leq \overline{\eta}$.

Under high care and maintenance equal to $\mu_1$ in the case of high demand in the product market, and high maintenance in the case of low demand, the entrepreneur's expected payoff is

$$\Pi_{\mu_1\overline{\mu}}(K) = pAf(K) - [r - (1 - \overline{\delta} + \mu_1 + (1-p)(\overline{\mu} - \mu_1))\gamma + p\overline{\beta}m(\mu_1)]K - \eta - p\phi$$

Denote by $K_{\mu_1\overline{\mu}}$ the level of capital input that maximizes $\Pi_{\mu_1\overline{\mu}}(K)$. If strictly positive, $K_{\mu_1\overline{\mu}}$ solves the following first-order condition:

$$pAf'(K) = r - [1 - \overline{\delta} + \mu_1 + (1-p)(\overline{\mu} - \mu_1)]\gamma + p\overline{\beta}m(\mu_1). \tag{2}$$

Proposition 1 suggests that if larger than $\underline{K}$, $K_{\mu_1\overline{\mu}}$ is the first-best investment. In the following proposition we characterize the first-best outcome for various values of $\phi$, under the assumption that when the capital usage is strong, maintenance is valuable regardless of care.

**Proposition 3** *Assume* $\eta \leq \overline{\eta}$. *If* $\phi \leq \overline{\phi}$, *the first-best outcome involves an investment in capital good equal to* $K_{\mu_1\overline{\mu}}$, *with the entrepreneur performing high care and maintenance equal to* $\mu_1$ *in the case of high product market demand and maintenance equal to* $\overline{\mu}$ *otherwise. If* $\phi > \overline{\phi}$, *the first-best outcome involves an investment in capital good equal to* $K_{\mu_0\overline{\mu}}$, *with the entrepreneur performing low care and maintenance equal to* $\mu_0$ *in the case of high product market demand and maintenance equal to* $\overline{\mu}$ *otherwise.*

To make the analysis interesting, we restrict attention to investment projects with $\phi$ and $\eta$ small and high care an maintenance welfare improving. Formally,

**Assumption 1** $\eta \leq \overline{\eta}$ *and* $\phi \leq \overline{\phi}$.

Assumption 1 guarantees that $K_{\mu_1 \overline{\mu}}$ exceeds $\underline{K}$ and is the first-best investment.

# 5 Buying for a financially constrained entrepreneur

In this section we analyse a situation where to carry out the project, the entrepreneur uses internal wealth ($W$) and external funding from competitive banks ($L$). We characterize the equilibrium outcome under the assumption that care and maintenance are not contractible.

From the previous section, we know that if $\eta \leq \overline{\eta}$ and $\phi \leq \overline{\phi}$, the first-best outcome involves high care and maintenance equal to $\mu_1$ when the capital usage is strong, and the highest level of maintenance when the capital usage is soft. However, if maintenance is not enforceable, a financially constrained entrepreneur could prefer to do not perform maintenance upon low demand in the product market. The intuition is as follows. When the cash flows fall short of the loan size, the entrepreneur must pledge part of the capital value to banks in case of default. This lowers the maintenance benefits and introduces an agency problem. Indeed, anticipating that she might not repossess (all) the capital input in default, the entrepreneur might choose to do not carry out the maintenance at the expense of the banks. In particular, in the limit case of zero initial wealth, banks expect the total residual value of capital input to be pledged as collateral if the cash flows of the project are small with respect to the required loan. In this situation, not benefiting from maintenance, the entrepreneur prefers to give it up because of non-pecuniary costs. Also in the more general case of strictly positive initial wealth, it is difficult to induce maintenance, given that a financially constrained firm repossesses only a fraction of the capital good.

The entrepreneur-bank contract specifies: $\{L; R; \lambda\}$, where $L$ is the loan, $R$ is the repayment obligation in case of success,[9] and $\lambda$ is the share of the scrap value of capital offered as collateral in case of default.

Under the assumption that it is not too costly to implement maintenance in the case of failure, the entrepreneur's optimization problem is defined by programme $\mathcal{P}_{\mathcal{B}1}$:

$$\max_{K,L,R,\lambda} pA(f(K)-R)+p((1-\overline{\delta}+\mu_1)\gamma-\overline{\beta}m(\mu_1))K+(1-p)(1-\lambda)(1-\overline{\delta}+\overline{\mu})\gamma K-\eta-p\phi+Wr$$

subject to

$$pR+(1-p)\lambda(1-\overline{\delta}+\overline{\mu})\gamma K-Lr\geq 0, \tag{3}$$

$$K\geq \underline{K}, \tag{4}$$

$$(1-\lambda)\overline{\mu}\gamma K\geq \eta, \tag{5}$$

$$Af(K)-\overline{\beta}m(\mu_1)K\geq R \tag{6}$$

$$\lambda\in[0,1], \tag{7}$$

$$L+W\geq K. \tag{8}$$

where condition (3) is the participation constraint requiring that investors get non-negative returns. Competition in banking implies that it is binding. If not, it would be possible to lower $R$, and increase the entrepreneur's profits. Constraints (4) and (5) are the incentive compatibility conditions preventing the entrepreneur from performing a suboptimal combination of care and maintenance in the good state and zero maintenance in the bad state, respectively. Conditions (6) and (7) are the limited liability constraints stating that the payment upon success cannot exceed the cash flows and the collateral upon failure cannot exceed the residual capital value, respectively. Condition (8) is the resource constraint ensuring

[9]Because cash flows are zero in the bad state, limited liability implies that the repayment to banks in this state s zero.

that the investment does not exceed available funds. To avoid multiple solutions, we assume that the entrepreneur pledges as little collateral as possible, in line with the idea that capital is more valuable in the hands of the entrepreneur.

Next proposition defines the condition for the first-best investment to be achieved even when care and maintenance are not contractible, and characterizes the first-best secured debt contract.

