

# Accounting Information, Renegotiation, and Debt Contracts\*

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## Abstract

We study the role of accounting measurement in the renegotiation of debt contracts. The use of accounting measurement in the control rights allocation rule has a trade-off. It improves the initial allocation of control rights but induces accounting manipulation. Renegotiation adds a new incentive for accounting manipulation and affects both aspects of the trade-off. A lower renegotiation cost reduces the benefit of accounting-based allocation of control rights and exacerbates accounting manipulation. With this interaction, we show that the ex-ante firm value is increasing in renegotiation cost if and only if the accounting quality is high and the manager's bargaining power is large. The interaction also generates some new insights about the equilibrium use of accounting measurement in debt contracts, accounting manipulation, the frequency of renegotiation and the interest rate.

**JEL classification:** M40, M41, G32

**Key Words:** incompleteness, renegotiation, accounting-based covenant, debt contract, accounting manipulation

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# 1 Introduction

Renegotiation and accounting-based allocation of control rights are two central features of debt contracts. Ex-ante the lender and the borrower may find it costly or impossible to fully describe all possible future contingencies that could arise in the bilateral relation. To deal with this contractual incompleteness, they agree on how to assign the initial control rights through an allocation rule. The optimal allocation rule is often contingent on accounting information, which is a primary source of contractible signals. [Armstrong, Guay, and Weber \(2010\)](#) provide a thorough review of the use of accounting measurement in the debt contract. Ex post, the initial control rights allocation may turn out to be such that the party with the control rights doesn't have the private incentive to take actions that maximize their joint surplus. In this case, the lender and the borrower can renegotiate the contractual terms to increase the joint surplus without making either party worse off. Thus, renegotiation frequently arises on the equilibrium path as an ex-post remedy to the contractual incompleteness and interacts with the initial allocation of control rights. [Roberts and Sufi \(2009\)](#) report that over 90% of long-term debt contracts are renegotiated before their stated maturity and the renegotiation process is partially controlled by the initial contractual design.

Despite the ubiquitous joint use of renegotiation and accounting-based allocation of control rights in debt contracts, their conceptual interaction is not clear. The accounting literature has paid little attention to renegotiation of the debt contract until recently. After reviewing the debt contracting literature, [Armstrong, Guay, and Weber \(2010\)](#) suggest promising “new lines of research” and state that “Second, there has been little research on the role of accounting information in the renegotiation process.” On the other hand, the literature on renegotiation, studied mainly in economics and finance (e.g., [Aghion and Bolton \(1992\)](#), [Rajan \(1992\)](#)), has treated accounting information as exogenous. [Christensen, Nikolaev, and Wittenberg-Moerman \(2016, p.413\)](#) state that “the key limitation of the theories discussed above is that they generally take the measurement and properties of accounting information as given. It is assumed that an accounting system measures the economic state (or effort) in an exogenous way. But, to accounting academics, it is important to understand the consequences of various accounting rules and information qualities.”

In this paper, we explicitly explore the interaction between renegotiation and accounting-based allocation of control rights in debt contracts. Our model augments a basic incomplete contracting

setting à la [Aghion and Bolton \(1992\)](#) with accounting manipulation. In the model, the socially optimal real action is state-contingent, but neither the lender nor the manager has private incentives to implement the socially optimal action in all states. The debt contract consists of an interest rate and an allocation rule of the control right based on an accounting measurement of the state. After the state and its accounting measurement are realized, the control rights (i.e., the right to make the real decision) are assigned according to the allocation rule. If the initial allocation of control rights is inefficient, the lender and the manager can renegotiate to increase the surplus and divide the surplus through Nash bargaining.

Departing from this basic setting in [Aghion and Bolton \(1992\)](#), we introduce a friction that the borrower-manager can manipulate the accounting report to avoid the loss of control rights. This friction, while assumed away in the incomplete contracting literature in economics and finance, has long been emphasized in the positive accounting theory. The contractual reliance on accounting information in debt contract induces the borrower to engage in accounting manipulation and that the properties of accounting information and its contractual use are jointly determined (e.g., [Watts and Zimmerman \(1986\)](#), [Armstrong, Guay, and Weber \(2010\)](#) and [Guttman and Marinovic \(2017\)](#)).<sup>1</sup> The lender rationally anticipates the upcoming accounting manipulation and price protects herself, and the manager internalizes the economic consequences of accounting manipulation. As a result, the presence of accounting manipulation alters the initial contractual design and its interaction with renegotiation

The optimal use of accounting information in the allocation rule involves a trade-off. On the one hand, it improves the initial allocation of control rights and reduces the frequency of subsequent costly renegotiation. On the other hand, the allocation rule's reliance on accounting information also induces the manager to engage in accounting manipulation, which not only consumes real resources but also leads to unnecessary misallocation of control rights from the social perspective. The optimal reliance on accounting information in the allocation rule is determined by this trade-off.

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<sup>1</sup>Its empirical test had been hampered by data availability, but has accelerated in the past decade (see [Armstrong, Guay, and Weber \(2010\)](#) for a survey). For example, [Dichev and Skinner \(2002\)](#) take advantage of the Dealscan database and provide strong evidence supporting the hypothesis. [Beatty and Weber \(2003\)](#) find that borrowers whose bank debt contracts allow accounting method changes to affect contract calculations are more likely to make income-increasing rather than income-decreasing changes and when the expected cost of technical violations is higher. In a survey of executives, [Graham, Harvey, and Rajgopal \(2005\)](#) find that firms closer to violating covenants are more likely to make accounting choices to avoid violating covenants.

Renegotiation affects both the benefit and cost of using accounting information in the allocation rule. First, the value of avoiding costly renegotiation is decreasing in renegotiation cost. As the renegotiation process becomes more efficient, it becomes less important to assign the initial control rights accurately ex-ante in the contract as two parties could use ex-post renegotiation to have the surplus-maximizing action taken. In one extreme, the initial allocation of control rights would be irrelevant for efficiency if renegotiation were costless, as implied by the celebrated Coase Theorem (Coase (1937)). Second, accounting manipulation, which is an endogenous cost of using accounting-based allocation of control rights, is also decreasing in renegotiation cost. As renegotiation becomes more efficient, the surplus from renegotiation becomes larger. Therefore, the initial control rights, which serve as the status quo of renegotiation, become more valuable to the manager. The manager thus manipulates more to jockey for a better position in the subsequent renegotiation.

This interaction between renegotiation and accounting-based allocation of control rights generates new insights. We show that a lower renegotiation cost reduces the ex-ante firm value if and only if the accounting quality is high and the manager's bargaining power is large. A lower renegotiation cost directly improves the ex-post surplus from renegotiation, which increases the firm value. This benefit is decreasing in accounting quality. When accounting quality is high, the optimal allocation rule relies heavily on accounting information and ex-post renegotiation is infrequent. As a result, the cost saving from a lower renegotiation cost is limited. However, anticipating the increased surplus from renegotiation, the manager engages in more accounting manipulation ex post to secure initial control rights. Since the lender price protects herself ex-ante, the cost of accounting manipulation is ultimately borne by the manager and reduces the firm value. This manipulation incentive is increasing in the manager's bargaining power as the latter increases his share of the surplus from renegotiation. Thus, a lower renegotiation cost results in lower firm value when the indirect effect dominates the direct effect, which occurs when the accounting quality is high and the manager's bargaining power is large.

The same interaction between renegotiation and accounting-based allocation of control rights also yields some new predictions about the equilibrium use of accounting information in the allocation rule, the equilibrium accounting manipulation level, the equilibrium misallocation of control rights and the frequency of renegotiation, and the equilibrium interest rates. For example, the

equilibrium manipulation is decreasing in renegotiation cost and accounting quality if the accounting quality is high, but increasing in renegotiation cost and invariant to accounting quality if the accounting quality is low. For another example, the equilibrium misallocation of control rights and the frequency of renegotiation are always decreasing in manipulation cost and in the renegotiation cost. All these results readily turn into testable empirical predictions.

Our paper contributes to the incomplete contracting literature on debt contracts. This literature, developed mainly in economics and finance, has focused on various institutions as solutions to the incomplete contracting problem, including bankruptcy (e.g., [Townsend \(1979\)](#)), bank monitoring (e.g., [Diamond \(1991\)](#)), capital structure (e.g., [Aghion and Bolton \(1992\)](#), [Rajan \(1992\)](#)), and ownership and integration (e.g., [Williamson \(1985\)](#), [Grossman and Hart \(1986\)](#)). A direct solution to the contractual incompleteness, however, is to measure the state and make it contractible. The accounting system, by measuring a firm’s transactions and events in a rigorous and systematic manner, is a major source of contractible signals. In fact, [Aghion and Bolton \(1992, p.477\)](#) define the “degree of incompleteness of the ex-ante contract” as the “distance” between the contractible signal and the state. In other words, contracting is incomplete only to the extent that accounting system is not perfect in measuring firms’ states. By incorporating the endogenous accounting information into the incomplete contracting literature, we enrich the set of solutions to deal with the contractual incompleteness and provide new insights on the design of debt contract. For example, we show that making renegotiation more costly could improve the firm value in the presence of endogenous accounting manipulation.

[Laux \(2018\)](#) applies the incomplete contracting approach to study debt contracting with renegotiation and accounting manipulation.<sup>2</sup> Affording lenders more protection through covenants is often viewed as desirable even in the presence of accounting manipulation, on the grounds that it improves both ex-post liquidation decisions and ex-ante managerial efforts incentives. [Laux \(2018\)](#) challenges this view and shows that it may not be true in the presence of renegotiation. In contrast, we use a different model to study a different research question. Starting from the premise (the main

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<sup>2</sup>Some have studied debt contracting with renegotiation but without accounting manipulation (e.g., [Gox and Wagenhofer \(2009\)](#), [Caskey and Hughes \(2012\)](#), [Gigler, Kanodia, Sapra, and Venugopalan \(2009\)](#), [Garleanu and Zwiebel \(2009\)](#), and [Li \(2013\)](#)). Others, such as [Gao \(2013\)](#) and [Guttman and Marinovic \(2017\)](#), have examined debt contracting with accounting manipulation but without permitting renegotiation. [Sridhar and Magee \(1996\)](#) study debt contracting with manipulation and covenant waiver, a restrictive form of renegotiation that doesn’t allow the substitution of interest rates and control rights.

result in [Laux \(2018\)](#)) that the optimal allocation of control rights is interior (not unilateral), we focus on how renegotiation and covenants interact in the presence of accounting manipulation. We don't model the ex-ante effort choices and our main result that renegotiation can reduce the firm value is absent in [Laux \(2018\)](#). Moreover, managers make accounting choices to avoid technical defaults of debt contracts in practice. While some might be illegal, many involve professional judgment and discretion and thus are not actionable by regulators. While [Laux \(2018\)](#) focuses exclusively on actionable accounting frauds to circumvent covenants, we accommodate both types of accounting manipulation.

Accounting research has also been influenced by the economic role of renegotiation in contract theory. In standard (complete) contracting setting where commitment is valuable such as those studied by [Fudenberg and Tirole \(1990\)](#), introducing renegotiation can be detrimental. The fundamental economic force is straightforward: in a world where commitment is valuable, reducing commitment such as allowing ex post renegotiation reduces the power of ex ante commitment, destroys incentives, and lowers social welfare. On the surface, our paper also features a detrimental effect of renegotiation because the equilibrium ex ante firm value can be increasing in renegotiation cost. However, our channel is qualitatively different: renegotiation becomes detrimental only when earnings manipulation is endogenous and when bargaining power and manipulation cost are both high enough.<sup>3</sup> As such, the detrimental effect of the renegotiation is induced by the interaction of manipulation and performance-based control right allocation. The relation between earnings manipulation and renegotiation in our model is also distinct from other applied work in accounting which studies renegotiation and earnings manipulation. For example, in [Demski and Frimor \(1999\)](#), performance garbling, interpreted as earnings manipulation helps to lower the ex ante agency cost imposed by the ex post renegotiation. Somewhat similarly, in [Arya, Glover, and Sunder \(1998\)](#), earnings manipulation become beneficial because it reduces the welfare loss due to the principal's inability to commit to not replace the agent in the interim stage. In contrast, the earnings manipulation in our paper provides no benefit to the economy and it is only tolerated as an unavoidable

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<sup>3</sup>In fact, our base-setting is reminiscent of the renegotiation benefit in optimal contract setting of [Hermalin and Katz \(1991\)](#), where the renegotiation opportunity restores first-best efficiency in a standard moral hazard setting with an additional assumption that the principal but not the judge observes agent's action choice. Here the opportunity to renegotiation improves welfare precisely because it offers flexibility: the principal will only renegotiate if he sees the agent has chosen the desirable action. Knowing this forthcoming opportunity, the agent has the ex ante incentive to provide the desirable action (unlike the [Fudenberg and Tirole \(1990\)](#) setting).

consequence of employing performance-based control right allocation.

