

INSURANCE, BOND COVENANTS, AND UNDER- OR OVER-INVESTMENT WITH RISKY ASSET RECONSTITUTION

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ABSTRACT

Traditional theory predicts that the shareholders of a limited liability company financed partly by bonds may underinvest by not replacing damaged company assets. It also precludes the possibility of overinvestment. By relaxing the restrictive assumption maintained under traditional theory, namely, that the effects of reconstituting damaged assets are nonstochastic, this article shows that both over and underinvestment are possible. It is shown that these moral hazard problems can be mitigated by incorporating appropriate insurance requirements into bond covenants. Moreover, it is shown that the insurance requirements for alleviating underinvestment and overinvestment are quite different. Particularly, for underinvestment, the required insurance only needs to make the bonds riskless in the best asset reconstitution states of the loss states in which the company value falls short of the promised bond repayment; however, for overinvestment, the required insurance should make the bonds totally riskless. The difference in insurance requirements is especially important when insurance is actuarially unfavorable such that more-than-required insurance is always undesirable.

INTRODUCTION

It is well known in the finance and economics literature that the presence of asymmetric information between stockholders and bondholders may lead to suboptimal corporate investment decisions. Two common examples are the asset substitution problem and the underinvestment problem introduced by Jensen and Meckling (1976) and Myers (1977). The seminal article of Mayers and Smith (1987) shows that the

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underinvestment problem may also occur in the case of reconstitution of damaged corporate assets. Risk-neutral shareholders, who have no precommitment to reconstituting damaged corporate assets, may choose not to replace lost assets in the states of nature in which the value of the company after asset reconstitution is raised but falls short of the bond repayment amount. To illustrate the underinvestment problem, Mayers and Smith (1987) assume that asset reconstitution raises company value and is riskless. Mayers and Smith (1987), Schnabel and Roumi (1989), and Garven and MacMinn (1993) propose that to mitigate the underinvestment problem, a bond covenant should be imposed, specifying that sufficient property insurance is purchased to make the bonds riskless and to prevent the shareholders from taking advantage of the limited liability provision by underinvesting in the states with large property losses.¹

Recently, some authors (e.g., De Meza and Webb, 1987; Berkovitch and Kim, 1990; Stulz, 1990; Harris and Raviv, 1996; Chung, 1998; Noe et al., 2002; Sigouin, 2003) suggest various reasons that overinvestment may also occur. For example, Berkovich and Kim (1990) suggest that if shareholders are allowed to issue nonsubordinated debt, then the relatively low cost of borrowing may create incentive for excessive investment. Noe et al. (2002) show that in international cooperative ventures, overinvestment occurs when the multinational's bargaining advantage is reinforced by an informational advantage. A natural question that one may ask is whether it is possible that shareholders may overinvest when deciding if damaged assets should be replaced. Under Mayers and Smith's (1987) riskless asset reconstitution assumption, overinvestment will never occur, because any asset reconstitution that reduces company value below the promised bond repayment amount also reduces shareholders' wealth with certainty. What if asset reconstitution is risky?

In reality, there are reasons why reconstituting damaged assets may not always raise the value of a company and may even be risky. For instance, the cost of raising immediate liquidity to finance asset reconstitution may exceed its benefit given imperfect short-term capital markets. Unless there are prearranged contingency loans (which are likely to be insufficient in the case of large property damage), the liquidity needed for asset reconstitution often has to be extracted from other important operations or production activities. With large property damage, asset reconstitution may use up a significant portion of prearranged credit or buffer cash initially planned for coping with other production and market shocks, introducing additional risk to the value of a company. Possible liquidity problems may have significantly negative impact on company value. Therefore, asset reconstitution can be risky, possibly resulting in positive or negative net present values in different states of nature. Moreover, the expected net present value of asset reconstitution can be positive or negative.

This article shows that both over and underinvestment problems may arise when asset reconstitution is risky. With risky asset reconstitution, given a certain level of asset damage, shareholders may not choose to reconstitute damaged assets even though doing so generates a positive expected net present value, giving rise to the underinvestment problem. This happens when the value of a company falls short of the promised bond repayment amount even in the best asset reconstitution states. In this case, asset reconstitution will only benefit bondholders, but not shareholders who are

¹ For further implications of the limited liability provision, see Esterbrook and Fischel's (1985) article.

already protected by the limited liability provision. The underinvestment problem will not arise in the absence of limited liability because a rise in company value due to asset reconstitution will relieve some shareholders' debt responsibilities. It also will not arise whenever company value exceeds the promised bond repayment amount in some asset reconstitution states, because asset reconstitution raises shareholders' wealth in these states.

On the contrary, given a certain level of asset damage, shareholders may opt for risky asset reconstitution with a negative expected net present value, giving rise to the overinvestment problem. This happens when the value of a company is higher than the bond repayment amount in some, but not all, asset reconstitution states. Shareholders, who are protected by the limited liability provision, will engage in risky asset reconstitution to raise their own wealth in solvent states, knowing that doing so lowers company value and bondholders' wealth in insolvent states, giving rise to an overall fall in expected company value and expected bondholders' wealth. The overinvestment problem will not arise in the absence of limited liability because any fall in company value will eventually raise shareholders' own debt responsibilities. It also will not arise whenever a company's value is lower than the promised bond repayment amount in all asset reconstitution states, because asset reconstitution will benefit no one.

Similar to Mayers and Smith's (1987) underinvestment problem under riskless asset reconstitution, bond covenants requiring the shareholders to purchase appropriate property insurance can be used to mitigate both underinvestment and overinvestment under risky asset reconstitution. Particularly, to avoid underinvestment, it suffices to specify an indemnity schedule to raise the value of the company sufficiently so that the bonds are made riskless in those insolvent states in which reconstituting damaged assets raises company value in order to provide an incentive for the shareholders to replace damaged assets to keep the company from going bankrupt. To avoid overinvestment, it suffices to specify an indemnity schedule to raise company value in potential insolvent states and hence shareholders' opportunity cost of asset reconstitution, so that it is no longer possible for shareholders to take advantage of the limited liability provision to increase their own wealth at the expense of bondholders.

The rest of the article is organized as follows: Section Company Value with Riskless or Risky Asset Reconstitution compares the case of risky asset reconstitution to the traditional case of riskless asset reconstitution. Section Underinvestment with Riskless or Risky Asset Reconstitution distinguishes the underinvestment problems with riskless and with risky asset reconstitution. Section Bond Covenant for Mitigating Underinvestment derives the required property insurance indemnity schedule that should be specified in a bond covenant to mitigate the underinvestment problem with risky asset reconstitution. Section Overinvestment with Risky Asset Reconstitution identifies the overinvestment problem with risky asset reconstitution. Section Bond Covenant for Mitigating Overinvestment derives the insurance indemnity schedule required for mitigating the overinvestment problem. Section Actuarially Unfavorable Insurance considers the effects of insurance loading. Final section concludes.