**Proposition 4** *The first-best investment, $K_{\mu_1\overline{\mu}}$, solves program $\mathcal{P}_{\mathcal{B}1}$ if and only if it satisfies the financing constraint:*

$$p(Af(K) - \overline{\beta}m(\mu_1)K) + (1-p)(1-\overline{\delta}+\overline{\mu})\frac{\overline{\mu}\gamma K - \eta}{\overline{\mu}} \geq (K-W)r. \tag{9}$$

*Moreover, at the first-best, the loan size is $L = K_{\mu_1\overline{\mu}} - W$, and the repayment and the fraction of residual capital pledged to investors are $R = \frac{r(K_{\mu_1\overline{\mu}}-W)}{p}$ and $\lambda = 0$ if $p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}) \geq r(K_{\mu_1\overline{\mu}} - W)$, and $R = Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}$ and $\lambda = \frac{r(K_{\mu_1\overline{\mu}}-W)-p(Af(K_{\mu_1\overline{\mu}})-\overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}})}{(1-p)(1-\overline{\delta}+\overline{\mu})\gamma K_{\mu_1\overline{\mu}}}$ otherwise.*

**Corollary 1** *For any fixed level of first-best expected firms value $\Pi^*_{\mu_1\overline{\mu}} > 0$, the financing constraint (9) becomes more severe for firms with investment projects characterized by lower cash flows and higher residual value of capital assets.*

Proposition 4 states that to be implementable the investment in capital good has to satisfy the financing constraint (9). It requires that the expected value of the highest incentive compatible pledgeable capital asset, $(1-p)(1-\overline{\delta}+\overline{\mu})\frac{\overline{\mu}\gamma K-\eta}{\overline{\mu}}$ is higher than the difference between the loan value, $(K-W)r$, and the expected cash flows net of monetary maintenance costs, $p(Af(K) - \overline{\beta}m(\mu_1)K)$. If $K_{\mu_1\overline{\mu}}$ satisfies the financial constraint, then the first best outcome can be costlessly implemented. In this case, the optimal entrepreneur-bank contract is described by Proposition 4 and entails a strictly positive collateral if cash flows are too low to repay all the debt in the good state. If, instead, $K_{\mu_1\overline{\mu}}$ does not satisfy constraint (9), then at the first-best investment level the entrepreneur has no incentive to do maintenance in the event of failure since the benefit from doing it is too small with respect to its cost, and an agency problem emerges.

Corollary 1 stresses that the agency problem is relevant only for projects whose expected cash flows are tiny and that employ in the production process only a small part of inputs, so that the residual value of capital is high. The intuition is as follows. The expected firm's value consists of two parts: the expected cash flows generated by the production process, $pAf(K)$, and the expected residual capital value, $(1 - \overline{\delta} + \mu_1 + (1 - p)(\overline{\mu} - \mu_1))\gamma K$. The higher the weight of the cash flows compared to that of the residual capital value, the more liquid a firm is. Let consider two firms, firm 1 and firm 2, with the same first-best expected value and a different degree of liquidity. More precisely, suppose that firm 1 is characterized by greater capital productivity, $A$, and greater capital depreciation rate, $\overline{\delta}$, than firm 2. Then, it is more difficult to implement the first-best investment for firm 2 than for firm 1. More in general, we can conclude that, regardless of the expected firm's value, the cash flows have to be large enough relative to the residual value of capital for the financing condition (9) to be satisfied.

## 5.1 Scenario 1: high maintenance and underinvestment

In the first scenario, to make worthwhile for the entrepreneur to do maintenance, the investment in the capital good has to be reduced sufficiently so that the financing condition (9) is satisfied. This is equivalent to choosing the level of capital inputs, $K(W)$, such that constraint (9) is binding. In this case, the loan size would be $L_1(W) \equiv K(W) - W$, the repayment $R_1(W) \equiv f(K(W)) - \overline{\beta} m(\mu_1) K(W)$, and the fraction of residual capital pledged to investors $\lambda_1(W) \equiv 1 - \frac{\eta}{\overline{\mu}\gamma K(W)}$.

## 5.2 Scenario 2: no maintenance upon low demand in the product market

In the second scenario, no maintenance is induced upon low demand, and the optimal capital, $K$, loan size, $L$, repayment, $R$, and fraction of the capital residual value that goes to the lender event of default, $\lambda$, solve the following maximization problem, $\mathcal{P}_{\mathcal{B}2}$:

$$\max_{K,L,R,\lambda} p(Af(K) - R) + p((1 - \overline{\delta} + \mu_1)\gamma - \overline{\beta} m(\mu_1))K + (1 - p)(1 - \lambda)(1 - \overline{\delta})\gamma K - p(\eta + \phi) + Wr$$

under the constraint that investors get non-negative returns

$$pR + (1 - p)\lambda(1 - \overline{\delta})\gamma K - Lr \geq 0, \tag{10}$$

the incentive constraint (4), the limited liability constraints (6) and (7), and the resource constraint (8).

Denote by $K_{\mu_1 \varnothing}$ the investment level maximizing the entrepreneur's expected payoff under zero maintenance in the case of low demand. Next proposition characterizes the solution of the constrained optimization problem, $\mathcal{P}_{\mathcal{B}2}$.

**Proposition 5** *Assume that the marginal productivity of the project is steeply sloped. If $A > A_{\varnothing}$, the investment level solving program $\mathcal{P}_{\mathcal{B}2}$ is $K_{\mu_1 \varnothing} < K_{\mu_1 \overline{\mu}}$, regardless of the entrepreneur's initial wealth. Moreover, the optimal loan size is $L_2(W) \equiv K_{\mu_1 \varnothing} - W$, and the repayment and the fraction of residual capital pledged to investors are $R_2(W)\frac{r(K_{\mu_1 \varnothing} - W)}{p}$ and $\lambda_2(W) = 0$ if $p(f(K_{\mu_1 \varnothing}) - \overline{\beta} m(\mu_1) K_{\mu_1 \varnothing}) \geq r(K_{\mu_1 \varnothing} - W)$, and $R_2(W) = f(K_{\mu_1 \varnothing}) - \overline{\beta} m(\mu_1) K_{\mu_1 \varnothing}$ and $\lambda_2(W) = \frac{r(K_{\mu_1 \varnothing} - W) - p(f(K_{\mu_1 \varnothing}) - \overline{\beta} m(\mu_1) K_{\mu_1 \varnothing})}{(1-p)(1-\overline{\delta})\gamma K_{\mu_1 \varnothing}}$ otherwise.*

Proposition 5 states that if the investment project is characterized by sufficiently liquid assets ($A > A_{\varnothing}$), then the capital level solving problem $\mathcal{P}_{\mathcal{B}2}$ is the investment $K_{\mu_1\varnothing}$ that maximizes the firm's value under the assumption of zero maintenance in the bad state of the world. Notice that the assumption that $A > A_{\varnothing}$ is necessary to ensure that the optimal investment $K_{\mu_1\varnothing}$ is always implementable with a secured debt contract, regardless of the entrepreneur's initial wealth. Indeed, when the project's cash flows are low, the scrap value of capital assets in the event of default may not be enough to cover the outstanding balance on the loan necessary to finance the desired investment $K_{\mu_1\varnothing}$.