The major application of the incomplete contracting approach to accounting research is the literature on subjective performance evaluation and relational contracts. When a performance measure is ex-ante not contractible (but ex-post observable), the contract, both between the principal and the agents and among agents, can be implicit and informal. The early literature has focused on one-period models (e.g., [Baiman \(1995\)](#), [Rajan and Reichelstein \(2009\)](#)) and later has developed into multi-period ones (e.g., [Arya, Fellingham, and Glover \(1997\)](#), [Baldenius, Glover, and Xue \(2016\)](#)). [Glover \(2012\)](#) provides an excellent review of the literature.

The rest of the paper proceeds as follows. We specify the model in [Section 2](#), characterize its equilibrium in [Section 3](#) and conduct comparative statics to present the main results in [Section 4](#). [Section 5](#) discusses the model’s empirical implications and [Section 6](#) concludes.

## 2 The model

We augment a basic incomplete contracting setting à la [Aghion and Bolton \(1992\)](#) with accounting manipulation. A penniless borrower-manager seeks funding for the set-up costs  $K$  of his new project at date 0. At this stage, the manager is facing identical lenders and thus has all the bargaining power. He makes a take-it-or-leave-it offer to a lender who accepts the offer that makes her break-even. This defines the lender’s individual rationality constraint. Due to the lender’s price protection, the manager’s expected payoffs at date 0 is equal to the expected social surplus or the (ex-ante) firm value. We thus use these three terms interchangeably. We refer to the manager as “he” and the lender as “she” for convenience.

If the project is funded, the state  $\theta$  is publicly realized and observed at date 1. State  $\theta$  can be interpreted as the project’s underlying economic profitability. It is either good or bad, *i.e.*,  $\theta \in \{G, B\}$ , with a common prior  $\Pr(\theta = B) = p$ . After observing the state  $\theta$ , the project can be either continued (kept at status quo) or restructured at date 2. The decision to continue is denoted as  $a = 1$  and to restructure as  $a = 0$ , *i.e.*,  $a \in \{0, 1\}$ . The project’s stochastic payoffs, realized at date 3, consist of both cash flows and non-plegible private benefit to the manager. Both components of the payoffs are jointly determined by the state  $\theta$  and the action  $a$ . Specifically, if it is continued in state  $\theta$ , the project pays out cash flow  $R$  with probability  $\gamma_\theta$  and 0 otherwise.

If it is restructured in state  $\theta$ , the project pays out cash flow  $R$  with probability  $\gamma_\theta$  and cash flow  $r < R$  with probability  $1 - \gamma_\theta$ . We assume that  $1 > \gamma_G > \gamma_B > 0$  so that the good versus bad states are properly defined and that  $R$  is sufficiently large so that the project is always funded.<sup>4</sup> In contrast, the manager receives a private benefit  $X$  if and only if the project is continued, regardless of the state. In other words, the private benefit is not “comonotonic” with the total payoffs, an interesting case studied in [Aghion and Bolton \(1992\)](#). In essence, the restructuring improves the project’s cash flow at the expense of sacrificing the manager’s private benefit. The expected joint surplus, defined as the sum of the cash flows and the private benefit, is thus

$$w(\theta, a) = \gamma_\theta R + aX + (1 - a)(1 - \gamma_\theta)r. \quad (1)$$

The central friction in this incomplete contracting setting is that state  $\theta$  is ex post observable but ex ante not contractible.<sup>5</sup> Instead, at date 1, there is a contractible signal  $s \in \{g, b\}$  that measures state  $\theta$ . Naturally, we interpret this contractible signal  $s$  as an accounting measurement of the state. In other words, the underlying economic profitability is not contractible, but its accounting measurement is contractible. [Aghion and Bolton \(1992\)](#) assumes that the exact mapping from state  $\theta$  to its accounting measurement  $s$  is exogenous, a key assumption we will relax later.

To deal with the contractual incompleteness, the debt contract designed at date 0 includes an accounting-based control rights allocation rule  $\sigma_s \in [0, 1]$ , in addition to a face value  $d$ . In exchange for the initial investment  $K$ , the manager promises to pay back an amount up to  $d$  at date 3 and to share the control rights at date 2 according to the allocation rule  $\sigma_s$ .  $\sigma_s$  stipulates the probability that the manager retains the control rights when the signal realization is  $s$ . It is more convenient to define  $\delta \equiv \sigma_g - \sigma_b \in [0, 1]$  and use the pair  $(\sigma_g, \delta)$  to represent the allocation rule.  $\delta$  measures the allocation rule’s reliance on accounting measurement.  $\delta = 0$  indicates that the allocation doesn’t rely on accounting report at all while  $\delta = 1$  indicates that the covenant is most sensitive to accounting report.<sup>6</sup> Let  $\tau = L$  ( $\tau = M$ ) denotes the event that the lender (the

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<sup>4</sup>Given our focus on the features of debt contract, we take standard-debt contracts as given in building our model. If other contracts forms such as equity contracts are considered, an upper bound on  $R$  can be imposed to ensure the superiority of debt-contracts. See footnote 11 for details.

<sup>5</sup>As [Aghion and Bolton \(1992\)](#) have discussed, the assumption that  $\theta$  is publicly observed ex-post is “mostly for convenience since it allows us to abstract away from issues of bargaining under asymmetric information.” (page 477)

<sup>6</sup>This probabilistic representation is used for simplicity reasons in order to make the economic forces transparent. In practice the precise use of accounting measurement can be extremely rich and complicated and here we abstract

manager) receives the control rights according to the allocation rule.

After the initial assignment of the control rights at date 2, the manager and the lender may renegotiate the contract. Since they are locked into the bilateral relation at this stage, the manager and the lender split the bargaining power with  $\kappa \in [0, 1]$  and  $1 - \kappa$ , respectively. Renegotiation is costly and consumes  $\lambda \in (0, 1)$  fraction of the joint surplus.<sup>7</sup> <sup>8</sup> For simplicity, we assume that the renegotiation cost is paid by the manager. After renegotiation, the action is taken and the project’s payouts are divided between the lender and the manager according to the (potentially renegotiated) contract.

Now we introduce our main departure from [Aghion and Bolton \(1992\)](#). As we have discussed in the Introduction, [Aghion and Bolton \(1992, p.477\)](#) defines the degree of contractual incompleteness as the distance between state  $\theta$  and its measurement  $s$ . However, they treat the distance as exogenously given. Instead, we assume that the manager can take actions to influence the quality of the measurement of the state. In other words, we endogenize the contractual incompleteness by incorporating a realistic feature of the production of contractible measurements. Specifically, we assume that the accounting system generates a perfect initial signal  $s' = \theta$  in absence of the manager’s manipulation.<sup>9</sup> However, after privately observing the initial signal  $s'$ , the manager can take a costly action  $m \in [0, 1]$  to change the bad signal  $s' = b$  to a favorable one  $s = g$  with probability  $m$  :

$$\Pr(s = g | s' = g, m) = 1 \quad \text{and} \quad \Pr(s = g | s' = b, m) = m. \quad (2)$$

We use the broad term “accounting manipulation” to refer to the manager’s activities that 

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away from the complexity and but capture the discretion in designing the degree (or strength) of its use. Similar assumptions are made by [Aghion and Bolton \(1992\)](#).

<sup>7</sup>In practice, renegotiation of a debt contract is not costless. In addition to direct costs such as legal fees, renegotiation is also costly in the form of time and efforts both the lender and borrower spend in understanding the proposed transactions and implications for both parties. The cost is also increasing in the dispersion of lenders. It is more costly to renegotiate a public bonds contract than a syndicated loans contract than a single-bank loan contract. We treat the renegotiation cost as exogenous to focus on its comparative statics. [Tirole \(2006\)](#) provides multiple ways to micro-found the indirect cost of renegotiation. For example, [Aghion and Bolton \(1992\)](#) endogenize the cost of renegotiation from the manager’s limited wealth. When the manager doesn’t have enough wealth to pay the lender for the control rights ex-post, renegotiation fails and the project is inefficiently liquidated.

<sup>8</sup>Assuming a fixed percentage of total renegotiation surplus is a transparent way of model the existence of the cost. An alternative specification (such a fixed dollar amount per occurrence) would lead to similar result but with cumbersome notations.

<sup>9</sup>Unlike [Aghion and Bolton \(1992\)](#), we assume away any noise in the initial signal so as to focus on the endogenous imperfection in the accounting report resulting from managerial opportunism. Our main results are qualitatively the same if the initial signal is imperfect and has exogenous noise.

influence the accounting report. The private cost of manipulation to the manager is  $C(m) = \frac{c}{2}m^2$  with  $c > 0$ . Since manipulation is the only source of imperfection in accounting reports, we use manipulation cost and accounting quality interchangeably and refer to a higher manipulation cost as higher accounting quality.

Finally, let  $L_G \equiv X - (1 - \gamma_G)r$  and  $L_B \equiv (1 - \gamma_B)r - X$ , we make three assumptions so as to assure that the control rights allocation rule is non-trivial.

$$\textit{Assumption 1} : (1 - \gamma_B)r > X > (1 - \gamma_G)r$$

$$\textit{Assumption 2} : K > r$$

$$\textit{Assumption 3} : (1 - p)L_G > pL_B$$

*Assumption 3* is made for convenience. It sets the default that the control rights should be assigned to the manager in the absence of any information about the state. Assuming otherwise doesn't qualitatively affect the results. We will explain below how *Assumption 1* and *Assumption 2* create a demand for state-contingent allocation of control rights.

The following time-line describes the events during the course of the debt contracting.

Date	0	1	2	3
Manager offers a debt contract $\{d, \delta, \sigma_g\}$ in exchange for $K$ ; If lender accepts, investment takes place		State $\theta$ is revealed; Manager observes $s'$ and chooses manipulation $m$ ; signal $s$ is realized	Initial control rights are assigned; Renegotiation, if any, takes place; action $a$ is chosen	Payoffs are realized.

Figure 1: The Time-line

An equilibrium in our model is characterized as a set values of the endogenous variables  $\langle \delta^*, \sigma_g^*, d^*, m^*, a^* \rangle$  such that the following incentive compatibility and rationality conditions are satisfied:

1. On date 2, the action  $a^*$  is chosen to maximize the joint surplus after possible renegotiation;

2. On date 1, the manager chooses manipulation  $m^*$  to maximize his expected payoff, condition on his private signal  $\langle s' \rangle$  and state  $\theta$ ;
3. On date 0, the manager designs debt contract  $\langle \delta^*, \sigma_g^*, d^* \rangle$  to maximize his expected payoff at date 0, subject to the lender's participation constraint.

### 3 The equilibrium characterization

We use backward induction to solve the model.

#### 3.1 Preliminary analysis

Before we proceed, we prepare preliminary analysis for solving the model. We first explain how *Assumption 1* and *Assumption 2* create a demand for state-contingent allocation of control rights.

First, the project's total expected payoff  $w(\theta, a)$  is defined in equation 1. The restructuring ( $a = 0$ ) essentially converts the manager's private benefit  $X$  to stochastic cash flow ( $r$ ). *Assumption 1* requires that this conversion is socially optimal (maximizes the joint surplus) in and only in the bad state. To see this, consider the difference of the total expected payoff under restructuring versus under continuation in the bad state  $\theta = B$  :

$$w(B, 0) - w(B, 1) = L_B \equiv (1 - \gamma_B)r - X > 0.$$

$L_B > 0$  is due to the first part of *Assumption 1* and implies it is socially optimal to restructure the project in the bad state.  $L_B$  thus measures the efficiency loss in the bad state when the action deviates from the first-best.

Similarly, in the good state  $\theta = G$ , the difference of the total expected payoff under continuation versus under restructuring is

$$w(G, 1) - w(G, 0) = L_G \equiv X - (1 - \gamma_G)r > 0.$$

$L_G > 0$  is due to the second part of *Assumption 1* and implies it is socially optimal to continue the project in the good state.  $L_G$  measures the efficiency loss in the good state when the action

deviates from the first-best. Therefore, under *Assumption 1*, the socially optimal action is state contingent:  $a_G^{FB} = 1$  and  $a_B^{FB} = 0$ . With the first-best actions, the firm value, which is the project's date-0 expected payoffs net of cost  $K$ , is

$$V^{FB} = E_\theta[w(\theta, a_\theta^{FB})] - K = \gamma R + (1 - p)X + p(1 - \gamma_B)r - K, \quad (3)$$

where  $\gamma \equiv (1 - p)\gamma_G + p\gamma_B$ .