COMPANY VALUE WITH RISKLESS OR RISKY ASSET RECONSTITUTION

The model to be analyzed is an extension of those of Mayers and Smith (1987), Schnabel and Roumi (1989), and Garven and MacMinn (1993). Suppose a limited liability

company is financed by both stocks and bonds. There are two time periods $t = 0$ and $t = 1$. At $t = 0$, the company issues bonds with promised repayment amount B^u . Right after the bond issue, the company faces random state of property damage $\tilde{s}$ with support $[\underline{s}, \bar{s}]$ such that the size of the property damage is given by the continuously differentiable, real-valued function L with $L(s) = 0$ for all $s \in [s^l, \bar{s}]$ (the set of no loss states) and $L(s) > 0$ with $L'(s) < 0$ for all $s \in [\underline{s}, s^l)$ (the set of loss states), where $s^l = \inf_s \{s \mid L(s) = 0\}$. At $t = 1$, the total value of the company is V if no property damage occurs. When there is property damage, the value of the company in loss state s equals $V - L(s)$.

Mayers and Smith (1987) assume that the shareholders of a limited liability company have the choice of replacing damaged assets fully and that the effect of asset reconstitution on the company's value is certain, depending only on realization s of $\tilde{s}$. They conclude that there may be underinvestment, as the shareholders may not replace damaged assets even when asset reconstitution results in an increase in the value of the company. The reason is that in the states with large property losses, the value of the company is lower than the amount needed for fully repaying the bondholders, even after asset reconstitution. Since the shareholders are protected by the limited liability provision, any increase in the value of the company in these loss states will benefit only the bondholders. Notice that with riskless asset reconstitution, overinvestment is impossible because the shareholders will not benefit from any riskless asset reconstitution that reduces the value of the company.

Two questions arise. First, is the riskless asset reconstitution assumption always reasonable? Second, if the riskless asset reconstitution assumption is relaxed, how will the conclusion on underinvestment and overinvestment be affected?

It is possible that asset reconstitution may reduce, instead of raise, the value of the company and, at the same time, may introduce a spread (or additional risk). There are several reasons for such stochastic deterioration of company value. First, even if the reinstallation or reproduction of damaged assets (possibly productive inputs or finished outputs) is successful with certainty, the cost and the timing of the reinstallation or reproduction may be stochastic, resulting in additional cost or production uncertainty. Second, the replenishing of damaged output may require the company to acquire additional raw materials and other inputs whose prices may be risky. As the size of asset damage is unknown *a priori*, no hedging against the fluctuation in input prices can be prearranged. Third, even if the damaged assets are fully replaced, there may be contract or production delay that creates additional risk as a result of uncertain contract penalty or fluctuation in output prices that has not been completely hedged against. Finally, asset reconstitution may utilize internal funds, causing some uncertain liquidity problems, depending on the realized loss size.

To model the additional risk introduced by asset reconstitution, denote the continuum of states of nature resulting from asset reconstitution by random variable $\tilde{\epsilon}$. At $t = 0$, prior to the bond issue, $\tilde{\epsilon}$ and $\tilde{s}$ have joint distribution function f . Assume that $\tilde{\epsilon}$ is realized right after $\tilde{s}$ has been realized and the shareholders have taken action to reconstitute any damaged assets.² Denote the probability density function of $\tilde{\epsilon}$ conditional

² Since interest rate is assumed to be zero, the exact time elapsed between the realizations of $\tilde{\epsilon}$ and $\tilde{s}$ is unimportant.

on realization s of $\tilde{s}$ by $f(\epsilon | s)$. Denote $I(\epsilon)$ as the “ultimate loss of company value” after asset reconstitution in realization ϵ of $\tilde{\epsilon}$, where I is a positive, continuously differentiable function with $I > 0$ and $I' > 0$ for all ϵ given any any loss state.³ Denote the support of $\tilde{\epsilon}$ conditional on realization s of $\tilde{s}$ by $[\underline{\epsilon}(s), \bar{\epsilon}(s)]$ with $f(\epsilon | s) > 0$ on the support. Here, $\underline{\epsilon}(s)$ and $\bar{\epsilon}(s)$ are real-valued functions representing the worst and the best states of asset reconstitution given s with $\underline{\epsilon}' < 0$ and $\bar{\epsilon}' < 0$. If the shareholders decide to replenish damaged assets, the value of the company at $t = 1$ is given by

$$V - I(\bar{\epsilon}).$$

To keep the problem simple and yet interesting, assume that for all $s \in [\underline{s}, \bar{s}]$, $I(\bar{\epsilon}(s)) < L(s) < I(\underline{\epsilon}(s)) \leq V$.

Denote the discount factors weighted by the joint probability of $\tilde{\epsilon}$ and $\tilde{s}$, the probability of $\tilde{\epsilon}$ conditional on $\tilde{s}$, and the marginal probability of $\tilde{s}$ by $p(\epsilon, s)$, $p(\epsilon | s)$, and $p(s)$, respectively. It is clear that $p(\epsilon, s) = f(\epsilon | s) p(s)$.

UNDERINVESTMENT WITH RISKLESS OR RISKY ASSET RECONSTITUTION

Using the notation in the previous section, it can be verified that the riskless asset reconstitution assumption of Mayers and Smith (1987) and subsequent researchers essentially requires that given any loss state s , $I(\bar{\epsilon}) = I(\underline{\epsilon}(s)) = I(\bar{\epsilon}(s)) = E[I(\tilde{\epsilon}) | s] = I[\epsilon_0(s)]$, where ϵ_0 is a nonstochastic, differentiable real-valued function with $\epsilon'_0 < 0$ such that $dI/ds = I'\epsilon'_0 < 0$ for all $s \in [\underline{s}, \bar{s}]$. Here, $E[\cdot | \cdot]$ is the conditional expectation operator. Mayers and Smith (1987) also assume that asset reconstitution raises the value of the company, that is, $V - I[\epsilon_0(s)] > V - L(s)$ for all $s \in [\underline{s}, \bar{s}]$. Under these assumptions, the shareholders replace damaged assets in any loss state s if, and only if