In the following, we will derive the entrepreneur's optimal investment and we will show when it is optimal to do maintenance and when it is not.

## 5.3 The equilibrium outcomes

In the previous section we stressed that an agency problem on the entrepreneur emerges if the first-best level of capital, $K_{\mu_1\overline{\mu}}$, does not satisfy the financing constraint (9). Indeed, to undertake the first-best production, the entrepreneur needs an investment $I = K_{\mu_1\overline{\mu}}$. When $W < I$, the loan necessary to carry out the project is $L = K_{\mu_1\overline{\mu}} - W$. If the cash flows in the case of high demand in the product market are too low to repay the debt, then the entrepreneur has to pledge collateral in the event of failure. The first-best residual capital value under low demand is $(1 - \overline{\delta} + \overline{\mu})\gamma K_{\mu_1\overline{\mu}}$. However, the fraction of the residual capital value pledged as collateral cannot exceed $1 - \frac{\eta}{\overline{\mu}\gamma K}$. Otherwise, the entrepreneur would enjoy a benefit from maintenance lower than its non-pecuniary cost and would choose not to do it. This may reduce the borrowing capacity of the entrepreneur and entail underinvestment.

Proposition 4 and Corollary 1 suggest that, depending on the characteristics of the investment project, such as cash flows, riskiness, capital depreciation rate, two extreme situations can arise. One in which the cash flows generated by the project are too low and do not allow to implement the first-best investment, even in the absence of constraints connected with incentives to maintain the capital assets. Another in which the cash flows are sufficiently high compared to the cost of capital to allow even an entrepreneur who has no initial wealth to make the first-best investment without incurring agency costs related to capital maintenance. Those intuitions are developed in the following Lemma.

**Lemma 1** *Assume that the marginal productivity of the project is steeply sloped. When the project's liquidity, $A$, is lower than the threshold $\underline{A}$, with $\underline{A} < A_{\varnothing}$, then if the entrepreneur has zero initial wealth the first-best investment cannot be implemented regardless of the non-monetary maintenance cost, $\eta$. When it is higher than the threshold $\overline{A}$, with $\overline{A} > \underline{A}$, then the first-best investment is costlessly implementable regardless of the entrepreneur's initial wealth.*

Lemma 1 states that if the cash flows generated by the project are too tiny ($A \leq \underline{A}$) and the entrepreneur has zero initial wealth, the financing incentive (9) is never satisfied, even in the absence of non-monetary maintenance cost. Indeed, low project's cash flows imply low repayments to banks in the event of success, since the scrap value of inputs in the good state cannot be used to repay the debt. This problem limits the amount of credit the entrepreneur can obtain from financiers. Moreover, $\underline{A}$ is below $A_{\varnothing}$, that is the lower bound for $A$ such that the level of capital $K_{\mu_1 \varnothing}$ that maximizes the firm's value under the assumption of zero maintenance in the event of default, can be implemented regardless of the entrepreneur's initial wealth (Proposition 5). Finally, Lemma 1 also points up that if liquid assets are high enough ($A \geq \overline{A}$), the financing constraint (9) is always slack and the maintenance incentive constraint (5) never affects investment, even for an entrepreneur with no wealth.

To simplify the analysis and to exclude uninteresting cases, we introduce the following assumption.

**Assumption 2** *The marginal productivity of the project is steeply sloped and* $A \in (A_{\varnothing}, \overline{A})$*.*

If the financing constraint (9) is not satisfied at the first-best investment level, to induce maintenance in the event of failure is costly. In this case, two possible scenarios can arise. In the first scenario, the entrepreneur reduces the need for external funds by downsizing the investment to a level that makes it always worthwhile to do maintenance. In the second scenario, the entrepreneur neglects the incentive constraint and chooses the level of investment that maximizes the firm's value under no maintenance in case of failure. The optimality of inducing maintenance in the bad state of the world or not, depends on the expected firm's value resulting in the two scenarios.

The following propositions and corollary characterize the equilibrium outcome, under Assumptions 1 and 2.

**Proposition 6** *Assume that the marginal productivity of the project is steeply sloped. There exists a critical level of the entrepreneur's initial wealth* $\overline{W} > 0$*, such that the entrepreneur finances the first-best investment,* $K_{\mu_1 \overline{\mu}}$ *and performs the first-best maintenance and care both in the event of success and in the event of default, that is,* $a = a_1$*,* $\mu_H = \mu_1$*, and* $\mu_L = \overline{\mu}$ *if and only if* $W \geq \overline{W}$*.*

**Corollary 2** *For all level of initial wealth* $W < \overline{W}$*, the entrepreneur is credit-constrained.*

**Proposition 7** *Assume that the marginal productivity of the project is steeply sloped. If the fixed maintenance cost* $\eta$ *is low enough then, for all* $W < \overline{W}$*, the entrepreneur invests*

*$K(W) < K_{\mu_1\overline{\mu}}$ and performs the first-best maintenance and care both in the event of success and in the event of default, that is, $a = a_1$, $\mu_H = \mu_1$, and $\mu_L = \overline{\mu}$. For higher values of the fixed maintenance cost $\eta$, there exists a critical level of the entrepreneur's initial wealth $\underline{W} < \overline{W}$, such that (i) for $\underline{W} \leq W < \overline{W}$, the entrepreneur invests $K(W) < K_{\mu_1\overline{\mu}}$, and performs the first-best maintenance and care both in the event of success and in the event of default, that is, $a = a_1$, $\mu_H = \mu_1$, and $\mu_L = \overline{\mu}$, (ii) for $W < \underline{W}$, the entrepreneur is credit-constrained, invests $K_{\mu_1\varnothing} < K_{\mu_1\overline{\mu}}$, and performs the first-best maintenance and care in the event of success, that is $a = a_1$, $\mu_H = \mu_1$, and zero maintenance in the event of default, that is $\mu_L = 0$. Moreover, $K(\underline{W}) < K_{\mu_1\varnothing}$.*

Propositions 6 and 7 state that if the entrepreneur is wealthy enough ($W \geq \overline{W}$), the first-best outcome is implemented at equilibrium. Moreover, in this case, the optimal debt contract is described by Proposition 4. As wealth comes down toward $\overline{W}$, first-best investment cannot be implemented and the entrepreneur is financially constrained. However, if $\eta$ is sufficiently large and $\underline{W} \leq W < \overline{W}$, the entrepreneur performs the first-best maintenance and care both in the event of success and in the event of default, while if $W$ is below $\underline{W}$, then no maintenance is performed in the case of failure.