The project's total expected payoff is divided between the manager  $w^M(\theta, a)$  and the lender  $w^L(\theta, a)$  under the debt contract  $d$ . For a given face value, the lender's share of the project's expected payoff in state  $\theta$  with action  $a$  is

$$w^L(\theta, a) = \gamma_\theta d + (1 - a)(1 - \gamma_\theta) \min\{d, r\}.$$

Even though the value  $d$  will be determined in equilibrium, we know that  $d \geq K$ . Otherwise, the lender cannot recoup the principal  $K$ . *Assumption 2* then implies that  $d > r$ . As a result,  $w^L(\theta, a)$  is simplified as

$$w^L(\theta, a) = \gamma_\theta d + (1 - a)(1 - \gamma_\theta)r.$$

It can be verified that  $w^L(\theta, 0) - w^L(\theta, 1) = (1 - \gamma_\theta)r > 0$ . Thus, under *Assumption 2*, the lender always prefers restructuring, regardless of the state.

Similarly, the manager's share of the project's expected payoff in state  $\theta$  with action  $a$  is

$$w^M(\theta, a) = w(\theta, a) - w^L(\theta, a) = \gamma_\theta(R - d) + aX.$$

It is straightforward that  $w^M(\theta, 1) - w^M(\theta, 0) = X > 0$ . Thus, under *Assumption 2*, the manager always prefers continuation, regardless of the state.

Collecting these results, we have the following lemma with its proof already given above.

**Lemma 1** *Under Assumption 1 and 2, the socially optimal action is to continue the project in and only in the good state. However, regardless of the state, the manager prefers continuation while the lender prefers restructuring. That is,  $a_G^{FB} = 1$  and  $a_B^{FB} = 0$ ,  $a_G^M = a_B^M = 1$ , and  $a_G^L = a_B^L = 0$ .*

The first-best state-contingent action is obtained in the absence of the fundamental friction of contractual incompleteness. If the state is contractible, then the first-best action can be contracted in the debt contract. Renegotiation and accounting-based allocation rule are two instruments to deal with the contractual incompleteness. In one extreme, if renegotiation ex-post is costless, then the celebrated Coase Theorem (Coase (1937)) states that renegotiation leads to the first-best action without additional cost. In the other extreme, if accounting information perfectly reveals the state, that is,  $s = \theta$ , then the accounting-based allocation of control rights  $\sigma_g = 1$  and  $\delta = 1$  also leads to the first-best action without renegotiation. Therefore, the interaction between renegotiation and accounting-based control rights allocation arises only when renegotiation is costly and when accounting information is imperfect, the interesting case we will focus on from now on.

### 3.2 Renegotiation and the continuation decision at date 2

Since the state  $\theta$  is not contractible, the control rights allocation rule can only be contingent on accounting signal  $s$ , which may not truthfully reflect the state due to manipulation. When the accounting measure deviates from the true state, the control rights may be initially assigned to the party who doesn't have the private incentive to take the socially optimal date-2 action. Specifically, misallocation arises either when the manager receives the control rights in the bad state or when the lender receives the control rights in the good state. In either situation, the manager and the lender may find ex-post renegotiation beneficial. We analyze each case separately.

**Misallocation scenario 1:** the manager receives the control rights in the bad state. In the absence of renegotiation, by Lemma 1, the manager prefers continuation that leads to an efficiency loss of  $L_B$ . Renegotiation helps the two parties to avoid this loss and create a net efficiency gain of  $(1 - \lambda)L_B$ , which is split between the manager and the lender according to their respective bargaining power ( $\kappa$  and  $1 - \kappa$ ).

Specifically, the renegotiation could be implemented as follows. The manager agrees to restructure the project provided that the lender is willing to reduce the face value by an amount  $\Delta d_B$ . The adjustment of the face value  $\Delta d_B$  is determined in such a way that the manager and the lender split the surplus from renegotiation according to their respective bargaining powers. The manager's net payoff is  $\gamma_B(R - d) + \gamma_B\Delta d_B - \lambda L_B$  with renegotiation and  $\gamma_B(R - d) + X$  without renegotiation.

Taking the difference of the two and equating it to  $\kappa(1 - \lambda)L_B$ , we can solve for the face value adjustment  $\Delta d_B$  as

$$\Delta d_B = \frac{X + \kappa(1 - \lambda)L_B + \lambda L_B}{\gamma_B}. \quad (4)$$

**Misallocation scenario 2:** the lender receives the control rights in the good state. By Lemma 1, the lender prefers to restructure the project in the absence of renegotiation, which results in an efficiency loss of  $L_G$ . Following the same argument above, the manager and the lender renegotiate to realize and divide the net efficiency of  $(1 - \lambda)L_G$ .

Specifically, this renegotiation outcome can be implemented as follows. The manager offers a higher face value to “buyback” back the control rights from the lender. The adjustment of the face value  $\Delta d_G$  is determined in such a way that the manager and the lender split the surplus from renegotiation according to their respective bargaining powers. The manager’s net payoff is  $\gamma_G(R - d) + X - \gamma_G\Delta d_G - \lambda L_G$  with renegotiation and  $\gamma_G(R - d)$  without renegotiation. Taking the difference of the two and equating it to  $\kappa(1 - \lambda)L_G$ , we can solve for the face value adjustment  $\Delta d_G$  as

$$\Delta d_G = \frac{(1 - \gamma_G)r + (1 - \kappa)(1 - \lambda)L_G}{\gamma_G}. \quad (5)$$

Because of renegotiation, the interim action is always chosen to maximize the joint surplus at date 2, *i.e.*,  $a_\theta^* = a_\theta^{FB}$ , regardless of the initial control rights allocation from the debt contract. However, this does not imply that the contractual design at date 0 is inconsequential for two reasons. First, since renegotiation is costly, a more accurate initial allocation of control rights still improves efficiency by reducing the frequency of subsequent costly renegotiation. Second, since renegotiation involves the division of the efficiency gain between the manager and the lender, it changes the manager’s manipulation incentives and the quality of accounting reports. The initial contract design is both affected by and affects the manager’s manipulation.

### 3.3 The accounting manipulation at date 1

At date 1 after the debt contract has been signed, the manager receives a private initial signal. If it is bad, *i.e.*,  $s' = b$ , the manager decides how much to manipulate.<sup>10</sup> Manipulation improves

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<sup>10</sup>If the initial signal is good (*i.e.*,  $s' = g$ ), the costly manipulation is not helpful to the manager at all and thus the manager chooses no manipulation.

the accounting report and thus affects the initial allocation of control rights. Specifically, with manipulation  $m$ , the manager expects to receive a good report with probability  $m$ . Thus, he receives the control rights with probability:

$$\Gamma(m) \equiv m\sigma_g + (1 - m)\sigma_b = m\delta - \delta + \sigma_g. \quad (6)$$

Since the manager doesn't receive the control rights in the bad state in the first-best benchmark,  $\Gamma$  also represents the misallocation of the control rights in the bad state. Moreover, since the misallocation of control rights always triggers renegotiation in our model,  $\Gamma$  also measures the frequency of renegotiation.

What is the value of the control right to the manager in the bad state? Without the control rights, the manager expects to receive  $\gamma_B(R - d)$  since the lender will restructure the project. With the control rights, the manager can renegotiate with the lender to restructure the project in exchange for a reduction in the face value of  $\Delta d_B$  and thus his expected off is  $\gamma_B(R - d) + \gamma_B\Delta d_B - \lambda L_B$ , as we have discussed in Section 3.2 (Misallocation Scenario 1). Thus, the value of the control rights to the manager in the bad state can be defined as the difference of the manager's payoffs with and without control rights:

$$\pi \equiv \gamma_B(R - d) + \gamma_B\Delta d_B - \lambda L_B - \gamma_B(R - d) = X + \kappa(1 - \lambda)L_B.$$

Intuitively, the value of control right to the manager has two components. First, the manager's private benefit  $X$  is his "fall-back" position in the event of renegotiation failure. It is the value of the control right to the manager in the absence of renegotiation. Renegotiation, by increasing the joint surplus, makes the control rights more valuable to the manager, as captured by the second component of  $\pi$ . Collecting these results, we have the following lemma whose proof has been explained above and thus is omitted.

**Lemma 2** *The value of control rights to the manager in the bad state is  $\pi = X + \kappa(1 - \lambda)L_B$ .  $\pi$  is decreasing in the renegotiation cost  $\lambda$  and increasing in the manager's bargaining power  $\kappa$ .*

Therefore, at date 1 upon learning of a bad state ( $\theta = B$ ), the manager's expected payoff with

manipulation  $m$  is

$$v(m) = \gamma_B(R - d) + \Gamma(m)\pi - \frac{c}{2}m^2.$$

The manager receives an expected payoff of  $\gamma_B(R - d)$  without control rights.  $\Gamma(m)\pi$  is the incremental payoff from receiving the control rights. The last term is the cost of manipulation the manager bears.

For a given contractual reliance on accounting measurement  $\delta$ , the manager responds with manipulation  $m \in [0, 1]$  to maximize  $v(m)$ . Denote the manager's best response as  $m^{BR}(\delta)$ . If the best response is interior,  $m^{BR}$  is given by the first-order condition

$$\pi\delta = cm^{BR}(\delta). \quad (7)$$

The best response may also reach the upper bound at  $m^{BR} = 1$  when the manipulation cost is sufficiently low. Therefore, the manager's manipulation best response is

$$m^{BR}(\delta) = \min\left\{1, \frac{\pi\delta}{c}\right\} \quad (8)$$

**Lemma 3** *When the manager's best manipulation response is interior, as defined in equation 7, it has the following properties:*

1. *it is increasing in the contractual use of accounting measurement  $\delta$  and the manager's bargaining power  $\kappa$ , and decreasing in renegotiation cost  $\lambda$  and manipulation cost  $c$ . That is,  $\frac{\partial m^{BR}}{\partial \delta} > 0$ ,  $\frac{\partial m^{BR}}{\partial \kappa} > 0$ ,  $\frac{\partial m^{BR}}{\partial \lambda} < 0$ , and  $\frac{\partial m^{BR}}{\partial c} < 0$ .*
2. *the sensitivity of the manager's manipulation response to the contractual use of accounting measurement is decreasing in  $\lambda$  and  $c$ , and increasing in  $\kappa$ . That is,  $\frac{\partial^2 m^{BR}}{\partial \delta \partial \lambda} < 0$ ,  $\frac{\partial^2 m^{BR}}{\partial \delta \partial c} < 0$ , and  $\frac{\partial^2 m^{BR}}{\partial \delta \partial \kappa} > 0$ .*

The marginal benefit of manipulation is  $\pi\delta$ . Manipulation increases the manager's probability of receiving the control rights by  $\frac{\partial \Gamma(m)}{\partial m} = \delta$  and the control rights are worth  $\pi$  to the manager. The manager trades off this marginal benefit against the marginal cost  $cm^{BR}$ . The marginal benefit of manipulation is larger either when the allocation rule relies more heavily on accounting measurement (a larger  $\delta$ ) or when the contractual rights are more valuable to the manager (a larger  $\pi$ ), the

determinants of which are discussed in Lemma 2. Hence the first part of the Lemma. The second part is also intuitive. Since  $\pi$  and  $\delta$  are complements, the manager's manipulation response is more sensitive to  $\delta$  when the control rights are valuable to the manager. Combining the analyses from equilibrium renegotiation and manipulation, we tabulate the equilibrium payoffs for each scenarios (and their associated equilibrium probabilities) in the Table below.

Scenario	$(\theta, \tau)$	Probability	Manager ( $w^M$ )	Lender ( $w^L$ )
1	$(B, M)$	$p\Gamma$	$\gamma_B(R - d) + \gamma_B\Delta d_B - \lambda L_B$	$\gamma_B d + (1 - \gamma_B)r - \gamma_B\Delta d_B$
2	$(G, L)$	$(1 - p)(1 - \sigma_g)$	$\gamma_G(R - d) + X - \gamma_G\Delta d_G - \lambda L_G$	$\gamma_G d + \gamma_G\Delta d_G$
3	$(B, L)$	$p(1 - \Gamma)$	$\gamma_B(R - d)$	$\gamma_B d + (1 - \gamma_B)r$
4	$(G, M)$	$(1 - p)\sigma_g$	$\gamma_G(R - d) + X$	$\gamma_G d$

Table 1: Payoff Upon Equilibrium Renegotiation

### 3.4 The contractual design at date 0

At date 0, the manager designs the debt contract  $(\sigma_g, \delta, d)$ , anticipating the subsequent renegotiation and manipulation. For any given contractual design  $(\sigma_g, \delta)$ , the face value  $d$  is chosen to satisfy the lender's individual rationality condition. Based on the lender's ex-post payoffs for each scenario specified in Table 1, the lender's ex-ante expected payoff can be calculated as a probability-weighted average of the ex-post payoffs, summarized in the following Lemma 4 (proof is straightforward and thus omitted).