$$V - I[\epsilon_0(s)] \geq B^u. \quad (1)$$

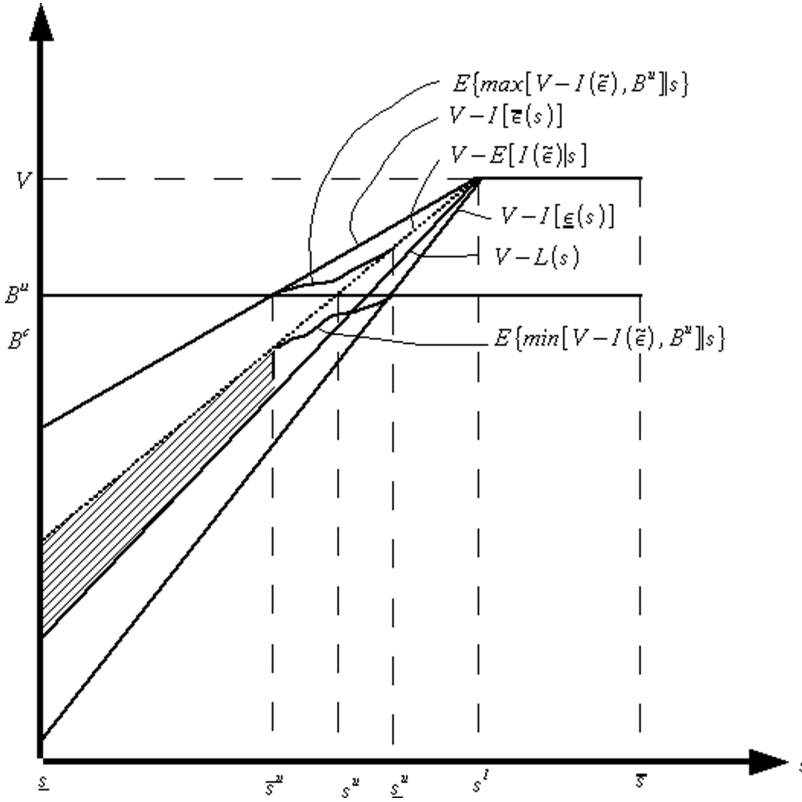
Define loss state s^u such that $V - I[\epsilon_0(s^u)] = B^u$. Assume that s^u exists. $dI/ds < 0$ implies that Equation (1) holds on $[s^u, \bar{s}]$ so that the shareholders will replace damaged assets for all $s \in [s^u, \bar{s}]$ to raise both the shareholders' wealth and the value of the company. This article follows the convention adopted by Mayers and Smith (1987) and others that the shareholders replace damaged assets whenever the company is kept from going bankrupt or better.⁴

On the contrary, for all $s \in [\underline{s}, s^u)$, being protected by the limited liability provision, any benefit from riskless asset reconstitution goes to the bondholders when $V - I[\epsilon_0(s)] < B^u$. The shareholders, therefore, have no incentive to replace damaged assets even though $V - I[\epsilon_0(s)] > V - L(s)$, giving rise to the underinvestment problem. The agency cost, therefore, equals

³ More correctly, the net loss of company value after asset reconstitution should be written as $I(\epsilon, s)$.

⁴ This convention is reasonable because bankruptcy is costly (though the cost of bankruptcy is not modeled in this article) and hence reduces the value of the company such that the issue price of the bonds is reduced further.

FIGURE 1
Underinvestment With Risky Asset Reconstitution



$$c^u = \int_{\underline{s}}^{\bar{s}^u} \{I[\epsilon_0(s)] - L(s)\} p(s) ds. \quad (2)$$

Now, suppose asset reconstitution is risky for the reasons stated in the previous section. Define $\bar{s}^u$ and $\underline{s}^u$ such that

$$V - I[\bar{\epsilon}(\bar{s}^u)] = B^u = V - I[\underline{\epsilon}(\underline{s}^u)]. \quad (3)$$

In words, $\bar{s}^u$ (c.f. $\underline{s}^u$) is the loss state in which the value of the company in the best (c.f. worst) state of asset reconstitution is just high enough for repaying the bonds. It is clear that $\bar{s}^u < \underline{s}^u$ (as shown in Figure 1).

To see that underinvestment is possible, assume that

$$V - I[\bar{\epsilon}(s)] > V - E[I(\bar{\epsilon}) | s] > V - L(s) > V - I[\underline{\epsilon}(s)], \quad (4)$$

for all $s \in [\underline{s}, s^l)$ such that the expected net value of the company rises after the reconstitution of damaged assets. Under the specification in Equation (4), underinvestment will not occur if the company is solely financed by stocks because the benefit of replacing damaged assets is fully captured by the shareholders. Also, underinvestment will not occur if $V - I[\bar{\epsilon}(s)] \geq B^u$ on $[\underline{s}, \bar{s}]$ such that $\bar{s}^u$ does not exist. As long as the shareholders are able to capture some benefits from asset reconstitution or to keep the company from going bankrupt, underinvestment will not occur.

Referring to Figure 1, for any $s \in [\underline{s}, \bar{s}^u)$, the total value of the company after asset reconstitution is smaller than the bond repayment amount, even in the best asset reconstitution state (i.e., $V - I[\bar{\epsilon}(s)] < B^u$). Being protected by the limited liability provision, the shareholders have no incentive to replace the damaged assets because any increase in the value of the company as a result of asset reconstitution will go to the bondholders. There is clearly underinvestment on $[\underline{s}, \bar{s}^u)$. For any $s \in [\bar{s}^u, \underline{s}^u)$, after asset reconstitution, the shareholders receive⁵

$$E\{\max[V - I(\bar{\epsilon}) - B^u, 0] | s\} \geq \max\{V - E[I(\bar{\epsilon}) | s] - B^u, 0\} \geq \max[V - L(s) - B^u, 0].$$

The shareholders' wealth is at least as high with than without asset reconstitution. This is true also for all $s \in [\underline{s}^u, s^l)$ in which

$$E\{\max[V - I(\bar{\epsilon}) - B^u, 0] | s\} = V - E[I(\bar{\epsilon}) | s] - B^u > V - L(s) - B^u > 0.$$

Therefore, there is no underinvestment on $[\bar{s}^u, s^l)$. The above suggests that the agency cost of underinvestment is given by

$$c^u = \int_{\underline{s}}^{\bar{s}^u} \{E[I(\bar{\epsilon}) | s] - L(s)\} p(s) ds. \quad (5)$$

This is represented by the shaded area in Figure 1 weighted by appropriate probabilities of loss states. Comparing the cases with riskless and risky asset reconstitution, it should be clear from Equations (2) and (5) that the underinvestment problem is less severe when asset reconstitution becomes risky as $\bar{s}^u < s^u$ such that $\bar{c}^u < c^u$.

In the presence of underinvestment, the bondholders receive

$$\begin{cases} V - L(s), & s \in [\underline{s}, \bar{s}^u) \\ E\{\min[V - I(\bar{\epsilon}), B^u] | s\}, & s \in [\bar{s}^u, \underline{s}^u), \\ B^u, & s \in [\underline{s}^u, \bar{s}] \end{cases}$$

where

$$E\{\min[V - I(\bar{\epsilon}), B^u] | s\} = \int_{\epsilon(s)}^{\bar{\epsilon}(s)} \min[V - I(\epsilon), B^u] f(\epsilon | s) d\epsilon. \quad (6)$$

⁵ Notice that the first inequality is strict for all $s \in (\bar{s}^u, \underline{s}^u)$. The last inequality is due to the second inequality in Equation (4) and is strict for all $s \in (s^u, \underline{s}^u]$.

