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Financing and Investment Efficiency, Information Quality, and Accounting Biases

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In this paper, we investigate the effect of accounting biases on firms' financing decisions and the role of accounting biases in endogenous information quality. We show that in industries with generally low-profit prospects, a downward-biased accounting system performs better than a neutral accounting system, and a more downward bias helps mitigate both investment and financing inefficiency; whereas for industries with generally high-profit prospects, an upward-biased accounting system is better than a neutral accounting system, and a more upward bias helps improve financing efficiency. In addition, we find that a more downward-biased accounting system motivates good firms to exert more effort to improve the information quality, which improves overall efficiency.

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1. Introduction

In this paper, we examine how accounting biases affect firm's financing and investment decisions. Accounting biases are pervasive in accounting standard setting and practice, and it is important to understand the real consequences of these biases. Our study shows that accounting biases may lead to less distorted financing and investment decisions in equilibrium. We also provide analysis on the effects of accounting biases on firms' endogenous information quality. Although accounting biases and accounting information quality have drawn attention from both regulators and academia, little has been done to examine the endogenous relationship between these two important issues. Our study contributes to the literature by demonstrating the unique interaction between firms' effort on information quality and the efficiency of firms' operating decisions. We show that a more downward-biased accounting system results in a higher level of information quality and improves the overall efficiency.

Specifically, we consider a setting in which a firm needs to decide whether to invest in a risky project, and if the firm decides to invest, it needs to finance the project either by debts or by its own equity. The firm privately observes the project's profitability type while outsiders only observe an imperfect signal that reveals the project's type with noise. However, the firm can make an effort to improve the information quality of the signal. Because of the information asymmetry between the firm and the debt market, the debt contract may be distorted and induce the firm to make suboptimal financing decisions, which in turn, also induces suboptimal investment decisions.

Our model indicates that a biased accounting information system functions better in improving firms' financing and investment efficiency than a neutral system, and the effect of accounting biases depends on firms' general profitability outlooks. In industries with generally low-profit prospects, a downward-biased accounting system performs better than a neutral accounting system, and a more downward bias helps mitigate both financing and investing inefficiency; for industries with generally high-profit prospects, an upward-biased accounting system is better than a neutral accounting system, and a more upward bias helps improve financing efficiency. The reason is twofold. First, on the financing decision, the effect of the bias depends on a trade-off between less bad firms' financing distortions when they obtain high signals and more good firms' suboptimal financing decisions when they obtain low signals. Second, on the investment decision, although the bias has no effect on good firms' investment decisions, it does affect bad firms' investment decisions because with a high signal, a bad firm is able to pool with good firms to borrow and invest in a negative net present value (NPV) project. In an industry with a generally high-profit prospect, the efficiency loss is mainly driven by good firms' distorted financing decisions.

Therefore, an upward-biased system performs better because it mitigates the inefficiency due to good firms' suboptimal financing decisions. In an industry with fewer good projects, the efficiency loss is mainly driven by bad firms' distorted financing and investment decisions, and a downward-biased accounting system performs better. In particular, because a downward bias alleviates bad firm's overinvestments without affecting good firms' investment decisions, when the investment friction is severe (i.e., the bad project's NPV is very negative), a downward-biased accounting system has a more pronounced effect in mitigating inefficiency and thus performs better in a larger parameter region.

Further, we explore how accounting biases affect the information quality. We find that a more downward-biased system motivates good firms to exert more effort to improve the information quality and helps improve overall efficiency. More specifically, a good firm is motivated to improve the information quality because higher information quality not only increases its probability of obtaining a high signal but also reduces its borrowing cost upon receiving a high signal. However, higher information quality may also bring benefit to a bad firm because the bad firm enjoys a lower cost of borrowing if it fortunately receives a good signal. The good firm bears all the cost of the improvement effort, but the benefit is shared between good and bad firms. This free-riding benefit for bad firms reduces the ex post marginal benefit for good firms from a higher information quality. As a result, the good firm's induced effort level is lower than the ex ante socially optimal effort level. A downward accounting bias limits the free-riding benefit for bad firms, and hence increases a good firm's marginal benefit from the information-quality improvement. Therefore, it results in more effort to improve the information quality, which in turn results in higher overall efficiency.