**Lemma 4** *For a given control rights allocation rule  $(\sigma_g, \delta)$ , the best-response face value  $d^{BR}$  of the debt-contact satisfies*

$$K = \gamma d^{BR} + p(1 - \gamma_B)r - p\Gamma\gamma_B\Delta d_B + (1 - p)(1 - \sigma_g)\gamma_G\Delta d_G \quad (9)$$

where  $\gamma \equiv (1 - p)\gamma_G + p\gamma_B$ .

Anticipating the manipulation and date-2 action and for given control rights allocation rule  $(\sigma_g, \delta)$ , the lender demands a face value  $d$  to break even. In exchange for providing capital  $K$  on date-0, the lender is compensated in two channels, shown in the right-hand-side (RHS) of equation

9. First, in the equilibrium, the project is continued in the good state and restructured in the bad state, resulting in cash flow  $R$  with probability  $\gamma = (1 - p)\gamma_G + p\gamma_B$  and  $r$  with probability  $p(1 - \gamma_B)$ . The lender receives face value  $d^{BR}$  in the former case and  $r$  in the latter (because  $\min(d^{BR}, r) = r$ ). This explains the first two terms of the RHS. Second, renegotiation occurs in equilibrium that adjusts the face value of the debt contract, as we have analyzed in Section 3.2. Specifically, in Misallocation Scenario 1, which occurs with probability  $p\Gamma$ , the lender makes a face value concession  $\Delta d_B$  to induce the manager to restructure the project. This reduces the lender's ex-ante payoff by  $p\Gamma\gamma_B\Delta d_B$ . Similarly, in Misallocation Scenario 2, which occurs with probability  $(1 - p)(1 - \sigma_g)$ , the manager offers an increase in face value  $\Delta d_G$  to induce the lender to continue the project. This increases the lender's ex-ante payoff by the last term in equation 9.

Since the lender breaks even at date 0, the manager's ex-ante payoff is the same as the firm value. Based on the manager's ex-post payoffs in each scenario specified in Table 1, the manager's ex-ante expected payoffs can be computed as a probability-weighted average of the ex-post payoffs. Substituting the best-response face value  $d^{BR}$  from equation 9 and subtracting the manipulation costs, we can write the date-0 firm value  $V$  as a function of  $\{\sigma_g, \delta\}$ :

$$V(\sigma_g, \delta) \equiv V^{FB} - (1 - p)(1 - \sigma_g)\lambda L_G - p\Gamma\lambda L_B - p\frac{c}{2}(m^{BR})^2. \quad (10)$$

The firm value is below the first-best value for three reasons. First, the control rights may be allocated to the lender in the good state. This occurs with probability  $(1 - p)(1 - \sigma_g)$ . Even though this misallocation of control rights can be corrected through renegotiation, the renegotiation is costly and reduces the firm value by  $\lambda L_G$ . Second, the control rights may also be allocated to the manager in the bad state. The probability of this event is  $p\Gamma$ . This misallocation decreases the firm value by  $\lambda L_B$ . Finally, the manager engages in costly manipulation  $m^{BR}$  in the bad state, which further reduces the firm value.

Now we are ready to state and solve the date-0 control rights allocation rule design problem, expressed as the following constrained optimization program:<sup>11</sup>

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<sup>11</sup>This optimization program restricts attention to standard-debt contract form we have laid out in the model. We also considered alternative contracts forms such as (a) managerial debt: manager is promised a fixed payment while the investor gets the residual and (2) non-voting equity: the total cash flow is split proportionally into investor's share and the manager's share. We can show that in a non-empty region of parameters  $c$  and  $R$  in which our standard debt contract is feasible, neither the managerial debt contract nor the non-voting equity contract is feasible. The exact

$$\begin{aligned}
& \max_{\sigma_g, \delta} V(\sigma_g, \delta) \\
\text{s.t. } & m^{BR}(\delta) = \min\left\{1, \frac{\pi\delta}{c}\right\} \\
& 0 \leq \delta \leq \sigma_g \leq 1
\end{aligned} \tag{11}$$

This optimization program can be solved with the standard Kuhn-Tucker technique. Substituting its solutions to the manager's best manipulation response  $m^{BR}$  and the lender's required face value  $d^{BR}$ , we can characterize the entire equilibrium. Define  $\bar{c} \equiv \frac{\pi(\pi+2\lambda L_B)}{\lambda L_B}$ .

**Proposition 1** *In the unique equilibrium,*

1. the equilibrium control rights allocation rule at date 0 is  $\sigma_g^* = 1$  and  $\delta^* = \min\left\{\frac{c}{\bar{c}}, 1\right\}$ ;
2. the equilibrium interest rate is  $\frac{d^*}{K} = \frac{K-p(1-\gamma_B)r}{\gamma K} + \frac{p\Gamma^*(\pi+\lambda L_B)}{\gamma K}$ ;
3. the manager's equilibrium manipulation at date 1 is  $m^* = \min\left\{\frac{\pi}{\bar{c}}, \frac{\pi}{c}\right\}$ .
4. the project is continued in the good state and restructured in the bad state, i.e.,  $a_G^* = 1$  and  $a_B^* = 0$ .

Proposition 1 highlights a number of features in the ex ante contractual design. First, the manager always retains the control rights when the accounting report is good, despite the possibility that the good report could result from manipulation. To see this, suppose  $\sigma_g < 1$ . An increase in  $\sigma_g$  (while keeping  $\delta$  constant so that manipulation is constant) relaxes the constraint  $\sigma_g \geq \delta$  without violating other constraints. Moreover, it affects the firm value in two ways. It improves the allocation of the control rights in the good state but increases the misallocation of the control rights in the bad state when the report is manipulated. The former saves the renegotiation cost  $\lambda L_G$  while the latter incurs renegotiation cost  $\lambda L_B$ . The net marginal effect of an increase in  $\sigma_g$  is  $(1-p)\lambda L_G - p\lambda L_B$ , which is positive by *Assumption 3*. Thus, the control rights are always assigned to the manager when the report is good.

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derivation of the parameter regions are available upon request.

Second, using accounting measurement in the control rights allocation rule has a trade-off. The reliance on accounting measurement improves the accuracy of the allocation rule but also induces manipulation. To see this, consider the marginal impact of  $\delta$  on the firm value:

$$\frac{dV}{d\delta} = p \left( (1 - m^{BR}) \lambda L_B - (\delta \lambda L_B + \pi \delta) \frac{\partial m^{BR}(\delta)}{\partial \delta} \right).$$

The marginal benefit of using accounting measurement in the allocation rule is  $(1 - m^{BR}) \lambda L_B$ . The benefit depends on the cost of the misallocation of control rights and the accuracy of the accounting report.  $\lambda L_B$  is the cost of misallocation of control rights and  $(1 - m^{BR})$  measures the accuracy of accounting report. If renegotiation is costless ( $\lambda = 0$ ) or when the accounting measurement is not informative at all ( $m^{BR} = 1$ ), then there would be no benefit of using accounting measurement to allocate the control rights. Intuitively, aggressive accounting manipulation neutralizes the benefit of using accounting information in the first place. On the other hand, the marginal cost of using accounting measurement in the allocation rule is  $(\lambda L_B + \pi) m^{BR}$  after some algebra. The reliance on accounting measurement induces the manager to engage in accounting manipulation, that is,  $\frac{\partial m^{BR}(\delta)}{\partial \delta} = \frac{\pi}{c} > 0$  as we have seen in Lemma 3. Accounting manipulation is costly for two reasons. First, it consumes resources at the marginal rate of  $cm^{BR} = \pi\delta$ . Second, it increases the misallocation of control rights by degrading the informativeness of accounting report. It increases misallocation at the marginal rate of  $\frac{\partial \Gamma(\delta, m^{BR})}{\partial m^{BR}} = \delta$  and misallocation costs  $\lambda L_B$ . The optimal use of accounting measurement in the allocation rule  $\delta^*$  is thus determined by this trade-off.

Finally, having solved for the optimal control rights allocation rule  $\{\sigma_g^*, \delta^*\}$ , we could obtain the equilibrium manipulation  $m^* = m^{BR}(\delta^*)$  and the equilibrium face value  $d^* = d^{BR}(\delta^*, \sigma_g^*)$  and evaluate the equilibrium firm value  $V^*$  as a function of only exogenous parameters.

## 4 The analysis

Now we analyze the model's equilibrium to provide insights into the interaction between renegotiation and accounting-based allocation of control rights in dealing with the contractual incompleteness. We examine the effects of renegotiation (such as renegotiation cost  $\lambda$  and bargaining power  $\kappa$ ) on the firm value, the use of accounting measurement in the optimal allocation rule  $\delta^*$ , equilibrium

accounting manipulation  $m^*$ , misallocation of control rights  $\Gamma^* = \Gamma(m^*)$ , and interest rate  $d^*/K$ . These comparative static results form the basis for empirical implications to be discussed in Section 5.

#### 4.1 The firm value

Substituting the equilibrium contract variables into the firm value expression 10 leads to

$$V(\sigma_g^*, \delta^*) = V^{FB} - p(m^* \delta^* - \delta^* + 1) \lambda L_B - p \frac{c}{2} (m^*)^2. \quad (12)$$

**Proposition 2** 1. *The firm value is increasing in manipulation cost  $c$ .*

2. *The firm value doesn't necessarily decrease in the renegotiation cost  $\lambda$ . In particular, there exists constants,  $\hat{\kappa} \in (0, 1)$  and  $\hat{c} > 0$  (defined in the proof) such that the firm value is increasing in the renegotiation cost if and only if  $\kappa > \hat{\kappa}$  and  $c > \hat{c}$ .*

3. *The firm value is decreasing in the manager's bargaining power  $\kappa$ .*

The first part of Proposition 2 is intuitive. A higher cost of manipulation makes ex-post manipulation less attractive. Lower manipulation improves the allocation of the control rights and saves the direct cost of manipulation, both contributing to higher firm value.

The second part of the proposition, that the firm value can be increasing in renegotiation cost, is perhaps surprising. Renegotiation cost is the ultimate source of inefficiency in the model. In the absence of renegotiation cost, the Coase Theorem would apply in our model, and the first-best could be obtained. However, as  $\lambda$  increases, the firm value may increase in our model. The key driver of this result is the endogenous nature of accounting information to which the prior incomplete contracting literature in economics and finance has paid little attention. Now we explore its intuition. By the envelope theorem, the effect of renegotiation cost on the firm value can be summarized as

$$\frac{dV^*}{d\lambda} = \frac{\partial V^*}{\partial \lambda} = -p\{(m^* \delta^* - \delta^* - 1)L_B + (\delta^* \lambda L_B + cm^*) \frac{\partial m^*}{\partial \lambda}\} \quad (13)$$

A higher renegotiation cost ( $\lambda$ ) has two countervailing effects. On one hand, holding the manipulation fixed, a higher  $\lambda$  directly reduces the firm value by increasing the expected renegotiation cost, as captured by the first term  $-\Gamma^*L_B = (m^*\delta^* - \delta^* - 1)L_B$ . Since the renegotiation cost is incurred only when the initial allocation of control rights is inefficient, this direct effect is increasing in the equilibrium misallocation  $\Gamma^*$ . Fixing the use of accounting measurement  $\delta$ , the misallocation of control rights results from manipulation and thus  $\Gamma^*$  is decreasing in the manipulation cost  $c$ . On the other hand, a higher  $\lambda$  indirectly affects the firm value through its interaction with manipulation. Specifically, fixing the use of accounting measurement  $\delta$ , manipulation is decreasing in renegotiation cost  $\lambda$ , *i.e.*,  $\frac{\partial m^{BR}}{\partial \lambda}|_{m^{BR}=m^*} < 0$ , as shown in Lemma 3. In turn, a lower manipulation improves the firm value. This indirect effect of renegotiation cost on the firm value is increasing in the manager's bargaining power  $\kappa$ . The higher renegotiation cost reduces the value of control rights to the manager and this effect is more prominent for the manager with larger bargaining power. In the extreme, if the manager has no bargaining power, then the value of control rights to the manager consists of only private benefit  $X$  and won't be affected by renegotiation cost. The direct effect is decreasing in manipulation cost  $c$  and the indirect effect is increasing in the manager's bargaining power  $\kappa$ . When both the manager has large bargaining power and the cost of manipulation is large, the indirect effect dominates the direct effect and an improvement of the renegotiation process reduces the firm value.