Therefore, the total value of the bonds equals

$$D(B^u) = \int_{\underline{s}}^{\bar{s}^u} [V - L(s)]p(s)ds + \int_{\bar{s}^u}^{\bar{s}} E\{\min[V - I(\bar{\epsilon}), B^u] | s\}p(s)ds + \int_{\bar{s}^u}^{\bar{s}} B^u p(s)ds \quad (7)$$

which is smaller than the present value of B^u .

BOND COVENANT FOR MITIGATING UNDERINVESTMENT

To mitigate the underinvestment problem, a bond covenant should be imposed requiring the shareholders to purchase sufficient property insurance. Keeping the net amount (net of insurance premium) of funds raised from the bondholders unchanged, a bond covenant that reduces the chance of default allows the company to issue the bonds at a lower promised repayment amount and to use part of the amount to pay for insurance premium p^c . Denote the promised bond repayment in the presence of the bond covenant by B^c . According to Garven and MacMinn (1993), the bond covenant should satisfy the following “financing constraint”:

$$D(B^u) = D(B^c) - p^c,$$

where $D(B^c)$ and $D(B^u)$ denote the bond prices with and without the bond covenant, respectively.

Define loss state $\bar{s}^c$ such that

$$V - I[\bar{\epsilon}(\bar{s}^c)] = B^c. \quad (8)$$

It is clear that $\bar{s}^c < \bar{s}^u$ because $B^c < B^u$ and $dI[\bar{\epsilon}(s)]/ds < 0$. For the bond covenant to be effective, the bonds should be made riskless in the best states of asset reconstitution, $\bar{\epsilon}(s)$, for all $s \in [\underline{s}, \bar{s}^c)$ in which $V - I[\bar{\epsilon}(s)] < B^c$, so that the shareholders have an incentive to replace damaged assets to avoid the company going bankrupt. In other words, the required indemnity schedule satisfies:

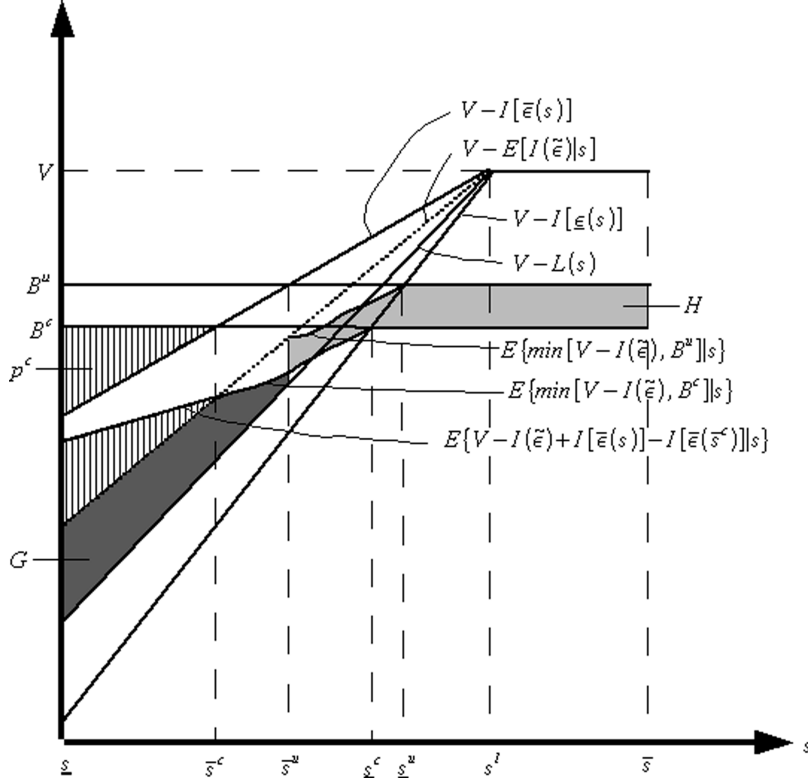
$$\begin{cases} I[\bar{\epsilon}(s)] - I[\bar{\epsilon}(\bar{s}^c)], & s \in [\underline{s}, \bar{s}^c) \\ 0, & \text{otherwise.} \end{cases}$$

The indemnity schedule essentially imposes a coinsurance clause and a deductible clause under which any property loss smaller than or equal to $L(\bar{s}^c)$ will not be indemnified. The insurance premium satisfies

$$p^c = \int_{\underline{s}}^{\bar{s}^c} \{I[\bar{\epsilon}(s)] - I[\bar{\epsilon}(\bar{s}^c)]\}p(s)ds.$$

Notice that the bond covenant has a second effect. The reduction in the promised bond repayment from B^u to B^c reduces the probability of bankruptcy (and hence default) and induces asset reconstitution for all $s \in [\bar{s}^c, \bar{s}^u)$. Notice also that unlike the case

FIGURE 2
Bond Covenant for Mitigating Underinvestment



with riskless asset reconstitution, the bond covenant will not make the bonds totally riskless, although it still raises the actual payment to the bondholders in all loss states $s \in [\underline{s}, \bar{s}^u]$.

Referring to Figure 2, area H weighted by appropriate probabilities represents the reduction in the bondholders' expected receipt as a result of the fall in the promised bond repayment amount. Area G weighted by appropriate probabilities represents the increase in the bondholders' expected receipt as a result of the elimination of the underinvestment problem.

With the bond covenant, the bondholders now receive

$$\begin{cases} E\{V - I(\tilde{\epsilon}) + I[\tilde{\epsilon}(s)] - I[\tilde{\epsilon}(s^c)] | s\}, & s \in [\underline{s}, \bar{s}^c] \\ E\{\min[V - I(\tilde{\epsilon}), B^c] | s\}, & s \in [\bar{s}^c, \underline{s}^c] \\ B^c, & s \in [\underline{s}^c, \bar{s}]. \end{cases}$$

Therefore, the value of the bonds is given by

$$D(B^c) = \int_{\underline{s}}^{\bar{s}^c} E\{V - I(\epsilon) + I[\bar{\epsilon}(s)] - I[\bar{\epsilon}(\bar{s}^c)] | s\} p(s) ds \\ + \int_{\bar{s}^c}^{\bar{s}} E\{\min[V - I(\epsilon), B^c] | s\} p(s) ds + \int_{\bar{s}^c}^{\bar{s}} B^c p(s) ds. \quad (9)$$

OVERINVESTMENT WITH RISKY ASSET RECONSTITUTION

Intuition suggests that the shareholders of a company may never engage in any asset reconstitution that leads to a stochastic deterioration of the value of the company.⁶ This is not true for limited liability companies partly financed by bonds. To see how overinvestment is possible with risky asset reconstitution, suppose

$$V - I[\bar{\epsilon}(s)] > V - L(s) > V - E[I(\bar{\epsilon}) | s] > V - I[\underline{\epsilon}(s)] \quad (10)$$

for all $s \in [\underline{s}, s^l]$. The second inequality specifies that conditional on any loss state s , the expected value of the company is lower with than without asset reconstitution. Under the specification in Equation (10), overinvestment will not occur if the company is solely financed by stocks, in which case the shareholders aim at maximizing the total expected value of the company such that there is no asset reconstitution in all loss states with $V - L(s) > V - E[I(\bar{\epsilon}) | s]$.