The remainder of this paper proceeds as follows. Section 2 provides a review of related studies. Section 3 outlines the main model setup. Section 4 analyzes a baseline setting with exogenous information quality to study the accounting biases' direct effects on financing and investing efficiency. Section 5 endogenizes the information quality of the signals to further analyze the interaction among accounting biases, firms' incentives to improve information quality, and the overall efficiency. Section 6 examines extensions of the main setting in which firms' financing structures are perfectly observable. Section 7 provides empirical implications and concludes the paper. All proofs are available in the appendix.

2. Literature Review

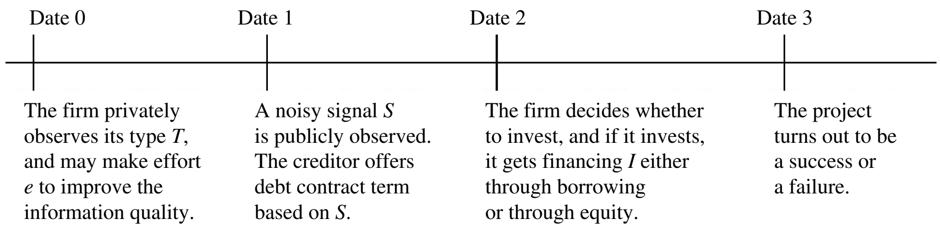
In the literature, there are studies to examine accounting biases regarding their stewardship value. For example, Chen et al. (2007) examine a setting in which accounting numbers serve both the valuation role in the capital market and the stewardship role in compensation contracting, and show that downward-biased accounting helps reduce the inferior risk sharing due to earnings management. Dutta and Gigler (2002) consider a setting in which managers are asked to give earnings forecasts, and show that it may be optimal to allow earning manipulation conditional on high earnings forecasts. Bushman and Indjejikian (1993) study the stewardship value of distorted accounting disclosures and show that biased information may be preferred. In a similar spirit, our paper also examines whether biased accounting information is more efficient than information generated by a neutral system. However, our model focuses on financing efficiency and endogenous information quality instead of agency problems.

There are also studies examining the effect of downward accounting biases on the inefficiency of debt contracts (Watts 2003, Gigler et al. 2009, Gox and Wagenhofer 2009, Chen and Deng 2010, Beyer 2012, Li 2013). Most of these studies focus on whether a downward bias is efficient in protecting debt holders' interest from aggressive risk-taking decisions by shareholders. Our study deviates from this line of literature in the sense that we focus on financing efficiency and financing cost instead of concentrating on the efficiency of debt contracts. In addition, we consider the interaction between accounting biases and firms' incentives to influence the information quality, and how that interaction affects the overall efficiency.

Our paper is also related to the literature on financing and investing efficiency. Myers and Majluf (1984) explain the pecking-order theory by information asymmetry and show that firms sometimes choose debt over issuing more shares as information asymmetry induces less investment distortion in borrowing than in issuing stocks. Similarly, we also show the role of information asymmetry in a firm's capital structure choices. However, in our model the investing inefficiency is not the main driving force; instead, the investing inefficiency is induced by financing inefficiency.

In addition, some studies have been done on the information quality or informativeness of accounting information. For example, Fan and Zhang (2012) study the relation between accounting biases and information quality in a setting in which a firm (which is the supplier of information) prefers the favorable classification based on a signal, whereas the end user of the information cares about the classification accuracy. In our model, it is the good firm who cares about the classification accuracy ex post and is self-motivated to improve the information quality to distinguish itself. Gigler and Hemmer (2001)

Figure 1 **Timeline**



examine the relation between accounting biases and managers' incentive to issue timely voluntary disclosures, and show that firms with relatively more conservative accounting are less likely to make timely voluntary disclosures. In contrast to their study, our paper examines firms' incentives to influence the information quality instead of the incentives on the timeliness of disclosures. Beyer (2012) examines the joint effect of conservatism and aggregation on both the cost of capital and the efficiency of debt contracts, and shows that fair value accounting may not be more informative than conservative accounting even with no manipulation. In Beyer's study the informativeness of accounting information depends on the accounting recognition and aggregation, whereas in our paper the information quality is endogenous and can be influenced through firms' effort.

3. The Main Model

We consider a representative risk-neutral firm that has an investment opportunity in a project. The project could be either a good one or a bad one, denoted by T, $T \in \{g, b\}$, where g (b) represents that the project is good (bad). The firm privately observes the type of its project. A good project has a higher probability of success than a bad project. We assume that $0 < P_b < P_g < 1$, where P_b and P_g are the probability of success for a bad project and a good project, respectively. The project will pay out a total cash flow of X in the case of success, and bring zero cash flow if it fails. We use z to denote the overall cash flow of the project, $z \in \{X, 0\}$. For convenience, we refer to a firm with a good project as "a good firm" and a firm with a bad project as "a bad firm," and we refer to a firm's project type as "a firm's type." We further assume that a good project has a positive NPV and a bad project has a negative NPV, regardless of the financing decision.[1] Figure 1 shows the timeline of our setting.