To conclude, notice that both the decision about the maintenance upon hard capital usage, and the decision about the care to have in managing the asset do not depend on the initial wealth of the entrepreneur. This is because those choices affect the value of the capital good only in case of high demand, when the entrepreneur is the owner of the asset. Hence, the benefits from high care and maintenance are unaffected by the entrepreneur's financial constraints.

# 6 Leasing

In the previous section, we have seen that it may be costly (or too costly) to induce maintenance on the entrepreneur. In the present section we want to investigate whether it is possible to overcome this incentive problem by relying on leasing contracts. In particular, we give the entrepreneur the possibility to lease the capital inputs rather than purchasing them. This allows the contractor to get the right to use the asset, leaving its servicing to the lessor, thereby saving the asset maintenance costs (and the related agency costs). However, as highlighted by Alchian and Demsetz and studied by Eisfeldt and Rampini (2009), the separation between ownership and control introduces another agency problem as the contractor, not being the owner of the capital good, may behave opportunistically and choose a suboptimal level of attention in its management. This in turn affects the liquidation value of the capital good in case of high demand and jeopardizes the return to the lender.

To model the leasing decision, we assume that on the market there exist leasing firms that buy capital goods incurring a financing cost $r^R \geq r$ and rent them to firms upon the payment of a leasing fee $F$. The leasing fee $F$ is paid upfront. If the entrepreneur has no own resources, she has to rely on external financiers. In particular, upon receiving the loan $L$, the firm makes a repayment to investors equal to $R$ in case of high demand or zero in case of low demand. The entrepreneur has to choose the level of attention to exert in the management of the leased good when production is high. We assume that this choice is not observable by the lessor.

In the case of strong capital usage, if it is not possible to induce the entrepreneur to pay attention in managing the capital good, the lessor chooses the optimum level of maintenance conditional on low care, that is, $\mu_H = \mu_0$. Instead, in the case of soft capital usage, no care is required to the entrepreneur, and the level of maintenance chosen by the lessor is set at its first-best level, $\mu_L = \overline{\mu}$. The financial contract sets the level of investment in the capital good $K$, the loan size $L$, the repayment $R$ and leasing fee $F$ to solve the following problem, $\mathcal{P}_{\mathcal{R}}$:

$$\max_{K,L,R,F} p(Af(K) - R)$$

subject to the participation constraints stating that the lessor and the investors make non-negative profits

$$Fr + [(1 - \overline{\delta} + \mu_0 + (1-p)(\overline{\mu} - \mu_0))\gamma - p\, m(\mu_0)]K - Kr^R - \eta \geq 0 \tag{11}$$

$$pR - Lr \geq 0, \tag{12}$$

and to the resource constraint

$$L = F - W.$$

**Proposition 8** *The equilibrium outcome solving program $\mathcal{P}_{\mathcal{R}}$ involves an investment in capital good equal to $K_{\mu_0\overline{\mu}} < K_{\mu_1\overline{\mu}}$ defined by condition (1), with the entrepreneur performing low care and maintenance equal to $\mu_0$ in the case of high product market demand and maintenance equal to $\overline{\mu}$ otherwise. Moreover, the rental fee is $F_R \equiv \frac{[r^R - (1-\overline{\delta}+\mu_0+(1-p)(\overline{\mu}-\mu_0))\gamma + p\, m(\mu_0)]K_{\mu_0\overline{\mu}} + \eta}{r}$, the loan size is $L_R \equiv F_R - W$, and the repayment is $R_R \equiv \frac{r(F_R - W)}{p}$.*

# 7 Leasing versus Buying

In the previous sections, we have seen that the maintenance incentive arising under a purchase contract can be controlled by relying on a leasing contract. However, this delegation does not allow to completely overcome the entrepreneur's moral hazard problem as, despite not having the ownership, the lessee still keeps control of the asset, and can exert a suboptimal level of care in managing it. In this section we want to shed light on the settings where the leasing contract is Pareto improving with respect to the second-best allocation induced by buying from a financially constrained entrepreneur.

With respect to the first-best, renting capital goods leads to a loss due to both the intermediation disadvantage of leasing companies relative to banks ($r^R > r$) and the higher capital depreciation induced by a suboptimal level of care and maintenance. Hence, even in the limit case where $r^R = r$, renting capital goods might not be Pareto improving if the loss associated to the reduced care upon strong capital usage overcomes the loss due to the absence of maintenance upon soft capital usage.[10] However, if the intermediation disadvantage of leasing companies relative to banks is small ($r^R$ close to $r$) and the expected loss due to no care in the good state of the world is lower than the expected loss due to the absence of maintenance in the bad state of the world, the expected firm's value under leasing may overcome the expected firm's value under buying in scenario 2. In this case there would exist a threshold wealth $W^R \in [\underline{W}, \overline{W})$ such that for all $W < W^R$ the leasing contract is Pareto improving with respect to the second-best allocation induced by buying from a financially constrained entrepreneur.

The key mechanism that makes the leasing contract emerge in equilibrium in our setting has to do with the asset value. This is so high relative to the firm's cash flows that, for a sufficiently high loan size, collateral pledging becomes the only way to secure lending. However, when incentive problems related to the maintenance of collateral exist, leasing may be the most

[10] In the scenario where the required capital inputs are below $\underline{K}$ and the first-best levels of care and maintenance are $a = a_0$ and $\mu_H = \mu_0$, the renting loss is only a consequence of the higher cost of raising funds on the market of rental firms. Then, if $r^R$ and $r$ are close enough, a financially constrained entrepreneur would prefer to lease capital inputs rather than buy them.

efficient way to get hold of these assets and overcome the credit rationing problem. Assets with such characteristics are typically those whose physical life exceeds the firm's economic life. This may explain why precisely these kinds of assets are more predisposed to being leased rather than being purchased.