When the company is partly financed by bonds, the moral hazard overinvestment problem may emerge. Being protected by the limited liability provision, the shareholders receive $V - I(\epsilon) - B^u$ if $V - I(\epsilon) > B^u$ and 0 otherwise when there is asset reconstitution; they receive $V - L(s) - B^u$ if $V - L(s) > B^u$ and 0 otherwise when there is no asset reconstitution. Therefore, conditional on any loss state $s \in [\underline{s}, s^l]$, the shareholders' wealth equals

$$E\{\max[V - I(\bar{\epsilon}) - B^u, 0] | s\}$$

with asset reconstitution and

$$\max[V - L(s) - B^u, 0]$$

without asset reconstitution. The shareholders will replace damaged assets if, and only if

$$E\{\max[V - I(\bar{\epsilon}) - B^u, 0] | s\} > \max[V - L(s) - B^u, 0] > 0. \quad (11)$$

The convention adopted here is that the shareholders will not attempt to hurt the bondholders unless the shareholders become strictly better off with positive expected payoff.

⁶ Here, a stochastic deterioration of the value of a company refers to a first-order stochastic dominated change in the Rothschild-Stiglitz sense.

Define loss state $\bar{s}^u$ such that Equation (3) holds as before; define loss state $\hat{s}^u (> \bar{s}^u)$ such that

$$E\{\max[V - I(\tilde{\epsilon}) - B^u, 0] | \hat{s}^u\} = V - L(\hat{s}^u) - B^u > 0. \quad (12)$$

The last inequality is because of the fact that $E\{\max[V - I(\tilde{\epsilon}) - B^u, 0] | s\} > 0$ for all $s \in (\bar{s}^u, \bar{s}]$. $\hat{s}^u$ is the loss state in which the expected shareholders' wealth is the same with or without asset reconstitution, taking account of the protection from the limited liability provision in the relatively bad asset reconstitution states in which the value of the company is below B^u . For the ease of exposition and without loss of too much generality, assume that $\hat{s}^u$ is unique.⁷

For all $s \in [\underline{s}, \bar{s}^u]$, the shareholders' wealth equals zero with or without asset reconstitution; therefore, the shareholders have no incentive to replace damaged assets. By the definition of $\hat{s}^u$, the shareholders will overinvest by replacing damaged assets for all $s \in (\bar{s}^u, \hat{s}^u)$, as Equation (11) holds, and will not replace damaged assets for all $s \in [\hat{s}^u, s^l]$, as the first inequality in Equation (11) is violated. The replacement of damaged assets on $(\bar{s}^u, \hat{s}^u)$ represents overinvestment because $V - E[I(\tilde{\epsilon})] < V - L(s)$. Notice that the interval $(\hat{s}^u, s^l)$ is nontrivial because when s approaches s^l from $\hat{s}^u (> \hat{s}^u)$, the shareholders' expected payoff becomes strictly lower with than without asset reconstitution such that

$$E\{\max[V - I(\tilde{\epsilon}) - B^u, 0] | s\} = V - E[I(\tilde{\epsilon}) | s] - B^u < V - L(s) - B^u$$

and the equality in Equation (12) is not satisfied.

Figure 3 allows the readers to visualize the overinvestment problem. The agency cost of overinvestment is given by

$$\bar{c}^u = \int_{\bar{s}^u}^{\hat{s}^u} \{E[I(\tilde{\epsilon}) | s] - L(s)\} p(s) ds \quad (13)$$

and is represented by the shaded area in Figure 3 weighted by appropriate probabilities of loss states.

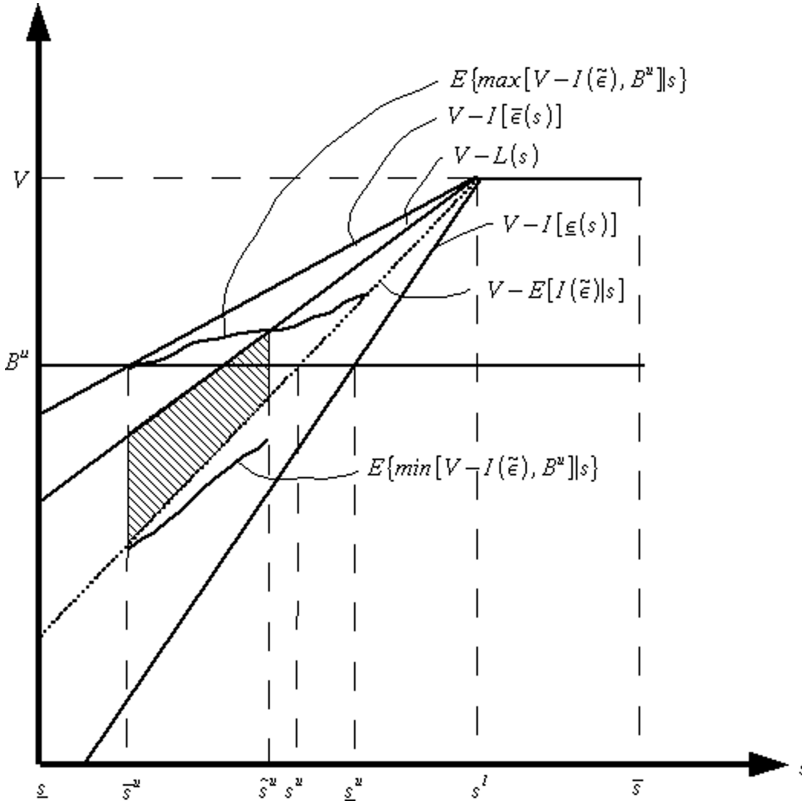
In the presence of overinvestment, the bondholders receive

$$\begin{cases} V - L(s), & s \in [\underline{s}, \bar{s}^u] \\ E\{\min[V - I(\tilde{\epsilon}), B^u] | s\}, & s \in (\bar{s}^u, \hat{s}^u) \\ B^u, & s \in [\hat{s}^u, \bar{s}]. \end{cases}$$

⁷ If $\hat{s}^u$ is not unique, there will be more than one mutually exclusive interval between $\bar{s}^u$ and the largest $\hat{s}^u$ in which Equation (11) holds, and the shareholders will overinvest.