At date 0, the firm privately observes its type T, and may make effort e to improve the informativeness of a forthcoming accounting signal. At date 1, before the firm makes an investing decision and seeks financing, anaccounting signal is generated by a mechanism and released to the public, which imperfectly reveals the firm's type. The signal S is either a high signal, S_H, or a low one, S_L; i.e., $S \in \{S_H, S_L\}$. As a baseline structure, if the firm does not make any effort to influence the informativeness of the signals (i.e., $e = 0$), the conditional probabilities of signals for different firm types are[2]

$$P(S_H \mid g) = \lambda + \delta \quad \text{and} \quad P(S_L \mid g) = 1 - \lambda - \delta,$$
$$P(S_H \mid b) = \delta \quad \text{and} \quad P(S_L \mid b) = 1 - \delta,$$

where $0 \le \lambda \le 1$ and $0 \le \delta \le 1 - \lambda$. The parameter λ is the difference between $P(S_H \mid g)$ and $P(S_H \mid b)$, and represents the informativeness of the signal. As λ increases, the signal is more informative in differentiating good firms from bad ones. In this paper, we assume that the signal is informative enough to avoid trivial cases of useless signals. That is, we assume $\lambda > \lambda^*$, where

$$\lambda^* \equiv \max\left\{\frac{\delta(B-\theta)}{\theta(1-B)}, \frac{(1-\delta)(\theta-B)}{\theta(1-B)}\right\},$$
$$B \equiv \frac{((1+c)/(1+r+cP_g))P_g - P_b}{P_g - P_b}.$$

(Details of this threshold for λ is in the appendix.) When λ is too low ($\lambda < \lambda^*$), the signals do not have any influence on firms' decisions and so they have no impact on economic efficiency.

The change in parameter δ captures the influence of accounting biases on the signals. In our paper, we define a neutral accounting system as the case in which the probability of a good firm getting S_H equals the probability of a bad firm getting S_L. That is, $P(S_H \mid g) = P(S_L \mid b)$, which implies that $\delta = (1-\lambda)/2$. In other words, $\delta = (1-\lambda)/2$ represents a neutral accounting system where the accounting signals indicate a firm's type with the same level of accuracy regardless of the firm type. A lower δ than $(1-\lambda)/2$ implies a downward-biased accounting system in which $P(S_H \mid g) < P(S_L \mid b)$, and a higher δ than

[1] That is, we assume P_g is high enough and P_b is low enough, such that (i) $P_b X - I < rI$ and $P_b X - I < cI(1-P_b)$, and (ii) $P_g X - I > rI$ and $P_g X - I > cI(1-P_g)$.

[2] In our information system, any increase in $P(S_H \mid g)$ is accompanied by a reduction of the same magnitude in $P(S_L \mid b)$. For the robustness test, we break this one-one trade-off and examine an alternative information system following Gigler and Hemmer (2001). We find that our results qualitatively remain with both exogenous and endogenous information quality.

$(1-\lambda)/2$ implies an upward-biased accounting system in which $P(S_H \mid g) > P(S_L \mid b)$. In addition, a decrease in δ represents a more downward accounting bias, whereas an increase in δ represents a more upward bias.

After the firm observes its type at date 0, it can make the effort to improve the information quality of the signal by $\Delta\lambda$. Our modelling of λ and $\Delta\lambda$ is motivated by the fact that there are some economy-wide information disclosure standards such as Generally Accepted Accounting Principles (GAAP) and International Finance Reporting Standards (IFRS) that all firms have to follow (λ), while each firm may still have the discretion to improve the informativeness, which is unobservable to the public ($\Delta\lambda$). For example, firms may exert effort to release information of higher relevance, or offer more precise estimations. We assume that the corresponding disutility of effort is $C(\Delta\lambda) > 0$; i.e., $e = C(\Delta\lambda)$. That is, choosing a certain level of effort e is equivalent to choosing a certain improvement $\Delta\lambda$. Without loss of generality, we assume that the cost function $C(\cdot)$ is a monotonically increasing and convex function, with $C(0) = C'(0) = 0$, $C'(\cdot) > 0$, and $C''(\cdot) > 0$.[3] The cost function is publicly known and the improved information quality is denoted by λ'; i.e., $\lambda' \equiv \lambda + \Delta\lambda$. With the firm's effort e, the conditional probabilities of signals for different firm types are[4]

$$P(S_H \mid g) = \lambda' + \delta \quad \text{and} \quad P(S_L \mid g) = 1 - \lambda' - \delta,$$
$$P(S_H \mid b) = \delta \quad \text{and} \quad P(S_L \mid b) = 1 - \delta.$$