These considerations allow us to formulate the following theoretical predictions.

**Prediction 1.** *Assets whose value is sensitive to maintenance are more likely to be leased than purchased.*

**Prediction 2.** *firms using the same type of assets are more likely to lease the more financially constrained they are.*

**Prediction 3.** *Firms with investment projects characterized by less liquid assets (lower cash flows and higher residual value of capital) are more likely to lease.*

# 8 Conclusion

The paper has presented a theory of leasing in which asset use and maintenance shape the firm's decision between purchasing and/or leasing productive assets. When the maintenance of the asset cannot be carefully specified as part of the loan agreement, a collateralized loan contract is time-inconsistent as the entrepreneur cannot be trusted that she will carry out maintenance, jeopardizing the lender's returns. As a result, the lender will only offer unsecured loan contracts, with a subsequent efficiency loss. One way out to restore maintenance incentives and avoid capital depletion is to rely on a leasing contract. With such a contract, the maintenance is delegated to the lessor. However, despite not having the ownership, the lessee still keeps control of the asset, and can exert a suboptimal level of (unobservable) care in managing it. The paper characterizes circumstances in which it may be optimal to rent rather than buy. We thus provide a new theory of leasing that not only rationalizes some observed features of renting/leasing contracts, but also offers some novel testable predictions. Our static analysis predicts that entrepreneurs using assets whose value is sensitive to maintenance are more likely to lease than purchase their assets. Moreover, within the same sector, they are more likely to lease the more financially constrained they are and the less liquid their assets are. We leave the empirical verification of these predictions to future research.

# Appendix

**Proof of Proposition 1.** It is straightforward to show that when $K \geq \underline{K}$, (i) $\mu\gamma K > \eta$, then the optimal level of maintenance in the bad state of the world is $\mu_L = \overline{\mu}$; and (ii) $(\mu_1\gamma - \overline{\beta}m(\mu_1))K - \phi \geq (\mu_0\gamma - m(\mu_0))K$ and $(\mu_1\gamma - \overline{\beta}m(\mu_1))K - \phi - \eta \geq 0$, then the optimal combination of care and maintenance in the good state of the world is $a = a_1$ and $\mu_H = \mu_1$.

■

**Proof of Proposition 2.** The entrepreneur's expected payoff conditional on $a = a_0$, $\mu_H = 0$, and $\mu_L = \overline{\mu}$, is $\Pi_{0\overline{\mu}}(K) = pAf(K) - [r - (1 - \overline{\delta} + (1-p)\overline{\mu})\gamma]K - p\,\eta$. Denote by $K_{0\overline{\mu}}$ the level of capital input that maximizes $\Pi_{0\overline{\mu}}(K)$ and define $\Pi^*_{0\overline{\mu}} \equiv \Pi_{0\overline{\mu}}(K_{0\overline{\mu}})$, $\Pi^*_{\mu_0\overline{\mu}} \equiv \Pi_{\mu_0\overline{\mu}}(K_{\mu_0\overline{\mu}})$, $\Delta^{\mu_0}_{0^*}(\eta) \equiv \Pi^*_{0\overline{\mu}} - \Pi_{\mu_0\overline{\mu}}(K_{0\overline{\mu}})$, $\Delta^{0}_{\mu_0^*}(\eta) \equiv \Pi^*_{\mu_0\overline{\mu}} - \Pi_{0\overline{\mu}}(K_{\mu_0\overline{\mu}})$, and $\Delta^{0^*}_{\mu_0^*}(\eta) \equiv \Pi^*_{\mu_0\overline{\mu}} - \Pi^*_{0\overline{\mu}}$. If $\eta = 0$, $\Delta^{\mu_0}_{0^*}(\eta) = -p(\mu_0\gamma - m(\mu_0))K_{0\overline{\mu}} < 0$ and then $\Pi^*_{0\overline{\mu}} < \Pi_{\mu_0\overline{\mu}}(K_{0\overline{\mu}}) < \Pi^*_{\mu_0\overline{\mu}}$. If $\eta = (\mu_0\gamma - m(\mu_0))K_{\mu_0\overline{\mu}}$, $\Delta^{0}_{\mu_0^*}(\eta) = (\mu_0\gamma - m(\mu_0))K_{\mu_0\overline{\mu}} - \eta = 0$ and then $\Pi^*_{\mu_0\overline{\mu}} = \Pi_{0\overline{\mu}}(K_{\mu_0\overline{\mu}}) < \Pi^*_{0\overline{\mu}}$. Since $\frac{\partial \Delta^{0^*}_{\mu_0^*}}{\partial \eta} \leq 0$, there exists a threshold $\overline{\eta} \in (0,\, (\mu_0\gamma - m(\mu_0))K_{\mu_0\overline{\mu}})$ such that $\Delta^{0^*}_{\mu_0^*}(\eta) \geq 0$ if and only if $\eta \leq \overline{\eta}$. ■

**Proof of Proposition 3.** Since $\eta \leq \overline{\eta}$ by assumption, from Proposition 2 $\Pi^*_{\mu_0\overline{\mu}} \geq \Pi^*_{0\overline{\mu}}$. Hence, the assertion is proved by showing that there exists a threshold $\overline{\phi}$ such that $\Pi^*_{\mu_1\overline{\mu}} \geq \Pi^*_{\mu_0\overline{\mu}}$