To see the importance of endogenous nature of accounting information, we provide a benchmark case in which manipulation is exogenous. In this case, the direct effect is still present but the indirect effect disappears. A lower renegotiation cost facilitates the ex-post renegotiation, improves the ex-post allocation of control right, and thus increases the ex ante firm value.

**Corollary 1** *Suppose the manager manipulation is fixed at  $\hat{m} \in (0, 1)$ . Then the equilibrium firm value is always decreasing in renegotiation cost.*

Finally, the manager's bargaining power ( $\kappa$ ) has a uniformly negative impact on the firm value. Ex post, a higher  $\kappa$  makes the control rights more valuable to the manager and induces the manager to manipulate more. The lender anticipates this ex-post manipulation and price protects herself through the initial contract. With the lender's price protection, accounting manipulation cost is ultimately borne by the manager and reduces the firm value.

## 4.2 The equilibrium use of accounting measurement

Now we examine the properties of the equilibrium use of accounting measurement in the control rights allocation rule  $\delta^*$ .

**Proposition 3** *The equilibrium use of accounting measurement in the control rights allocation rule  $\delta^*$  has the following properties: 1)  $\delta^*$  is positive for any  $c > 0$ ; 2)  $\delta^*$  is increasing in manipulation cost  $c$ , renegotiation cost  $\lambda$ , and decreasing in the manager’s bargaining power  $\kappa$ . That is,  $\frac{d\delta^*}{dc} \geq 0$ ,  $\frac{d\delta^*}{d\lambda} \geq 0$ ,  $\frac{\partial\delta^*}{\partial\kappa} \leq 0$ , where the inequality is strict when  $c < \bar{c}$ .*

Proposition 3 shows that  $\delta^*$  has an endogenous lower bound above 0 despite the fact that manipulation cost  $c$  can approach 0. That is, the optimal allocation rule always relies on accounting measurement even if manipulation is a severe threat. The reason is that accounting manipulation is induced by the use of accounting measurement in the allocation rule and that the manipulation’s adverse effect is “secondary” to the value of using accounting measurement in the allocation rule. To see this, reconsider the marginal impact of  $\delta$  on the firm value (equation 13) evaluated at  $\delta = 0$  and thus  $m^{BR} = 0$ :

$$\frac{dV}{d\delta} \Big|_{\delta=0, m^{BR}=0} = p\lambda L_B > 0.$$

When the allocation rule doesn’t utilize accounting information ( $\delta = 0$ ), the misallocation of the initial control rights is maximal ( $\Gamma^* = 1$ ) even though the manager doesn’t manipulate ( $m^{BR} = 0$ ). At this point, a marginal increase in the reliance on accounting measurement has a first-order effect on reducing the misallocation of control rights but only a second-order effect on the manipulation cost. Therefore, the optimal allocation rule always relies on accounting measurement, that is,  $\delta^* > 0$  for any  $c > 0$ . The same logic that  $\delta$  has a first-order effect on the firm value compared to manipulation also leads to the result that  $\delta^* = 1$  is possible, as we have shown in Proposition 1.

The comparative statics for  $\delta^*$  are intuitive. The equilibrium  $\delta^*$  is increasing in the manipulation cost  $c$ . As the manipulation cost increases, manipulation responds less aggressively to the contractual use of accounting measurement. This increases the marginal benefit of improved accuracy in the initial allocation of control rights and reduces the marginal cost of induced manipulation, pushing the equilibrium use of accounting measurement higher.

The equilibrium  $\delta^*$  is also increasing in the renegotiation cost  $\lambda$ . On one hand, a higher renegotiation cost  $\lambda$  reduces the efficiency of renegotiation, making it more important to allocate the control rights accurately through accounting-based allocation rule. In other words, a higher  $\lambda$  increases the marginal benefit of using accounting measurement in the allocation rule. On the other hand, a higher renegotiation cost  $\lambda$  reduces the manager's response sensitivity to the contractual use of accounting measurement and thus mitigates the marginal cost of using accounting measurement in the allocation rule. Both forces push for the more aggressive use of accounting measurement as renegotiation cost increases.

Finally, the equilibrium use accounting measurement in the control rights allocation rule is decreasing in the manager's bargaining power  $\kappa$ .  $\kappa$  affects the equilibrium only through its effect on the manager's manipulation. By part 1 of Lemma 4, a higher  $\kappa$  leads to higher equilibrium manipulation. By part 2 of Lemma 3, a higher  $\kappa$  also implies that the manager responds more aggressively to the use of accounting measurement in the allocation rule. Both forces lead to a higher marginal benefit and lower cost of using accounting measurement in equilibrium.

### 4.3 The equilibrium manipulation

Along with the contractual use of accounting measurement, the equilibrium manipulation of the accounting report is also endogenous. Specifically, as given in Proposition 3, the equilibrium manipulation is  $m^* = \min\{\frac{\pi}{c}, \frac{\pi}{\bar{c}}\}$ , whose properties are characterized as below:

**Proposition 4** *The equilibrium manipulation  $m^*$  has the following properties:*

1.  $m^*$  has an upper bound of  $\frac{\pi}{\bar{c}}$ ;
2. *If the manipulation threat is mild (i.e.,  $c \geq \bar{c}$ ),  $m^*$  is decreasing manipulation cost  $c$  and renegotiation cost  $\lambda$ , and increasing in the manager's bargaining power  $\kappa$ . That is, if  $c \geq \bar{c}$ , then  $\frac{dm^*}{dc} < 0$ ,  $\frac{dm^*}{d\lambda} < 0$ , and  $\frac{dm^*}{d\kappa} > 0$ .*
3. *If the manipulation threat is severe (i.e.,  $c < \bar{c}$ ),  $\delta^*$  is invariant to manipulation cost  $c$ , increasing in renegotiation cost  $\lambda$ , and decreasing in the manager's bargaining power  $\kappa$ . That is, if  $c < \bar{c}$ , then  $\frac{dm^*}{dc} = 0$ ,  $\frac{dm^*}{d\lambda} > 0$ , and  $\frac{dm^*}{d\kappa} < 0$ .*

Proposition 4 shows that the equilibrium manipulation is endogenously bound away from 1. When the manipulation threat is mild (a large  $c$ ), the optimal contract makes maximal use of accounting measurement by setting  $\delta^* = 1$  despite the fact that such reliance on accounting measurement induces manipulation. As  $c$  becomes smaller, the manager becomes more aggressive and accounting manipulation becomes very costly to the firm value. In response, the optimal contract reduces its reliance on accounting information from  $\delta^* = 1$ , which mitigates the manager's manipulation incentives. Substituting  $\delta^* = \frac{c}{\bar{c}}$ , we have  $m^* = \frac{\pi}{\bar{c}} < 1$ . There is an endogenous upper bound of manipulation. As we have discussed following Proposition 3, since accounting manipulation is induced by the contractual use of accounting measurement, the induced manipulation is always secondary to the use of accounting measurement.

The comparative statics for the equilibrium manipulation in Proposition 4 take into account the endogenous contractual design. Recall that part 1 of Lemma 3 summarizes the properties of the manager's best manipulation response to a given contract design  $\delta$ . Their differences thus highlight the impact of the joint determination of manipulation and contractual design on the properties of the equilibrium manipulation. With exogenous contractual design  $\delta$ , manipulation is strictly decreasing in manipulation cost  $c$  and in renegotiation cost  $\lambda$ , and increasing in the manager's bargaining power  $\kappa$ . With the endogenous contractual design  $\delta^*$ , the relation depends on the level of manipulation threat.

When manipulation threat is mild (i.e.,  $c$  is high), the optimal contract tolerates manipulation by using accounting measurement fully with  $\delta^* = 1$ . In this case, the contractual design is constrained at the corner and thus we don't have the joint determination any longer. As a result, the determinants of manipulation are the same as if the contractual design is treated as exogenous. It decreases in manipulation cost  $c$  and renegotiation cost  $\lambda$ , but increases in the manager's bargaining power  $\kappa$ .

When manipulation threat becomes severe, then the optimal contract is altered to directly counteract the impact of manipulation. As we have discussed in part 1 of Lemma 3, the manager manipulation is increasing in the contractual use of accounting measurement. When manipulation threat is severe, the optimal contract reduces its reliance on accounting measurement to reduce manipulation incentive. As we have discussed in Proposition 3, the equilibrium  $\delta^*$  is increasing in

manipulation cost  $c$  and renegotiation cost  $\lambda$ , and decreasing in the manager’s bargaining power  $\kappa$ . Thus, all three parameters have both a direct and indirect effects on the equilibrium manipulation, and the direct and indirect effects have opposite signs. Proposition 4 shows that the indirect effect always dominates the direct effects for all three determinants and thus the comparative statics all change signs as the manipulation threat becomes severe. The reason that the indirect effect always dominates the direct effect is because accounting manipulation is only induced by the use of accounting measurement in the allocation rule and thus the latter has a dominant effect.

Proposition 3 formalizes the joint determination problem of the debt covenant hypothesis in the positive accounting theory (e.g., Watts and Zimmerman (1986), Watts and Zimmerman (1990), Armstrong, Guay, and Weber (2010)). The literature has long informally conjectured that the contractual use of accounting measurement and the manager’s manipulation of accounting measurement are jointly determined and that this endogenous nature of accounting measurement may affect our predictions about the effects of the contractual environment parameters on the equilibrium manipulation. Proposition 3 confirms this conjecture. We discuss its empirical implications in Section 5.

#### 4.4 The equilibrium allocation of control rights and the frequency of renegotiation

The misallocation of control rights, which in equilibrium is equivalent to the probability that the manager receives the control rights in the bad state, are captured in our model by  $\Gamma^* = 1 - (1 - m^*)\delta^*$ . All else equal, the misallocation increases as  $m^*$  increases or  $\delta^*$  decreases. Both manipulation and the reduction in the use of accounting in the allocation rule exacerbates the misallocation of the control rights.

**Proposition 5** *The equilibrium misallocation of control rights is decreasing in manipulation cost  $c$ , in renegotiation cost  $\lambda$ , but increasing in the manager’s bargaining power  $\kappa$ . That is,  $\frac{d\Gamma^*}{dc} < 0$ ,  $\frac{\partial\Gamma^*}{\partial\lambda} < 0$ ,  $\frac{\partial\Gamma^*}{\partial\kappa} > 0$ .*

These results rely on Proposition 3 and 4. In the case where  $\delta^*$  reaches its maximum, an increase in manipulation cost  $c$  reduces manipulation (as shown in Proposition 4) but doesn’t affect

the equilibrium contractual use of accounting measurement. As a result, it reduces the misallocation of control rights. In the case where  $\delta^*$  is interior, an increase in manipulation cost  $c$  doesn't affect manipulation any longer, but it increases  $\delta^*$  (as shown in Proposition 3), again resulting in lower misallocation of control rights.

Similarly, when  $\delta^*$  is fixed at maximum, an increase in renegotiation cost (or a decrease in the manager's bargaining power) reduces manipulation (as shown in Proposition 4) without affecting  $\delta^*$ , resulting in lower misallocation. When  $\delta^*$  is interior, an increase in  $\lambda$  (or a decrease in  $\kappa$ ) increases manipulation but also increases  $\delta^*$ . Again the direct effect of increasing  $\delta^*$  dominates the indirect effect of increasing manipulation, resulting in lower misallocation.

#### 4.5 The equilibrium interest rate

In our model, the financing cost, expressed as the interest rate, can be written as  $\frac{d}{K}$ . Based on Lemma 4, we substitute the optimal control rights allocation in Proposition 1 into equation 9 and re-write the equilibrium interest rate as

$$\frac{d^*}{K} = \frac{K - p(1 - \gamma_B)r}{\gamma K} + \frac{p\Gamma^*\gamma_B\Delta d_B}{\gamma K}$$

In absence of misallocation of control rights (*i.e.*,  $\Gamma^* = 0$ ), the interest rate is  $\frac{d^*}{K} = \frac{K - p(1 - \gamma_B)r}{K\gamma}$ . After lending  $K$  to the manager, the lender expects to receive  $d^*$  with probability  $\gamma$  and  $\min(d^*, r) = r$  with probability  $p(1 - \gamma_B)$ . The first term would be the break-even interest rate in the first-best allocation of control rights. Now consider the impact of the misallocation of control rights on the interest rate. In equilibrium, the misallocation takes the form of allocating the control rights to the manager in the bad state (Misallocation Scenario 1), whose probability is  $p\Gamma^*$ . In this scenario, the lender makes a face value concession of  $\Delta d_B$  to the manager to persuade him to restructure the project. Anticipating this concession in the subsequent renegotiation, the lender protects herself by demanding a higher interest rate, resulting in the second component of the equilibrium interest rate.