At date 1, an accounting signal is realized and publicly observed. At date 2, the firm makes its financing and investment decisions, considering the available borrowing cost and the cost of internal equity. The available borrowing cost (i.e., the debt contract terms offered by the debt market) depends on the realized public signal. The debt market, or a representative creditor, offers the firm a debt contract asking for a repayment rate of y (in other words, y is one plus the interest rate for the loan) based on the firm's public accounting signal S and her conjectures about good and bad firms' investment and financing strategies, as well as good firms' effort decision. We assume that the representative creditor is risk neutral, and that the discount rate is zero.[5] If the firm borrows D amount of debt, the firm is required to repay $Y = yD$, $X > Y > 0$. If the firm defaults ($z < Y$), following Liang and Zhang (2006), we assume that the creditor will not receive any repayment; in addition, the default triggers a loss, $c \cdot D$, to the creditor.[6] This loss could be interpreted as a payment to attorneys or a bankruptcy court, the cost for the creditor to verify the default status, or the dead-weight loss incurred in the process of liquidating pledged assets.[7] Conditional on the realization of accounting signals and the creditor's conjectures ($\Omega = \{\{\hat{V}(\cdot), \hat{D}(\cdot), \hat{E}(\cdot)\}, \hat{e}(\cdot), S\}$), the creditor chooses the debt contract term to make the expected repayment from the firm equal to the expected cost of lending. The creditor's break-even condition is

$$\Pr(z = X \mid \Omega) \cdot Y = D + cD(1 - \Pr(z = X \mid \Omega)). \qquad (1)$$

Instead of seeking debts, the firm may also get financing through its own internal funds. (The amount of internal funds is denoted by E.) We assume that the firm has sufficient equity to finance the project, but there is a cost of financing through internal funds because its use tightens the firm's alternative use of the funds to generate a return of $r \cdot E$, where r is the rate of return of the alternative use. In this paper, the firm's equity is exchangeable with the firm's internal funding. We have also examined a setting in which we explicitly model the equity financing as current shareholders issue a certain amount of equity shares to the stock market with an issuing cost. In that

[3] To ensure the interior results in the effort decision, we assume that $C''(\cdot)$ is sufficiently high.

[4] This model implicitly assumes that firms can only improve the information quality. Alternatively, we could allow a firm to influence its probability of obtaining a high signal by making efforts to garble the information. For example, we may assume that $P(S_H \mid g) = \lambda + \delta + \Delta\lambda$ and $P(S_L \mid g) = 1 - \lambda - \delta - \Delta\lambda$, and $P(S_H \mid b) = \delta + \eta$ and $P(S_L \mid b) = 1 - \delta - \eta$, where $\Delta\lambda$ (η) is the increase of probability of obtaining a high signal for a good (bad) firm, and the corresponding disutility of a good (bad) firm's effort is $C(\Delta\lambda)$ ($J(\eta)$). Our results remain the same as long as the penalty for misreporting ($J(\eta)$) is sufficiently high. Detailed analysis is available upon request. We also examined two settings to study the case of observable aggregate information quality. In one setting, outsiders observe a noisy signal about the overall information quality $\lambda' \equiv \lambda + \Delta\lambda$; in the second setting, the overall information quality λ' is perfectly observable, but outsiders cannot observe λ or $\Delta\lambda$ separately. We find that our results in the endogenous information quality analysis qualitatively remain the same. We thank an anonymous reviewer for this point.

[5] All the qualitative analysis remains if we assume a nonzero discount rate for the creditor.

[6] The assumption that the loss is proportional to the debt amount is not critical. The same results are obtained if we assume a fixed loss upon project failure. Similarly, the assumption that the creditor pays all of the loss is not critical. All results remain as long as the creditor partially shares the bankruptcy loss.