if and only if $\phi \le \overline{\phi}$, where $\Pi^*_{\mu_1\overline{\mu}} \equiv \Pi_{\mu_1\overline{\mu}}(K_{\mu_1\overline{\mu}})$. Define $\Delta^{\mu_1}_{\mu_0^*}(\phi) \equiv \Pi^*_{\mu_0\overline{\mu}} - \Pi_{\mu_1\overline{\mu}}(K_{\mu_0\overline{\mu}})$, $\Delta^{\mu_0}_{\mu_1^*}(\phi) \equiv \Pi^*_{\mu_1\overline{\mu}} - \Pi_{\mu_0\overline{\mu}}(K_{\mu_1\overline{\mu}})$, and $\Delta^{\mu_1^*}_{\mu_0^*}(\phi) \equiv \Pi^*_{\mu_0\overline{\mu}} - \Pi^*_{\mu_1\overline{\mu}}$. If $\phi = 0$, $\Delta^{\mu_1}_{\mu_0^*}(\phi) = -p[(\mu_1\gamma - \overline{\beta}m(\mu_1)) - (\mu_0\gamma - m(\mu_0))]K_{\mu_0\overline{\mu}} < 0$ and then $\Pi^*_{\mu_0\overline{\mu}} < \Pi_{\mu_1\overline{\mu}}(K_{\mu_0\overline{\mu}}) < \Pi^*_{\mu_1\overline{\mu}}$. If $\phi = [(\mu_1\gamma - \overline{\beta}m(\mu_1)) - (\mu_0\gamma - m(\mu_0))]K_{\mu_1\overline{\mu}}$, $\Delta^{\mu_0}_{\mu_1^*}(\phi) = p[(\mu_1\gamma - \overline{\beta}m(\mu_1)) - (\mu_0\gamma - m(\mu_0))]K_{\mu_1\overline{\mu}} - p\phi = 0$ and then $\Pi^*_{\mu_1\overline{\mu}} = \Pi_{\mu_0\overline{\mu}}(K_{\mu_1\overline{\mu}}) < \Pi^*_{\mu_0\overline{\mu}}$. Since $\frac{\partial \Delta^{\mu_1^*}_{\mu_0^*}}{\partial \phi} \le 0$, there exists a threshold $\overline{\phi} \in \big(0,\, [(\mu_1\gamma - \overline{\beta}m(\mu_1)) - (\mu_0\gamma - m(\mu_0))]K_{\mu_1\overline{\mu}}\big)$ such that $\Delta^{\mu_1^*}_{\mu_0^*}(\phi) \ge 0$ if and only if $\phi \le \overline{\phi}$.

■

**Proof of Proposition 4.** Using $L = K - W$ from the resource constraint in the participation constraint (3) gives $pR = (K - W)r - (1-p)\lambda(1 - \overline{\delta} + \overline{\mu})\gamma K$. By combining the participation constraint and the incentive compatibility constraint (5), and substituting out in the limited liability constraints gives $1 - \frac{\eta}{\overline{\mu}\gamma K} \in [0,\, 1]$, and $p(Af(K) - \overline{\beta}m(\mu_1)K) \ge (K - W)r - (1-p)\frac{\overline{\mu}\gamma K - \eta}{\overline{\mu}}(1 - \overline{\delta} + \overline{\mu})$. Moreover, (4) implies the limited liability constraint $1 - \frac{\eta}{\overline{\mu}\gamma K} \in [0,\, 1]$. Indeed, $1 - \frac{\eta}{\overline{\mu}\gamma K} \ge 0$ whenever $K \ge \frac{\eta}{\overline{\mu}\gamma}$, with $\frac{\eta}{\overline{\mu}\gamma} < \underline{K}$, and $1 - \frac{\eta}{\overline{\mu}\gamma K} \le 1$ for all $K \ge \underline{K}$. Substituting $pR$ from the participation constraint (3) in the entrepreneur's profits, the optimisation problem can be written as

$$\max_K\, pAf(K) + [(1 - \overline{\delta} + \mu_1 + (1-p)(\overline{\mu} - \mu_1))\gamma - p\overline{\beta}m(\mu_1)]K - (K - W)r - \eta - p\phi$$

subject to (4) and (9). The level of capital inputs that maximizes the objective function is the first-best investment, $K_{\mu_1\overline{\mu}}$, solving the first-order condition (2). By Assumption 1, it satisfies constraint (4). If $K_{\mu_1\overline{\mu}}$ also satisfies constraint (9), then the level of capital solving the entrepreneur's maximization problem $\mathcal{P}_{\mathcal{B}1}$ is the first-best investment. The loan size is $L = K_{\mu_1\overline{\mu}} - W$, and any combination $R$ and $\lambda$ that satisfies the incentive constraint (5) and such that $R \le \min\{\frac{r(K_{\mu_1\overline{\mu}} - W)}{p},\; p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}})\}$ and $\lambda = \frac{r(K_{\mu_1\overline{\mu}} - W) - pR}{(1-p)(1-\overline{\delta}+\overline{\mu})\gamma K_{\mu_1\overline{\mu}}}$ is an optimal solution of Problem $\mathcal{P}_{\mathcal{B}1}$. Since we assumed that the entrepreneur pledges as little collateral as possible, $R = \frac{r(K_{\mu_1\overline{\mu}} - W)}{p}$ and $\lambda = 0$ if $p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}) \geq r(K_{\mu_1\overline{\mu}} - W)$, and $R = Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}$ and $\lambda = \frac{r(K_{\mu_1\overline{\mu}} - W) - p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}})}{(1-p)(1-\overline{\delta}+\overline{\mu})\gamma K_{\mu_1\overline{\mu}}}$ otherwise.

■

**Proof of Corollary 1.** Let be $\overline{\delta}(A)$ the function implicitly defined by $\Pi^*_{\mu_1\overline{\mu}}(A, \overline{\delta}(A)) - \Pi^*_{\mu_1\overline{\mu}} \equiv 0$, with $\frac{\partial\overline{\delta}(A)}{\partial A} = \frac{pf(K_{\mu_1\overline{\mu}})}{\gamma K_{\mu_1\overline{\mu}}}$. Let be $IC_1(A) \equiv p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}) + (1-p)(1-\overline{\delta}(A) + \overline{\mu})\frac{\overline{\mu}\gamma K_{\mu_1\overline{\mu}} - \eta}{\overline{\mu}} - K_{\mu_1\overline{\mu}}r$. By the chain rule:

$$\frac{\mathrm{d}IC_1}{\mathrm{d}A} = \frac{\partial IC_1}{\partial K_{\mu_1\overline{\mu}}}\left(\frac{\partial K_{\mu_1\overline{\mu}}}{\partial A} + \frac{\partial K_{\mu_1\overline{\mu}}}{\partial\overline{\delta}(A)}\frac{\partial\overline{\delta}(A)}{\partial A}\right) + \frac{\partial IC_1}{\partial A} + \frac{\partial IC_1}{\partial\overline{\delta}(A)}\frac{\partial\overline{\delta}(A)}{\partial A}.$$