FIGURE 3

Overinvestment With Risky Asset Reconstitution



Therefore, the value of the bonds in the presence of overinvestment

$$D(B^u) = \int_{\underline{s}}^{\bar{s}^u} [V - L(s)] p(s) ds + \int_{\bar{s}^u}^{\hat{s}^u} E\{\min[V - I(\epsilon), B^u] | s\} p(s) ds + \int_{\hat{s}^u}^{\bar{s}} B^u p(s) ds. \quad (14)$$

Notice the difference between Equations (7) and (14).

BOND COVENANT FOR MITIGATING OVERINVESTMENT

Similar to the underinvestment case, the introduction of an appropriate bond covenant, requiring the shareholders to purchase well-specified property insurance, helps mitigate the overinvestment problem. To discourage the shareholders from overinvesting, the property insurance should raise the opportunity cost of asset reconstitution so that the shareholders will not attempt to take advantage of the limited liability provision. Again, the financing constraint requires $D(B^u) = D(B^c) - p^c$.

Define $\bar{s}^c$ such that Equation (8) holds as before. Define $\hat{s}^c$ such that

$$E\{\max[V - I(\epsilon), B^c] | \hat{s}^c\} = V - L(\hat{s}^c)$$

The following claim is useful for the forthcoming analysis:

Claim 1: *For every $s \in (\bar{s}^c, s^l)$ at which $E\{\max[V - I(\bar{\epsilon}), B^c | s]\} > V - L(s)$, there exists a unique $\theta(s) > 0$ such that*

$$E\{\max[V - I(\bar{\epsilon}) + \theta(s) - B^c, 0 | s]\} = V - L(s) + \theta(s) - B^c. \quad (16)$$

Proof: See Appendix.

Notice that the proof of Claim 1 does not rely on any uniqueness assumption on $\hat{s}^c$ or $\hat{s}^u$. Equation (15) and Claim 1 suggest that to discourage overinvestment, the insurance indemnity schedule should be specified as follows: First, the property insurance should consist of deductible $L(\hat{s}^c)$ such that any property damage smaller than or equal to $L(\hat{s}^c)$ will not be indemnified. In addition, the insurance should also have a coinsurance clause such that, for all $s \in (\bar{s}^c, \hat{s}^c)$, the indemnity schedule satisfies Equation (16) so that the shareholders' wealth is the same with or without asset reconstitution.

Notice also that indemnity $\theta(s)$ satisfying Equation (16) must be sufficiently large; particularly, it must satisfy

$$\theta(s) > B^c - [V - L(s)], \quad \text{for all } s \in (\bar{s}^c, \hat{s}^c). \quad (17)$$

That is, it must be more than sufficient to make the bonds just riskless on $(\bar{s}^c, \hat{s}^c)$. To see this, consider for all $s \in (\bar{s}^c, \hat{s}^c)$,

$$V - I[\bar{\epsilon}(s)] - B^c > 0$$

and hence

$$E\{\max[V - I(\bar{\epsilon}) - B^c, 0 | s]\} > 0.$$

Suppose by contradiction that $\theta(s) < B^c - [V - L(s)]$ and that there is no overinvestment. The last two inequalities imply that

$$E\{\max[V - I(\bar{\epsilon}) + \theta(s) - B^c, 0 | s]\} > 0 > V - L(s) + \theta(s) - B^c$$

satisfying Equation (11). Therefore, there will be overinvestment. A contradiction.

There are several concerns remaining. First, $\theta(s)$ defined in Equation (16) may not be monotonic in s ; that is, θ may decrease as L increases. A nonmonotonic indemnity schedule $\theta(s)$ is very uncommon and seems to violate the principle of indemnity. Denote $\theta^* : [\underline{s}, s^l] \rightarrow \Re_+$ as the required indemnity schedule to be specified under the bond covenant. A simple solution is to set $\theta(s)$ such that Equation (16) holds and then to set

$$\theta^*(s) = \sup_{(s, \hat{s}^c)} [\theta(s)] \quad (18)$$

for all $s \in (\bar{s}^c, \hat{s}^c)$ so as to guaranty that $\theta^*(s)$ is nondecreasing as $L(s)$ increases. Now, Equation (26) in the proof of Claim 1 and Equations (16) and (18) together imply that (15) holds at $\theta = \theta^*(s)$ and there is no incentive for the shareholders to replace damaged assets on $(\bar{s}^c, \hat{s}^c)$.

Second, if the shareholders set $\theta(s) = 0$ for all $s \in [\underline{s}, \bar{s}^c]$, there will not be overinvestment on $[\underline{s}, \bar{s}^c]$. However, it is impracticable to set $\theta(s) = 0$ when asset damage is large. Alternatively, the shareholders may set $\theta(s) = \lim_{t \rightarrow \bar{s}^c} \theta(t)$ for all $s \in [\underline{s}, \bar{s}^c]$. Unfortunately, this may create additional overinvestment problems on $[\underline{s}, \bar{s}^c]$. To see this, suppose $\underline{s}$ is sufficiently small such that there exists $s^* \in (\underline{s}, \bar{s}^c)$ satisfying $V - L(s^*) + \theta(\bar{s}^c) - B^c = 0$ (as $L' < 0$ and $V - L(\bar{s}^c) + \theta(\bar{s}^c) - B^c > 0$). According to Equation (10),

$$V - I[\bar{\epsilon}(s^*)] + \theta(\bar{s}^c) - B^c > V - L(s^*) + \theta(\bar{s}^c) - B^c = 0,$$

which implies that

$$E\{\max[V - I(\bar{\epsilon}) + \theta(\bar{s}^c) - B^c, 0] | s^*\} > 0 = V - L(s^*) + \theta(\bar{s}^c) - B^c,$$

which satisfies Equation (11), giving rise to overinvestment.

To satisfy Equation (18) and to guaranty that there is no additional overinvestment as a result, the bonds must also be made riskless on $[\underline{s}, \bar{s}^c]$. In fact, the required indemnity in each loss state $s < \bar{s}^c$ should again be sufficiently large such that the following holds:

Claim 2: $\theta^*(s) > B^c - [V - L(s)]$, for all $s \in [\underline{s}, \bar{s}^c]$.

Proof: See Appendix.