**Proposition 6** *The equilibrium interest rate is decreasing in manipulation cost  $c$  and increasing in the manager's bargaining power  $\kappa$ . It could either increase or decrease in the renegotiation cost*

$\lambda$ . That is,  $\frac{dd^*}{dc} < 0$ ,  $\frac{dd^*}{d\kappa} > 0$ , but  $\frac{dd^*}{d\lambda}$  can be either positive or negative.

As manipulation cost  $c$  increases, the manager manipulates less and the misallocation of control rights decreases. As a result, the lender demands a lower interest rate. The effects of the manager's bargaining power  $\kappa$  and the renegotiation cost  $\lambda$  on the interest rate are more complicated because they affect not only the misallocation of control rights but also the amounts the lender receives in various scenarios. We start with  $\kappa$ . As  $\kappa$  increases, we know from Proposition 5 that the misallocation of control rights increases. This leads to higher interest rates. Moreover, an increase in  $\kappa$  also means that the lender has to make a larger concession to the manager in the renegotiation when the control rights are misallocated to the manager, increasing the interest rate even further. Now we turn to  $\lambda$ . On one hand, an increase in  $\lambda$  reduces the misallocation of control rights. This pushes interest rate lower. On the other hand, an increase in  $\lambda$  implies that in the event of a misallocation, the lender's expected payoff is smaller as the total surplus from renegotiation shrinks. This effect pushes up the interest rate. The overall effect of  $\lambda$  on the equilibrium interest rate is determined by the trade-off of these two effects and could go in either direction.

## 5 The empirical implications

Individually and as a whole, the comparative statics results derived in Section 4 give rise to some empirical implications. We now discuss these implications by considering each key parameter of the model: (1) manipulation cost parameter  $c$ , interpreted as accounting quality, corporate governance strength, or regulatory enforcement quality); (2) manager's bargaining power  $\kappa$ , interpreted as legal or political institutions favoring management (and/or against lenders) or weaker investor protection; and (3) renegotiation cost parameter  $\lambda$ , interpreted as barriers to renegotiation (see footnote 5 for more details).

For firms with higher accounting quality (a higher parameter  $c$ ), our model predicts that we should observe higher firm value, more contractual reliance on accounting measurement, less frequent renegotiation, and lower interest rates in debt-contracts.

For firms with higher managerial bargaining power (a higher parameter  $\kappa$ ), our model predicts that we should observe lower firm value, less contractual reliance on accounting measurement, more

frequent renegotiation and higher interest rate in debt-contracts. However, our model predicts that the effect of managerial bargain power on accounting manipulation is not monotonic. Instead, the effect interacts with accounting quality and is positive (negative) only for firms with high (low) accounting quality.

For firms with higher renegotiation cost (a higher parameter  $\lambda$ ), our model predicts that we should observe more contractual reliance on accounting measurement and less frequent renegotiation. Moreover, the effects of renegotiation cost on firm value and manipulation are more nuanced. An increase in renegotiation cost improves the value of firms with high accounting quality and high managerial power and reduces accounting manipulation for firms with high accounting quality. In other words, there are interaction effects between renegotiation costs and accounting quality in studying control-right motivated accounting manipulation. Finally, our model generates ambiguous predictions about the effect of renegotiation cost on interest rates.

We believe some predictions of our model can be connected to existing empirical work. For example, our comparative static results of equilibrium use of accounting measurement in control right allocation are consistent with empirical findings such as [Hong, Hung, and Zhang \(2016\)](#) who suggest that law enforcement facilitates the use of covenants: evidenced by more prevalent debt covenants (higher equilibrium use of accounting measurement  $\delta^*$  in our model) in countries with stronger law enforcement (higher manipulation cost  $c$  in our model) or [Saavedra \(2018\)](#) who suggests more stringent use of covenants when renegotiation costs are high: evidenced by contracts with large syndicates (higher renegotiation costs  $\lambda$  in our model) being more likely to principally rely on covenants that are directly linked to the current performance of the borrower (which denotes more stringent and less flexible covenants in the study or higher  $\delta^*$  in our model). Additionally, [Ferracutia and Morrissa \(2017\)](#) show evidence that the likelihood of covenant violation increases when renegotiation cost falls, consistent with our prediction in Proposition 5 that equilibrium misallocation ( $\Gamma^*$ ) is decreasing in renegotiation costs ( $\lambda$ ).

A key overriding theme in the model predictions can be traced to the idea of the joint determination in the debt covenant hypothesis in positive accounting theory (e.g., [Watts and Zimmerman \(1986\)](#), [Watts and Zimmerman \(1990\)](#), [Armstrong, Guay, and Weber \(2010\)](#)). Generally, the joint determination of contractual use of accounting measurement and accounting manipulation either

changes the signs or reduces the magnitude of some otherwise intuitive empirical relations. Our empirical predictions are useful for researchers to understand the exact consequences of this joint determination for various equilibrium variables.

## 6 The conclusion

With extant empirical work in debt-contracting, two regularities are well recognized: (1) popular use of accounting measurement in debt contracts (surveyed by [Armstrong, Guay, and Weber \(2010\)](#)) and (2) high frequency of renegotiation during the life of debt-contracts (reported by [Roberts and Sufi \(2009\)](#)). Under the simple, received understanding of debt contracts, their joint existence would be puzzling. If a high quality (or informativeness) of accounting measurements is the reason behind the wide-spread use of accounting measurement in covenants to allocate control right, the frequency of renegotiation should be low, not high. This is because, the allocation based on accounting measurement would have been correct frequently rendering renegotiation at low frequency. If the low cost of renegotiation is the reason behind the high frequency of occurrence, the use of accounting-based allocation would not necessarily be high as its role become less important. In the limit, with costless renegotiation, allocation is irrelevant and unnecessary.

Our paper is motivated to improve our understanding of the puzzle conceptually. The key is the joint determination hypothesis. The paper offers an economic analysis of contract renegotiation when both the contractual use of accounting measurement and the underlying property of the accounting measurement are jointly determined. In a world of incomplete contracts, renegotiation and accounting-based control right allocation are two common tools to improve contracting efficiency. When borrowers and lender agree to use an accounting measure to allocate the right of control subsequent a financing agreement, both parties anticipate the quality of that accounting measure will be affected by ex-post influencing activities such as accounting manipulation. As such, the ex ante contractual use and the ex-post informativeness of accounting measurement are jointly determined and endogenous to the contracting environment. Within this joint-determination framework, renegotiation plays a critical role as it interact with both (marginal) benefit and cost of the contractual use of accounting measurement.

Consequently, earnings manipulation is the economic mechanism that conceptually bring the two

empirical phenomena together. In particular, it is possible in our model that the use of accounting measurement is maximal ( $\delta = 1$ ) while renegotiation frequency ( $\Gamma$ ) is also at its maximal. This conceptual link is made possible precisely by building a model of endogenous earnings manipulation within an incomplete contract setting such as ours. To us, this is a strong reason to build and solve the model like ours and for us to believe our modeling approach and our main results are important and contribute to the accounting literature. In our revised version, we have reenforced this overview of our approach in the conclusion section.

Our model captures the essential elements of the overall framework, and the closed-form solutions allow us to compute comparative static results. These results shed light on the nature of the interaction between renegotiation (its cost and bargaining power distribution) and the equilibrium debt contracts. Specifically, we identified a key economic channel: costly renegotiation makes ex-post control right less valuable to the borrower which, in turn, lowers the incentive to manipulate accounting information. This economic force is at work for all the main results of our paper. In conclusion, our analysis highlights the importance of joint determination idea in incomplete contracting settings.

## 7 Appendix: Proofs

### 7.1 Proof of Lemma 3: accounting manipulation

We have explained the derivation of  $m^{BR}$  in the text. When  $m^{BR}$  is interior, it is equal to  $m^{BR} = \frac{\pi\delta}{c}$ . Recognizing  $\pi = X + \kappa(1 - \lambda)L_B$ , it is immediate that

$$\frac{\partial m^{BR}}{\partial \delta} = \frac{\pi}{c} > 0; \tag{14}$$

$$\frac{\partial m^{BR}}{\partial c} = -\frac{\pi\delta}{c^2} < 0; \tag{15}$$

$$\frac{dm^{BR}}{d\lambda} = \frac{\delta\kappa(-L_B)}{c} < 0; \tag{16}$$

$$\frac{\partial m^{BR}}{\partial \kappa} = \frac{\delta(1 - \lambda)L_B}{c} > 0. \tag{17}$$

Moreover, we have

$$\frac{\partial^2 m^{BR}}{\partial \delta \partial c} = -\frac{\pi}{c^2} < 0; \quad (18)$$

$$\frac{\partial^2 m^{BR}}{\partial \delta \partial \lambda} = \frac{\kappa(-L_B)}{c} < 0; \quad (19)$$

$$\frac{\partial^2 m^{BR}}{\partial \delta \partial \kappa} = \frac{(1-\lambda)L_B}{c} > 0. \quad (20)$$

Q.E.D.

## 7.2 Proof of Proposition 1: the equilibrium

Based on Table 1, the date-0 manager's expected payoff is

$$V = \gamma(R-d) + (1-p)X + p\Gamma(\gamma_B \Delta d_B - \lambda L_B) - (1-p)(1-\sigma_g)(\gamma_G \Delta d_G + \lambda L_G) - p\frac{c}{2}(m^{BR})^2$$

After substituting the expressions of  $\Delta d_B$  (equation 4),  $\Delta d_G$  (equation 5) and  $d = d^{BR}$  (equation 9),  $V$  can be rewritten as

$$V = V^{FB} - (1-p)(1-\sigma_g)\lambda L_G - p\Gamma\lambda L_B - p\frac{c}{2}(m^{BR})^2$$

as given in the text.

Now we use Kuhn-Tucker techniques to find the solutions  $\delta$  and  $\sigma_g$  to the following optimal contracting problem:

$$\begin{aligned} & \max_{\sigma_g, \delta} V \\ m^{BR} &= \min\left\{1, \frac{\pi\delta}{c}\right\} \\ 0 &\leq \delta \leq \sigma_g \leq 1 \end{aligned}$$

We first prove by contradiction that  $\frac{\pi\delta}{c} \geq 1$ , or equivalently,  $\delta \geq \frac{c}{\pi}$ , cannot arise in equilibrium. Suppose  $\delta > \frac{c}{\pi}$ . Then  $m^{BR} = \min\left\{1, \frac{\pi\delta}{c}\right\} = 1$  and  $\Gamma = m^{BR}\delta - \delta + \sigma_g = \sigma_g$ . Reducing  $\delta$  to  $\delta = \frac{c}{\pi}$  relaxes the last inequality constraint without affecting the objective function as both  $\Gamma$  and

$m^{BR}$  remain equal to  $\sigma_g$ . Now suppose  $\delta = \frac{c}{\pi}$ .  $m^{BR} = \min\{1, \frac{\pi\delta}{c}\} = \frac{\pi\delta}{c}$ . Evaluating the objective function at this point, we have

$$\begin{aligned}
\frac{dV}{d\delta}\Big|_{\delta=\frac{c}{\pi}} &= -p \left[ \lambda L_B \frac{\partial \Gamma}{\partial \delta} + cm^{BR} \frac{\partial m^{BR}}{\partial \delta} \right] \Big|_{\delta=\frac{c}{\pi}} \\
&= -p \left[ \lambda L_B \left( m^{BR} - 1 + \delta \frac{\partial m^{BR}}{\partial \delta} \right) + cm^{BR} \frac{\partial m^{BR}}{\partial \delta} \right] \Big|_{\delta=\frac{c}{\pi}} \\
&= -p \left[ (\lambda L_B \delta + cm^{BR}) \frac{\partial m^{BR}}{\partial \delta} \right] \Big|_{\delta=\frac{c}{\pi}} \\
&= -p (\lambda L_B \delta + cm^{BR}) \frac{\pi}{c} \\
&< 0.
\end{aligned}$$

Therefore, reducing  $\delta$  from  $\frac{c}{\pi}$  by an infinitesimal amount doesn't affect the last inequality constraint but strictly improves the objective function. In other words,  $\delta \geq \frac{c}{\pi}$  cannot be optimal in equilibrium. Thus, we have  $\delta < \frac{c}{\pi}$  and  $m^{BR} = \min\{1, \frac{\pi\delta}{c}\} = \frac{\pi\delta}{c}$  in equilibrium. We can now write out the Lagrangian as:

$$\begin{aligned}
L &= V - \beta_\delta(-\delta) - \beta_{\delta_g}(\delta - \sigma_g) - \beta_g(\sigma_g - 1) \\
&= V^{FB} - (1-p)(1-\sigma_g)\lambda L_G - p(\delta m^{BR} - \delta + \sigma_g)\lambda L_B - p\frac{c}{2}(m^{BR})^2 \\
&\quad - \beta_\delta(-\delta) - \beta_{\delta_g}(\delta - \sigma_g) - \beta_g(\sigma_g - 1),
\end{aligned}$$

where  $\beta_\delta \geq 0$ ,  $\beta_{\sigma_g} \geq 0$  and  $\beta_g \geq 0$  are Lagrangian multipliers such that

$$\begin{aligned}
\beta_\delta(-\delta) &= 0, \\
\beta_{\delta_g}(\delta - \sigma_g) &= 0, \\
\beta_g(\sigma_g - 1) &= 0.
\end{aligned}$$

The first-order-conditions with respect to  $\sigma_g$  and  $\delta$  are

$$\frac{dL}{d\sigma_g} = (1-p)\lambda L_G - p\lambda L_B + \beta_{\delta g} - \beta_g = 0; \quad (21)$$

$$\frac{dL}{d\delta} = -p \frac{d\Gamma(\delta, m^{BR}(\delta))}{d\delta} \lambda L_B - p c m^{BR} \frac{\partial m^{BR}}{\partial \delta} + \beta_\delta - \beta_{\delta g} \quad (22)$$

$$\begin{aligned} &= p[(1-2m^{BR})\lambda L_B - \pi m^{BR}] + \beta_\delta - \beta_{\delta g} \quad (23) \\ &= 0. \end{aligned}$$

Now we determine the optimal solution  $\sigma_g^*$  and  $\delta^*$  in three steps.