From the first-order condition (2), $\frac{\partial IC_1}{\partial K_{\mu_1\overline{\mu}}} = p(Af'(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)) + (1-p)(1-\overline{\delta}+\overline{\mu})\gamma - r = -p(1-\overline{\delta}+\mu_1)\gamma < 0$. From the implicit function theorem, $\frac{\partial K_{\mu_1\overline{\mu}}}{\partial A} = -\frac{f'(K_{\mu_1\overline{\mu}})}{Af''(K_{\mu_1\overline{\mu}})} > 0$ by the concavity of $f(K)$. Finally, $\frac{\partial IC_1}{\partial A} = pf(K_{\mu_1\overline{\mu}}) > 0$. Moreover, $\frac{\partial K_{\mu_1\overline{\mu}}}{\partial\overline{\delta}(A)} = \frac{\gamma}{pAf''(K_{\mu_1\overline{\mu}})} < 0$, and $\frac{\partial IC_1}{\partial\overline{\delta}(A)} = -(1-p)\frac{\overline{\mu}\gamma K_{\mu_1\overline{\mu}} - \eta}{\overline{\mu}} < 0$. Hence

$$\frac{\mathrm{d}IC_1}{\mathrm{d}A} =$$

$$-p(1-\overline{\delta}+\mu_1)\gamma\left(-\frac{f'(K_{\mu_1\overline{\mu}})}{Af''(K_{\mu_1\overline{\mu}})} + \frac{f(K_{\mu_1\overline{\mu}})}{Af''(K_{\mu_1\overline{\mu}})K_{\mu_1\overline{\mu}}}\right) + pf(K_{\mu_1\overline{\mu}}) - (1-p)\frac{\overline{\mu}\gamma K_{\mu_1\overline{\mu}} - \eta}{\overline{\mu}}\frac{pf(K_{\mu_1\overline{\mu}})}{\gamma K_{\mu_1\overline{\mu}}} =$$

$$\frac{-p(1-\overline{\delta}+\mu_1)\gamma}{Af''(K_{\mu_1\overline{\mu}})K_{\mu_1\overline{\mu}}}\left(f(K_{\mu_1\overline{\mu}}) - f'(K_{\mu_1\overline{\mu}})K_{\mu_1\overline{\mu}}\right) + pf(K_{\mu_1\overline{\mu}})\left(1 - (1-p) + \frac{(1-p)\eta}{\overline{\mu}\gamma K_{\mu_1\overline{\mu}}}\right) > 0.$$

Indeed, from the assumption of positive expected profits,

$$pf(K_{\mu_1\overline{\mu}}) > \frac{r - [1-\overline{\delta}+\mu_1+(1-p)(\overline{\mu}-\mu_1)]\gamma + p\overline{\beta}m(\mu_1)}{A}K_{\mu_1\overline{\mu}} = pf'(K_{\mu_1\overline{\mu}})K_{\mu_1\overline{\mu}}$$

by the first-order condition (2). ■

**Proof of Proposition 5.** Assume $-Af''(\underline{K}) > \frac{(1-\overline{\delta}+\mu_1)\gamma}{\underline{K}}$ and $f'''(K) > 0$. This implies that $-Af''(K) > \frac{(1-\overline{\delta}+\mu_1)\gamma}{\underline{K}}$ for all $K \geq \underline{K}$. Define the marginal productivity of the project steeply sloped if this condition is satisfied. The participation constraint (10) has to be binding at the optimum. Substituting out $L = K - W$ from the resource constraint gives

$pR = (K - W)r - (1-p)\lambda(1-\overline{\delta}+\overline{\mu})\gamma K$. By combining the participation constraint and the limited liability constraints gives $p(Af(K) - \overline{\beta}m(\mu_1)K) + (1-p)(1-\overline{\delta})\gamma K \geq (K-W)r$. Substituting out $pR$ in the entrepreneur's profits, the optimisation problem $\mathcal{P}_{\mathcal{B}2}$ can be written as

$$\max_K pAf(K) + [(1-\overline{\delta})\gamma + p(\mu_1\gamma - \overline{\beta}m(\mu_1))]K - r(K-W) - p(\eta+\phi)$$

subject to (4) and

$$p(Af(K) - \overline{\beta}m(\mu_1)K) + (1-p)(1-\overline{\delta})\gamma K \geq (K-W)r. \tag{13}$$

The level of capital inputs that maximizes the objective function is $K_{\mu_1\varnothing}$ solving the following first-order condition:

$$pA\frac{\partial f}{\partial K} = r - (1-\overline{\delta})\gamma - p(\mu_1\gamma - \overline{\beta}m(\mu_1)).$$

If $K_{\mu_1\varnothing}$ satisfies constraint (13), then it solves problem $\mathcal{P}_{\mathcal{B}2}$. The loan size is $L_2(W) \equiv K_{\mu_1\varnothing} - W$, and any combination $R$ and $\lambda$ such that $R \leq \min\{\frac{r(K_{\mu_1\varnothing}-W)}{p},\ p(Af(K_{\mu_1\varnothing}) - \overline{\beta}m(\mu_1)K_{\mu_1\varnothing})\}$ and $\lambda = \frac{r(K_{\mu_1\varnothing}-W)-pR}{(1-p)(1-\overline{\delta})\gamma K_{\mu_1\varnothing}}$ is an optimal solution of Problem $\mathcal{P}_{\mathcal{B}2}$. Since we assumed that the entrepreneur pledges as little collateral as possible, $R_2(W) = \frac{r(K_{\mu_1\varnothing}-W)}{p}$ and $\lambda_2(W) = 0$ if $p(f(K_{\mu_1\varnothing}) - \overline{\beta}m(\mu_1)K_{\mu_1\varnothing}) \geq r(K_{\mu_1\varnothing} - W)$, and $R_2(W) = f(K_{\mu_1\varnothing}) - \overline{\beta}m(\mu_1)K_{\mu_1\varnothing}$ and $\lambda_2(W) = \frac{r(K_{\mu_1\varnothing}-W)-p(f(K_{\mu_1\varnothing})-\overline{\beta}m(\mu_1)K_{\mu_1\varnothing})}{(1-p)(1-\overline{\delta})\gamma K_{\mu_1\varnothing}}$ otherwise. By the strict concavity of the production function, $K_{\mu_1\varnothing} < K_{\mu_1\overline{\mu}}$ and, by Assumption 1, $K_{\mu_1\varnothing} > \underline{K}$. To conclude the proof, we have to show that there exists a threshold $\underline{A}_{\varnothing} > 0$ such that for all $A > \underline{A}_{\varnothing}$, $K_{\mu_1\varnothing}$ satisfies constraint (13).