Last, the functions $E\{\max[V - I(\bar{\epsilon}), B^c] | s\}$ and $V - L(s)$ may cross each other more than once.⁸ Denote $s_0 = \bar{s}^c$. Suppose the functions cross at $s_1, s_2, \dots, s_n$, where $n \geq 3$ is an odd integer and $s_0 < s_1 < s_2 < \dots < s_n$ such that

$$E\{\max[V - I(\bar{\epsilon}), B^c] | s\} < (>) V - L(s), \forall s \in (s_i, s_{i+1}) \text{ where } i \text{ is even (odd)}.$$

For all $s \in [s_i, s_{i+1})$ where i is even or 0, to discourage the shareholders from replacing damaged assets, it suffices to pick $\theta(s)$ such that Equation (16) holds. Then set $\theta^*(s)$ such that Equation (18) holds. For all $s \in [s_i, s_{i+1})$ where i is odd, it suffices to set $\theta^*(s) = \theta^*(s_{i+1})$.

Equation (17) and Claim 2 together suggest that the bond covenant should specify the required indemnity schedule such that with no asset reconstitution, the value of the company should always exceed the promised bond repayment amount so that the bondholders always receive B^c for all $s \in [\underline{s}, \bar{s}]$. This distinguishes it from the underinvestment case in which the bonds are not made fully riskless.

⁸ In fact, the two functions may coincide with each other on some nontrivial intervals. The assumption that they cross only at finitely many points simplifies the exposition without losing too much generality.

One can refer to Figure 4 to visualize the relation between $D(B^u)$, $D(B^c)$, and p^c . The four areas A_1 , A_2 , A_3 , and A_4 weighted by appropriate probabilities of loss states have the following meaning: A_1 represents the increase in the shareholders' expected wealth resulting from the insurance indemnity. A_2 represents the increase in the bondholders' expected receipt as a result of the insurance indemnity. The sum of A_1 and A_2 represents the fair premium of the required insurance. A_3 represents the bondholders' additional expected receipt as a result of the elimination of overinvestment. Finally, A_4 represents the expected reduction in bond repayment that the bondholders are willing to accept when the bond covenant is introduced. It can be checked that $D(B^c) - D(B^u) = A_2 + A_3 - A_4$, whereas $p^c = A_1 + A_2$. According to the financing constraint, therefore, $A_3 = A_1 + A_4$.

Notice that it is assumed in Figure 4 that $B^u > B^c$. However, B^u can actually be smaller than B^c , unlike the case of underinvestment. If $A_1 > A_3$ when B^c is set equal to B^u , then B^c should be raised above B^u (such that A_4 is negative) until the financing constraint is satisfied. Similarly, if $A_1 < A_3$ when B^c is set equal to B^u , then B^c should be lowered so that $B^c < B^u$. In either case, the value of the bonds in the presence of the bond covenant equals the present value of B^c .

ACTUARIALLY UNFAVORABLE INSURANCE

Allowing insurance to be actuarially unfavorable does not lead to any drastic changes in the results derived in sections 4 and 6. Following Garven and MacMinn (1993), assume that the loading charge of an insurance policy is proportional to its premium. Consider first the case of underinvestment. Denote the fair premium of the required unfavorable property insurance by p^λ . The total premium equals $(1 + \lambda)p^\lambda$, where $\lambda > 0$ is the constant loading factor. The financing constraint now requires that

$$D(B^u) - D(B^\lambda) = (1 + \lambda)p^\lambda,$$

where $D(B^\lambda)$ and B^λ are the bond price and the promised bond repayment given the purchase of appropriate unfavorable insurance. Define $\bar{s}^\lambda$ and $\underline{s}^\lambda$ such that

$$V - I[\bar{\epsilon}(\bar{s}^\lambda)] = B^\lambda = V - I[\underline{\epsilon}(\underline{s}^\lambda)].$$

To discourage the shareholders from underinvesting in the states with large property losses, the bond covenant should make the bonds riskless in the best asset reconstitution states on $[\underline{s}, \bar{s}^\lambda]$ as before. The fair premium of the required insurance now equals

$$p^\lambda = \int_{\underline{s}}^{\bar{s}^\lambda} \{I[\bar{\epsilon}(s)] - I[\bar{\epsilon}(\bar{s}^\lambda)]\} p(s) ds.$$

To pay for the loading, λp^λ , the bond price should be raised from B^c to $B^\lambda (> B^c)$, similar to the case with riskless asset reconstitution (see Garven and MacMinn, 1993). Notice that the loading charge must be sufficiently small such that the expected shareholders' wealth rises as a result of the asset reconstitution on $[\underline{s}, \bar{s}^\lambda)$ (i.e., $\bar{c}^u - \lambda p^\lambda > 0$, where $\bar{c}^u$ is the agency cost as defined in Equation (5)). Otherwise, the shareholders will have

no incentive to reconstitute damaged assets on $[\underline{s}, \bar{s}^\lambda]$. Since the bonds are riskless on $[\bar{s}^\lambda, \bar{s}]$, but are riskless only in the best asset reconstitution states on $[\underline{s}, \bar{s}^\lambda]$, the change in expected bond repayment, $(1 + \lambda)p^\lambda - p^c$, due to the loading does not equal the present value of $B^\lambda - B^c$, unlike the case of riskless asset reconstitution (see Garven and MacMinn, 1993).

Next, consider the case of overinvestment. Define $\hat{s}^\lambda$ such that

$$E\{\max[V - I(\bar{\epsilon}), B^\lambda] | \hat{s}^\lambda\} = V - L(\hat{s}^\lambda).$$

Assume for simplicity that $\hat{s}^\lambda$ is unique. To compare the indemnity schedules with fair and unfavorable insurance, define indemnity schedule θ_λ satisfying

$$E\{\max[V - I(\bar{\epsilon}) + \theta_\lambda(s) - B^\lambda, 0] | s\} - [V - L(s) + \theta_\lambda(s) - B^\lambda] = 0 \quad (19)$$

for all $(\bar{s}^\lambda, \hat{s}^\lambda)$. Now, define

$$\Delta(B, \theta) = E\{\max[V - I(\bar{\epsilon}) + \theta - B, 0] | s\} - [V - L(s) + \theta - B].$$

It is clear that

$$0 > \frac{\partial \Delta(B, \theta)}{\partial \theta} = -\frac{\partial \Delta(B, \theta)}{\partial B}. \quad (20)$$

The inequality is due to Equation (A4) in the proof of Claim 1.

For $\theta(s)$ satisfying Equation (16), it is clear that Equation (20) and $B^\lambda > B^c$ imply that

$$E\{\max[V - I(\bar{\epsilon}) + \theta(s) - B^\lambda, 0] | s\} - [V - L(s) + \theta(s) - B^\lambda] > 0. \quad (21)$$

For the left side of Equation (21) to become zero such that Equation (19) holds, Equation (20) suggests that one must set

$$\theta_\lambda(s) > \theta(s) \text{ for all } s \in [\bar{s}^\lambda, \hat{s}^\lambda]. \quad (22)$$

Denote the required indemnity schedule of the unfavorable insurance by θ_λ^* . The following states the effect of insurance loading on the required indemnity schedule:

Claim 3: $\theta_\lambda^*(s) > \theta^*(s)$, for all $s \in [\underline{s}, \hat{s}^\lambda]$.