Step 1: We first prove that  $\sigma_g^* = 1$ . Suppose  $\sigma_g^* < 1$ , then  $\beta_g = 0$  and we have

$$\begin{aligned} \frac{dL}{d\sigma_g} &= (1-p)\lambda L_G - p\lambda L_B + \beta_{\delta g} \\ &= \lambda[(1-p)L_G - pL_B] + \beta_{\delta g} > 0 \end{aligned}$$

The inequality is due to Assumption 3 and that  $\beta_{\sigma g} \geq 0$ . Therefore,  $\sigma_g^* < 1$  would lead to a contradiction to the first-order-condition for  $\sigma_g$  (equation 21). Thus, we have proved that  $\sigma_g^* = 1$ .

Step 2: We now prove  $\delta^* > 0$ . Suppose  $\delta^* = 0$ , then we have  $m^{BR} = \frac{\delta\pi}{c} = 0$  and  $\beta_{\delta g} = 0$ . Substituting these two results into  $\frac{dL}{d\delta}$  (equation 23), we have

$$\begin{aligned} 0 &= \frac{dL}{d\delta} = p[(1-2m^{BR})\lambda L_B - \pi m^{BR}] + \beta_\delta - \beta_{\delta g} \\ &= p\lambda L_B + \beta_\delta > 0. \end{aligned}$$

Therefore,  $\delta^* = 0$  would lead to a contradiction to the first-order-condition for  $\delta$  (equation 23).

Thus, we have proved that  $\delta^* > 0$ . That is, either  $\delta^* \in (0, 1)$  or  $\delta^* = 1$ . Moreover,  $\delta^* > 0$  implies  $\beta_\delta = 0$ .

Step 3: Now we show that  $\delta^* = \min\{1, \frac{c}{\bar{c}}\}$ . Define  $\bar{c} \equiv \frac{\pi(2\lambda L_B + \pi)}{\lambda L_B}$ . Consider first the case  $\frac{c}{\bar{c}} \geq 1$  (equivalently  $c \geq \bar{c}$ ). Suppose in this case  $\delta^* < 1$ . Then  $\beta_{\delta g} = 0$ . In addition,  $\beta_\delta = 0$  as obtained

from Step 2 above. The first-order condition for  $\delta$  (equation 23) can be rewritten as

$$\begin{aligned}
0 &= \frac{dL}{d\delta} = p[(\lambda L_B - (2\lambda L_B + \pi)m^{BR}] + \beta_\delta - \beta_{\delta g} \\
&= p[(\lambda L_B - (2\lambda L_B + \pi)\frac{\pi}{c}\delta^*] \\
&> p[(\lambda L_B - (2\lambda L_B + \pi)\frac{\pi}{c}] \\
&\geq p[(\lambda L_B - (2\lambda L_B + \pi)\frac{\pi}{\bar{c}}] \\
&= 0.
\end{aligned}$$

The first inequality is due to  $\delta^* < 1$  and the second inequality is due to  $\frac{c}{\bar{c}} \geq 1$ . Thus, in the case of  $c \geq \bar{c}$ ,  $\delta^* < 1$  would lead to a contradiction to  $\frac{dL}{d\delta} = 0$ . Therefore, if  $c \geq \bar{c}$ , then  $\delta^* = 1$ .

We finally solve for the case of  $c < \bar{c}$ . Suppose  $\delta^* = 1$ , then  $\beta_{\delta g} > 0$ . Then we have

$$\begin{aligned}
0 &= \frac{dL}{d\delta} = p[(\lambda L_B - (2\lambda L_B + \pi)m^{BR}] + \beta_\delta - \beta_{\delta g} \\
&= p[(\lambda L_B - (2\lambda L_B + \pi)\frac{\pi}{c}\delta^*] - \beta_{\delta g} \\
&\leq p[(\lambda L_B - (2\lambda L_B + \pi)\frac{\pi}{\bar{c}}\delta^*] - \beta_{\delta g} \\
&= -\beta_{\delta g} \\
&< 0.
\end{aligned}$$

This is a contradiction. Thus, in the case of  $c < \bar{c}$ ,  $\delta^* < 1$  and  $\beta_{\delta g} = 0$ . Substituting  $\beta_{\delta g} = 0$  into  $\frac{dL}{d\delta}$  (equation 23), we have

$$\begin{aligned}
0 &= \frac{dL}{d\delta} = p[(\lambda L_B - (2\lambda L_B + \pi)m^{BR}] \\
&= p[(\lambda L_B - (2\lambda L_B + \pi)\frac{\pi}{c}\delta^*].
\end{aligned}$$

Thus,

$$\delta^* = \frac{c\lambda L_B}{(2\lambda L_B + \pi)\pi} = \frac{c}{\bar{c}}.$$

Collecting all the results shown so far, part 1 of Proposition 1 is proved. Part 2 and 3 of the proposition are proved by substituting  $(\delta^*, \sigma_g^*)$  to equation 9 and equation 8. Part 4 of the proposition is proved in Lemma 1. Now we have proved all claims in Proposition 1. Q.E.D.

### 7.3 Proof of Proposition 2 and Corollary 1: the firm value

Substituting the equilibrium solutions in Proposition 1 to the firm value expression 10, we obtain

$$V^* = V^{FB} - p \left( (m^* \delta^* - \delta^* + 1) \lambda L_B + \frac{cm^{*2}}{2} \right). \quad (24)$$

By the Envelope theorem, we have

$$\begin{aligned} \frac{dV^*}{dc} &= \frac{\partial V^*}{\partial c} = -p \left( \frac{\partial m^*}{\partial c} \delta^* \lambda L_B + \frac{\partial}{\partial c} \left( \frac{cm^{*2}}{2} \right) \right) \\ &= -p \left( \frac{\partial m^*}{\partial c} \delta^* \lambda L_B + \frac{\partial}{\partial c} \left( \frac{(\pi \delta^*)^2}{2c} \right) \right) \\ &= -p \left( \frac{\partial m^{BR}}{\partial c} \delta^* \lambda L_B - \frac{(\pi \delta^*)^2}{2c^2} \right) \\ &> 0. \end{aligned}$$

The last equality uses the fact that  $\frac{\partial m^*}{\partial c} = \frac{\partial m^{BR}}{\partial c}$  and the last inequality uses  $\frac{\partial m^{BR}}{\partial c} < 0$  as we have proved in Lemma 3.

We also have

$$\frac{dV^*}{d\kappa} = \frac{\partial V^*}{\partial \kappa} = -p(\delta^* \lambda L_B + cm^*) \frac{\partial m^*}{\partial \kappa} = -p(\delta^* \lambda L_B + cm^*) \frac{dm^{BR}}{d\kappa} < 0.$$

Finally, the effect of  $\lambda$  on the firm value is more complicated. By the Envelope theorem, we

have

$$\begin{aligned}
\frac{dV^*}{d\lambda} &= \frac{\partial V^*}{\partial \lambda} = -p \left( \left( \frac{\partial m^*}{\partial \lambda} \delta^* \right) \lambda L_B + (m^* \delta^* - \delta^* + 1) L_B + c m^* \frac{\partial m^*}{\partial \lambda} \right) \quad (25) \\
&= -p L_B \left( (m^* \delta^* - \delta^* + 1) + \left( \delta^* \lambda + \frac{c m^*}{L_B} \right) \frac{\partial m^*}{\partial \lambda} \right) \\
&= -p L_B \left( (m^* \delta^* - \delta^* + 1) + \left( \lambda + \frac{\pi}{L_B} \right) \delta^* \frac{\partial m^*}{\partial \lambda} \right) \\
&= -p L_B \left( \left( \frac{\pi}{c} (\delta^*)^2 - \delta^* + 1 \right) + \left( \lambda + \frac{\pi}{L_B} \right) (\delta^*)^2 \frac{\partial \pi}{\partial \lambda} \frac{1}{c} \right) \\
&= -p L_B \left( \left( \frac{\pi}{c} (\delta^*)^2 - \delta^* + 1 \right) - \left( \lambda + \frac{\pi}{L_B} \right) \frac{\kappa L_B}{c} (\delta^*)^2 \right) \\
&= -p L_B \left( \left( \frac{\pi}{c} - \left( \lambda + \frac{\pi}{L_B} \right) \frac{\kappa L_B}{c} \right) (\delta^*)^2 - \delta^* + 1 \right) \\
&= p L_B \left( (\pi \kappa - \pi + \kappa \lambda L_B) \frac{(\delta^*)^2}{c} + \delta^* - 1 \right) \\
&= p L_B \left( ((1 - \lambda) L_B \kappa^2 + (X + 2\lambda L_B - L_B) \kappa - X) \frac{(\delta^*)^2}{c} + \delta^* - 1 \right) \\
&= p L_B \left( f(\kappa) \frac{\delta^{*2}}{c} + \delta^* - 1 \right). \quad (26)
\end{aligned}$$

In the last step, we have denoted the coefficient of  $(\delta^*)^2$  (except the scalar  $c$ ) as  $f(\kappa) \equiv (1 - \lambda) L_B \kappa^2 + (X + 2\lambda L_B - L_B) \kappa - X$ . It is straightforward to see that  $f(\kappa)$  has two solutions. Moreover,  $f(0) = -X < 0$  and  $f(1) = \lambda L_B > 0$ . Therefore, there exists one and only one solution between 0 and 1. Denote this interior solution as  $\hat{\kappa}$ . Then  $f(\kappa) > 0$  if and only if  $\kappa > \hat{\kappa}$ .

We consider the two cases of  $c$  separately. First, consider the case of  $c \in (0, \bar{c})$ . In this case,  $\delta^* = \min\{\frac{c}{\bar{c}}, 1\} = \frac{c}{\bar{c}}$ . Substituting  $\delta^* = \frac{c}{\bar{c}}$  into equation 26 and moving the term  $pL_B$  to the left to simplify the exposition, we have

$$\begin{aligned}
\frac{dV^*}{d\lambda} \frac{1}{pL_B} &= f(\kappa) \frac{\delta^{*2}}{c} + \delta^* - 1 \\
&= f(\kappa) \frac{c}{\bar{c}^2} + \delta^* - 1 \\
&= \frac{c}{\bar{c}} \left( \frac{f(\kappa) + \bar{c}}{\bar{c}} \right) - 1.
\end{aligned}$$

Note first that  $\frac{dV^*}{d\lambda}$  is increasing in  $c$  because  $f(\kappa) + \bar{c} = \pi \kappa - \pi + \kappa \lambda L_B + \bar{c} > 0$  (which is due

to  $\bar{c} > \pi$ ). Define  $\hat{c}$  as  $\frac{\hat{c}}{\bar{c}}(f(\kappa) + \bar{c}) = 1$ , or equivalently,

$$\hat{c} \equiv \bar{c} \frac{\bar{c}}{f(\kappa) + \bar{c}}.$$

Thus,  $\frac{dV^*}{d\lambda} > 0$  is equivalent to  $c \in [\hat{c}, \bar{c}]$ . This region is not empty if and only if  $f(\kappa) > 0$ , which is equivalently to  $\kappa > \hat{\kappa}$ .