Let be $IC_2(A) \equiv p(Af(K_{\mu_1\varnothing}) - \overline{\beta}m(\mu_1)K_{\mu_1\varnothing}) + (1-p)(1-\overline{\delta})\gamma K_{\mu_1\varnothing} - K_{\mu_1\varnothing}r$. By the chain rule:

$$\frac{\mathrm{d}IC_2}{\mathrm{d}A} = \frac{\partial IC}{\partial K_{\mu_1\varnothing}}\frac{\partial K_{\mu_1\varnothing}}{\partial A} + \frac{\partial IC}{\partial A}.$$

$\frac{\partial IC_2}{\partial A} = pf(K_{\mu_1\varnothing}) > 0$, $\frac{\partial IC}{\partial K_{\mu_1\varnothing}} = -p(1-\overline{\delta}+\mu_1)\gamma < 0$, and $\frac{\partial K_{\mu_1\varnothing}}{\partial A} = -\frac{f'(K_{\mu_1\varnothing})}{Af''(K_{\mu_1\varnothing})} > 0$. Hence

$$\frac{\mathrm{d}IC_2}{\mathrm{d}A} = -p(1-\overline{\delta}+\mu_1)\gamma\,\frac{f'(K_{\mu_1\varnothing})}{-Af''(K_{\mu_1\varnothing})} + pf(K_{\mu_1\varnothing}) > 0$$

since $f(K_{\mu_1\varnothing}) - f'(K_{\mu_1\varnothing})K_{\mu_1\varnothing} > 0$ from the proof of Corollary 1, and

$$\frac{\partial IC_2}{\partial A} > pf'(K_{\mu_1\varnothing})K_{\mu_1\varnothing} - p(1-\overline{\delta}+\mu_1)\gamma\frac{f'(K_{\mu_1\varnothing})}{-Af''(K_{\mu_1\varnothing})} > 0$$

if the marginal productivity of the project is steeply sloped. Since $\lim_{A\to\infty} IC_2(A) = \infty$ and $\lim_{A\to 0} IC_2(A) < 0$, there exists a threshold $A_\varnothing > 0$ such that $IC_2(A) \geq 0$ for all $A \geq A_\varnothing$. ■

**Proof of Lemma 1.** Assume $-Af''(\underline{K}) > \frac{(1-\overline{\delta}+\mu_1)\gamma}{\underline{K}}$ and $f'''(K) > 0$. The proof that the thresholds $\underline{A}$ and $\overline{A}$ exist is similar to the proof on the existence of $A_\varnothing$ in Proposition 5 and will be omitted. To show that $A_\varnothing > \underline{A}$, define $IC_0(A, \overline{\mu}) \equiv p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}) + (1-p)(1-\overline{\delta}+\overline{\mu})\gamma K_{\mu_1\overline{\mu}} - K_{\mu_1\overline{\mu}}r$. By the chain rule:

$$\frac{\mathrm{d}IC_0}{\mathrm{d}A} = \frac{\partial IC_0}{\partial K_{\mu_1\overline{\mu}}}\frac{\partial K_{\mu_1\overline{\mu}}}{\partial A} + \frac{\partial IC_0}{\partial A} > 0$$

and

$$\frac{\mathrm{d}IC_0}{\mathrm{d}\overline{\mu}} = \frac{\partial IC_0}{\partial K_{\mu_1\overline{\mu}}}\frac{\partial K_{\mu_1\overline{\mu}}}{\partial \overline{\mu}} + \frac{\partial IC_0}{\partial \overline{\mu}}.$$

From the implicit function theorem, $\frac{\partial K_{\mu_1\overline{\mu}}}{\partial\overline{\mu}} = -\frac{(1-p)\gamma}{Af''(K_{\mu_1\overline{\mu}})} > 0$ by the concavity of $f(K)$. Moreover, $\frac{\partial IC_0}{\partial\overline{\mu}} = (1-p)\gamma K_{\mu_1\overline{\mu}} > 0$. Hence

$$\frac{\mathrm{d}IC_0}{\mathrm{d}\overline{\mu}} = -p(1-\overline{\delta}+\mu_1)\gamma\,\frac{(1-p)\gamma}{-Af''(K_{\mu_1\overline{\mu}})} + (1-p)\gamma K_{\mu_1\overline{\mu}} > 0$$

if the marginal productivity of the project is steeply sloped, and $A_\varnothing > \underline{A}$. Finally, to show that $\overline{A} > \underline{A}$, define $IC(A,\eta) \equiv p(Af(K_{\mu_1\overline{\mu}}) - \overline{\beta}m(\mu_1)K_{\mu_1\overline{\mu}}) + (1-p)(1-\overline{\delta}+\overline{\mu})\frac{\overline{\mu}\gamma K_{\mu_1\overline{\mu}}-\eta}{\overline{\mu}} - K_{\mu_1\overline{\mu}}r$, and notice that $\frac{\partial IC}{\partial\eta} = -\frac{(1-p)(1-\overline{\delta}+\overline{\mu})}{\overline{\mu}} < 0$. Since $IC_0(A,\overline{\mu}) = IC(A, \eta = 0)$, this combined with $\frac{\partial IC}{\partial A} > 0$ imply that $\overline{A} > \underline{A}$. ■

**Proof of Proposition 8.** Consider program $\mathcal{P}_{\mathcal{R}}$. Both participation constraints have to be binding at the optimum. If not, it would be possible to lower $F$ and/or $R$ and increase the entrepreneur's profits. Using $Fr$ from the lessor's participation constraint (11) in the resource constraint, and substituting out in the investors' participation constraint (12) gives $pR = [r^R - (1-\overline{\delta}+\mu_0+(1-p)(\overline{\mu}-\mu_0))\gamma + p\,m(\mu_0)]K + \eta - Wr$. Substituting out $pR$ in the entrepreneur's profits, the optimisation problem can be written as

$$\max_K pAf\left(K\right) - (r^R - (1-\overline{\delta}+\mu_0+(1-p)(\overline{\mu}-\mu_0))\gamma + p\,m(\mu_0)]K - \eta + Wr.$$

The first-order condition is defined by condition (1). ■

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