Proof: The claim is a direct consequence of Equation (22) and the concerns raised in Section Bond Covenant for Mitigating Overinvestment (particularly, Equation (18)).

Q.E.D

Notice that for any loss state $s \in [\bar{s}^\lambda, \hat{s}^\lambda]$, it can be checked using Leibniz's rule (similar to the proof of Claim 1) that $dE\{\max[V - I(\bar{\epsilon}), B] | s\}/dB > 0$. Since $V - L(s)$ is increasing in s , it will cross $E\{\max[V - I(\bar{\epsilon}), B^\lambda] | s\} (> E\{\max[V - I(\bar{\epsilon}), B^c] | s\})$ at $s = \hat{s}^\lambda$, which is clearly greater than $\hat{s}^c$. Notice also that similar to the underinvestment case, to mitigate the overinvestment problem, the loading charge must be sufficiently small such that the change in the shareholders' expected wealth is positive (i.e., $\bar{c}'' - \lambda p^\lambda > 0$,

where $\bar{c}''$ is as defined in Equation (13)). Finally, since the bonds are made riskless on $[\underline{s}, \bar{s}]$ due to the conclusion on θ^* in Section Bond Covenant for Mitigating Overinvestment and Claim 3, the change in expected bond repayment, $(1 + \lambda)p^\lambda - p^c$, due to the loading equals the present value of $B^\lambda - B^c$, contrary to the underinvestment case with risky asset reconstitution.

CONCLUSION

Mayers and Smith (1987) and subsequent researchers have analyzed the underinvestment problem of the shareholders of a limited liability company financed partly by bonds when the net effect of replacing damaged property is certain. They suggest that a bond covenant specifying an appropriate insurance requirement mitigates the problem. Recently, asymmetric information overinvestment problems have been studied extensively in the economics and finance literature but have received little attention in the insurance literature. This article suggests that both overinvestment and underinvestment are common potential asymmetric information problems inherent in the reconstitution of damaged assets whose effects are stochastic. These problems cannot be prevented by conventional investment restrictions in bond covenants that require new projects to be undertaken if and only if they have positive net present values. The reason is that replacing damaged assets is not recorded as a new investment in general. Similar to the underinvestment problem with riskless asset reconstitution, the underinvestment and overinvestment problems with risky asset reconstitution can be mitigated by imposing bond covenants containing appropriate insurance requirements.

A standard insurance requirement in a bond covenant is often simple because of cost consideration and the difficulties in monitoring and enforcing. It often states that the borrowing company should purchase insurance "to substantially the same extent as its competitors" (see e.g., Smith and Warner, 1979). According to the results derived in this article, however, such a requirement is generally not very effective. In addition, this article shows that the indemnity schedules required for mitigating typical underinvestment and overinvestment problems are very different in general. Of course, the difference is unimportant when insurance is actuarially fair, in which case the shareholders can simply be required to buy full insurance, which is always sufficient (but not necessary) for solving both problems. The difference becomes critical when insurance is actuarially unfavorable and more-than-required insurance is always undesirable.

APPENDIX

Proof of Claim 1: Fix any $s \in (\bar{s}^c, s^l)$ at which

$$E\{\max[V - I(\bar{\epsilon}) - B^c, 0] | s\} > V - L(s) - B^c. \quad (A1)$$

For θ sufficiently large such that $V - I[\underline{\epsilon}(s)] + \theta \geq B^c$, it can be verified that

$$E\{\max[V - I(\bar{\epsilon}) + \theta - B^c, 0] | s\} = E[V - I(\bar{\epsilon}) + \theta - B^c | s] < V - L(s) + \theta - B^c. \quad (A2)$$

The inequality in Equation (A2) is due to Equation (10). Define $\epsilon^*(\theta; s)$ such that $V - I[\epsilon^*(\theta; s)] + \theta = B^c$. One can write

$$E\{\max[V - I(\tilde{\epsilon}) + \theta - B^c, 0] | s\} = \int_{\epsilon^*(\theta; s)}^{\tilde{\epsilon}(s)} [V - I(\epsilon) + \theta - B^c] f(\epsilon | s) d\epsilon. \quad (\text{A3})$$

Using Equation (A3) and differentiating with respect to θ using Leibniz's Rule gives

$$\frac{d}{d\theta} \{E\{\max[V - I(\tilde{\epsilon}) + \theta - B^c, 0] | s\} - [V - L(s) + \theta - B^c]\} = \int_{\epsilon^*(\theta; s)}^{\tilde{\epsilon}(s)} f(\epsilon | s) d\epsilon - 1 < 0. \quad (\text{A4})$$

Therefore, $E\{\max[V - I(\tilde{\epsilon}) + \theta, B^c] | s\} - [V - L(s) + \theta]$ is strictly decreasing in θ . This together with Equations (A1) and (A2) implies that there exists a unique θ for every $s \in (\bar{s}^c, s^l)$ such that Equation (16) holds. This proves part (a). Q.E.D.

Proof of Claim 2: Suppose by contradiction that there exists $s^{**} \in [\underline{s}, \bar{s}^c)$ such that $0 \leq \theta^*(s^{**}) < B^c - [V - L(s^{**})]$. For ease of exposition, denote $\theta^\# = \theta^*(s^{**})$ such that $0 \leq \theta^\# < B^c - [V - L(s^{**})]$. This together with no overinvestment implies that

$$V - I[\tilde{\epsilon}(s^{**})] + \theta^\# - B^c < 0. \quad (\text{A5})$$

Now, Equation (A5) together with $V - I[\tilde{\epsilon}(\bar{s}^c)] - B^c = 0$ and $I' < 0$ implies that there exists $s^\# \in (s^{**}, \bar{s}^c)$ such that $V - L(s^\#) + \theta^\# - B^c > 0$ and $\theta(s^\#) = \theta^\#$ satisfies Equation (16) at $s = s^\#$, that is,

$$E\{\max[V - I(\tilde{\epsilon}) + \theta^\# - B^c, 0] | s^\#\} = V - L(s^\#) + \theta^\# - B^c. \quad (\text{A6})$$

Equation (A6) implies that

$$V - I[\tilde{\epsilon}(s^\#)] + \theta^\# - B^c > V - L(s^\#) + \theta^\# - B^c. \quad (\text{A7})$$

Now, let $s^\#$ fall so that the left side of Equation (A7) tends to 0^+ such that the right side eventually becomes negative implying that the shareholders will replace damaged assets and there will be overinvestment. A contradiction. Q.E.D.

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