Now we consider the other case of  $c \geq \bar{c}$ . In this case  $\delta^* = \min\{\frac{c}{\bar{c}}, 1\} = 1$ . Substituting  $\delta^* = 1$  into equation 26 and moving the term  $pL_B$  to the left to simplify the exposition, we have

$$\begin{aligned} \frac{dV^*}{d\lambda} \frac{1}{pL_B} &= f(\kappa) \frac{\delta^{*2}}{c} + \delta^* - 1 \\ &= \frac{f(\kappa)}{c}. \end{aligned}$$

$\frac{dV^*}{d\lambda} > 0$  if and only if  $f(\kappa) > 0$ , which is equivalent to  $\kappa > \hat{\kappa}$ . Combining the two cases, we have proved that

$$\left\{ \frac{dV^*}{d\lambda} > 0 \right\} \Leftrightarrow \{ \kappa > \hat{\kappa}, c > \hat{c} \}.$$

Hence, we have proved Proposition 2.

Corollary 1 is proved by evaluating equation 25 at  $\frac{\partial m^*}{\partial \lambda} = \frac{\partial \hat{m}}{\partial \lambda} = 0$ . That is,

$$\begin{aligned} \frac{dV^*(\hat{m})}{d\lambda} &= \frac{\partial V^*(\hat{m})}{\partial \lambda} = -p \left( \left( \frac{\partial m^*}{\partial \lambda} \delta^* \right) \lambda L_B + (m^* \delta^* - \delta^* + 1) L_B + c m^* \frac{\partial m^*}{\partial \lambda} \right) \Big|_{m^* = \hat{m}} \\ &= -p (\hat{m} \delta^* - \delta^* + 1) L_B < 0. \end{aligned}$$

Q.E.D.

## 7.4 Proof of Proposition 3: the equilibrium use of accounting measurement

Part 1 of Proposition 3 is straightforward from Proposition 1 that  $\delta^* = \min\{\frac{c}{\bar{c}}, 1\} > 0$ .

Denote a parameter  $x \in \{c, \lambda, \kappa\}$ . When  $c \geq \bar{c}$ ,  $\delta^* = \min\{\frac{c}{\bar{c}}, 1\} = 1$  and thus is invariant to  $x$ .

Now we look at the other case of  $c \in (0, \bar{c})$ . We have  $\delta^* = \min\{\frac{c}{\bar{c}}, 1\} = \frac{c}{\bar{c}} < 1$ . In this case, we have  $0 < \delta^* < \sigma_g^* = 1$  and thus  $\beta_\delta = \beta_{\delta g} = 0$ . An affine rewriting of the first order condition of  $\delta$

(equation 23) is

$$F(\delta^*, x) = F(\delta, x)|_{\delta=\delta^*} = 0,$$

where  $F(\delta, x)$  is defined as

$$F(\delta, x) = -(2m^{BR}(\delta, x) - 1)\lambda L_B - m^{BR}(\delta, x)\pi.$$

By the implicit function theorem, we can derive the comparative statics for  $\delta^*$  with respect to  $x$ :

$$\frac{d\delta^*}{dx} = -\frac{F_x}{F_\delta}|_{\delta=\delta^*},$$

where  $F_i$  represents the partial derivative of  $F$  with respect to its respective argument,  $i \in \{x, m, \delta\}$ . The denominator  $F_\delta|_{\delta=\delta^*}$  is negative because it is the second-order condition for the optimal choice of  $\delta$ . Thus,  $\frac{d\delta^*}{dx}$  has the same sign as the numerator  $F_x|_{\delta=\delta^*}$ . Moreover,

$$\begin{aligned} F_\lambda &= \left( \frac{\partial(1 - 2m^{BR})}{\partial\lambda} \lambda L_B + (1 - 2m^{BR}) L_B - \frac{\partial\pi}{\partial\lambda} m^{BR} - \pi m_\lambda^{BR} \right) \\ &= -2 \frac{\partial m^{BR}}{\partial\lambda} \lambda L_B + (1 - 2m^{BR}) L_B - \frac{\partial\pi}{\partial\lambda} m^{BR} - \pi \frac{\partial m^{BR}}{\partial\lambda}. \end{aligned}$$

We have  $\frac{\partial m^{BR}}{\partial\lambda} < 0$  by Lemma 3 and  $\frac{\partial\pi}{\partial\lambda} < 0$  by Lemma 2. Moreover,

$$(1 - 2m^{BR})|_{\delta=\delta^*} = 1 - 2m^* = 1 - \frac{2\pi}{\bar{c}} = \frac{1}{\bar{c}}(\bar{c} - 2\pi) = \frac{1}{\bar{c}}\left(\frac{\pi(\pi + 2\lambda L_B)}{\lambda L_B} - 2\pi\right) = \frac{\pi}{\bar{c}}\left(\frac{\pi}{\lambda L_B}\right) > 0.$$

Therefore,  $F_\lambda|_{\delta=\delta^*} > 0$  and  $\frac{d\delta^*}{d\lambda} > 0$ .

Similarly,  $\frac{d\delta^*}{dc} > 0$  because

$$F_c = -2 \frac{\partial m^{BR}}{\partial c} \lambda L_B - \pi \frac{\partial m^{BR}}{\partial c} > 0;$$

and  $\frac{d\delta^*}{d\kappa} < 0$  because

$$F_\kappa = -2 \frac{\partial m^{BR}}{\partial \kappa} \lambda L_B - \frac{\partial \pi}{\partial \kappa} m^{BR} - \pi \frac{\partial m^{BR}}{\partial \kappa} < 0.$$

Thus, we have proved Proposition 3. Q.E.D.

## 7.5 Proof of Proposition 4: the equilibrium manipulation

In the case of  $c \geq \bar{c}$ , we have  $m^* = \min\{\frac{\pi}{c}, \frac{\pi}{\bar{c}}\} = \frac{\pi}{c}$ . Thus, we have

$$\begin{aligned} \frac{dm^*}{dc} &= -\frac{\pi}{c^2} < 0; \\ \frac{dm^*}{d\lambda} &= \frac{1}{c} \frac{d\pi}{d\lambda} < 0; \\ \frac{dm^*}{d\kappa} &= \frac{1}{c} \frac{d\pi}{d\kappa} > 0. \end{aligned}$$

Now we turn to the other case of  $c \in (0, \bar{c})$ , in which  $m^* = \min\{\frac{\pi}{c}, \frac{\pi}{\bar{c}}\} = \frac{\pi}{\bar{c}}$ . We have

$$\begin{aligned} \frac{dm^*}{dc} &= \frac{d}{dc} \left( \frac{\pi}{\bar{c}} \right) = 0; \\ \frac{dm^*}{d\lambda} &= \frac{d}{d\lambda} \left( \frac{\pi}{\bar{c}} \right) = \frac{\pi^2}{\lambda^2 L_B} \frac{(\pi + \kappa \lambda L_B)}{(\bar{c})^2} > 0; \\ \frac{dm^*}{d\kappa} &= \frac{d}{d\kappa} \left( \frac{\pi}{\bar{c}} \right) = -\frac{(1-\lambda)\pi^2}{\lambda L_B (\bar{c})^2} < 0. \end{aligned}$$

Therefore, we have proved Proposition 4. Q.E.D.

## 7.6 Proof of Proposition 5: the misallocation of control rights

Recall that the equilibrium misallocation of control rights is captured by  $\Gamma^* \equiv \Gamma(\delta^*, m^*) = m^* \delta^* - \delta^* + 1$ . When  $c \geq \bar{c}$ ,  $\delta^* = 1$  and  $\Gamma^* = m^*$ . Thus, from the proof of Proposition 4, we have

$$\begin{aligned} \frac{d\Gamma^*}{dc} &= \frac{dm^*}{dc} < 0; \\ \frac{d\Gamma^*}{d\lambda} &= \frac{dm^*}{d\lambda} < 0; \\ \frac{d\Gamma^*}{d\kappa} &= \frac{dm^*}{d\kappa} > 0. \end{aligned}$$

When  $c \in (0, \bar{c})$ , then  $\delta^* = \frac{c}{\bar{c}}$  and  $\Gamma^* = m^*\delta^* - \delta^* + 1 = 1 - (1 - m^*)\delta^*$ . Combining the proofs of Proposition 3 and 4, we have

$$\begin{aligned}
\frac{d\Gamma^*}{dc} &= -(1 - m^*)\frac{d\delta^*}{dc} < 0; \\
\frac{d\Gamma^*}{d\lambda} &= \frac{dm^*}{d\lambda}\delta^* - (1 - m^*)\frac{d\delta^*}{d\lambda} < 0; \\
\frac{d\Gamma^*}{d\kappa} &= \frac{dm^*}{d\kappa}\delta^* - (1 - m^*)\frac{d\delta^*}{d\kappa} \\
&= \frac{d}{d\kappa}\left(\frac{\pi}{\bar{c}}\right)\delta^* - (1 - m^*)\frac{\partial}{\partial\kappa}\left(\frac{c}{\bar{c}}\right) \\
&= (\pi\delta^* - (1 - m^*)c)\frac{\partial}{\partial\kappa}\left(\frac{1}{\bar{c}}\right) + \frac{\delta^*}{\bar{c}}\frac{\partial\pi}{\partial\kappa} \\
&= (2\pi\delta^* - c)\frac{\partial}{\partial\kappa}\left(\frac{1}{\bar{c}}\right) + \frac{\delta^*}{\bar{c}}\frac{\partial\pi}{\partial\kappa} \\
&= (2\pi\frac{c}{\bar{c}} - c)\frac{\partial}{\partial\kappa}\left(\frac{1}{\bar{c}}\right) + \frac{\delta^*}{\bar{c}}\frac{\partial\pi}{\partial\kappa} \\
&= \left(\frac{2\pi - \bar{c}}{\bar{c}}\right)c\frac{\partial}{\partial\kappa}\left(\frac{1}{\bar{c}}\right) + \frac{\delta^*}{\bar{c}}\frac{\partial\pi}{\partial\kappa} \\
&> 0.
\end{aligned}$$

The last inequality is true because  $2\pi - \bar{c} = -\frac{\pi^2}{\lambda L_B} < 0$ ,  $\frac{\partial d}{\partial\kappa}\left(\frac{1}{\bar{c}}\right) < 0$  and  $\frac{\partial\pi}{\partial\kappa} > 0$ . Q.E.D.

## 7.7 Proof of Proposition 6: the equilibrium interest rate

The equilibrium interest rate is reproduced here from Proposition 1:

$$\begin{aligned}
\frac{d^*}{K} &= \frac{K - p(1 - \gamma_B)r}{\gamma K} + \frac{p\Gamma^*\gamma_B\Delta d_B}{\gamma K} \\
&= \frac{K - p(1 - \gamma_B)r}{\gamma K} + \frac{p\Gamma^*(\pi + \lambda L_B)}{\gamma K}.
\end{aligned}$$

We thus have

$$\frac{d}{dc}\left(\frac{d^*}{K}\right) = \frac{p(\pi + \lambda L_B)}{\gamma K}\frac{d\Gamma^*}{dc} < 0.$$

$\frac{d\Gamma^*}{dc} < 0$  is from Proposition 5.

Moreover,

$$\frac{d}{d\kappa}\left(\frac{d^*}{K}\right) = \frac{p}{K\gamma}\left((\pi + \lambda L_B)\frac{d\Gamma^*}{d\kappa} + \Gamma^*L_B(1 - \lambda)\right) > 0.$$

$\frac{d\Gamma^*}{d\kappa} > 0$  is from Proposition 5.

Finally, we have

$$\frac{d}{d\lambda} \left( \frac{d^*}{K} \right) = \frac{p}{K\gamma} \left( (\pi + \lambda L_B) \frac{d\Gamma^*}{d\lambda} + \Gamma^* (1 - \kappa) L_B \right).$$

Since  $\frac{d\Gamma^*}{d\lambda} < 0$  (from Proposition 5),  $\frac{d}{d\lambda} \left( \frac{d^*}{K} \right)$  could be either positive or negative.

Finally, note that  $d^*$  is increasing in  $\Gamma^*$  and thus is minimized at  $\Gamma^* = 0$ . Thus, the minimum  $d_{\min}^*$  is  $\frac{K-p(1-\gamma_B)r}{\gamma}$ . As a result, Assumption 2 is sufficient to assure that  $d^* \geq d_{\min}^* = \frac{K-p(1-\gamma_B)r}{\gamma} > \frac{r-p(1-\gamma_B)r}{\gamma} > r$ . Q.E.D.

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