[7] In the case that the firm pledges assets such as equipment or plant buildings for loans, the creditor obtains the assets if the firm defaults, but it incurs a dead-weight cost. Following the arguments by Gox and Wagenhofer (2009), the dead-weight loss can be interpreted as follows: the net value of the pledged assets to the creditor is typically lower than to the firm because of different preferences, specificity of the assets for the borrower's business, or the liquidation cost to convert the assets into cash. The firm loses the pledged assets when the project fails, which is not modeled in this paper. Nevertheless, we have explicitly modeled the case with pledged assets, and the results are similar. Thus, we see no reason to burden the model with more notations and algebra.

setting, we assume the same information asymmetry in both the stock market and the debt market. The results are qualitatively the same, but more algebraically cumbersome.[8]

The firm will invest if it is profitable after taking into account the financing cost. We denote the firm's investing decision by V, $V \in \{I, 0\}$, where $V = I$ represents the decision that the project is undertaken and $V = 0$ means the project has been forgone. We also use I to represent the amount of investment needed to undertake the project. The firm chooses the optimal decisions to maximize its expected payoff. Its optimization program is

$$\max_{E(\cdot),D(\cdot),V(\cdot)} \{P_T[X - Y - (1+r)E] - (1-P_T)(1+r)E\}. \tag{2}$$

In our model, the debt contract and the financing decision are decided *after* the signal is publicly observed, which is different from other studies on accounting biases and debt contracts, such as Gigler et al. (2009), Chen and Deng (2010), and Li (2013).[9] Upon observing the signal, the debt market updates its belief on the firm's type. The debt contract will require lower repayment if the signal is S_H than if the signal is S_L. In return, the firm's financing decision will also depend on the realization of the signal.

Before we proceed to a detailed analysis, we define the equilibrium we are examining:

Definition 1. The equilibrium consists of a firm's investment and financing strategy $\{V(\cdot), D(\cdot), E(\cdot)\}$, the firm's effort strategy $e(\cdot)$, and the creditor's debt repayment rate $y(\cdot)$, such that,

(i) given $y(\cdot)$ and the firm's private information about its type T, the firm's investment and financing strategy $\{V(\cdot), D(\cdot), E(\cdot)\}$ maximizes $P_T[X - Y - (1+r)E] - (1-P_T)(1+r)E$;

(ii) given $\{V(\cdot), D(\cdot), E(\cdot)\}$, $y(\cdot)$, and the firm's private information about its type T, the firm's effort $e(\cdot)$ maximizes $E[P_T[X-Y-(1+r)E]-(1-P_T)(1+r)E - e \mid T, \{V(\cdot),D(\cdot),E(\cdot)\}, y(\cdot)]$;

(iii) the creditor chooses the required repayment rate $y(\cdot)$ to break even, given the creditor's conjecture of the firm's strategy $\{\hat{V}(\cdot), \hat{D}(\cdot), \hat{E}(\cdot)\}$, the creditor's conjecture of the firm's effort $\hat{e}(\cdot)$, and the signal S—that is, $Y(\cdot)$ satisfies

$$Y(\Omega) = \frac{1 + c(1 - \Pr(z = X \mid \Omega))}{\Pr(z = X \mid \Omega)} D(\cdot),$$

where $\Omega = \{\{\hat{V}(\cdot),\ \hat{D}(\cdot),\ \hat{E}(\cdot)\},\ \hat{e}(\cdot), S\}$;

(iv) the creditor's conjectures are true—that is, $\{\hat{V}(\cdot), \hat{D}(\cdot), \hat{E}(\cdot)\} = \{V(\cdot), D(\cdot), E(\cdot)\}$ and $\hat{e}(\cdot) = e(\cdot)$.

Furthermore, to facilitate our analysis on the efficiency of firms' investment and financing decisions, we use the first-best equilibrium with no information asymmetry as a benchmark. In this way, we are able to measure the inefficiency as the deviation from the first-best, full-information decisions. In the full-information case, a good (bad) firm chooses to invest in (forgo) the project since a good (bad) project has a positive (negative) NPV regardless of the financing decision. Given that the good firm chooses to invest ($V(g) = I$) and the firm's optimization program (2), it is obvious that the good firm will choose either full-debt financing ($D = I$) if $r > c(1 - P_g)$, or full-equity financing ($E = I$) if $r < c(1 - P_g)$. Note that $c(1 - P_g)$ is the borrowing cost of a good firm in the full-information case. To avoid trivial cases that even good firms choose not to finance through the debt market and information is useless, we assume that $c(1 - P_g) < r$ throughout the paper. That is, a good firm's actual borrowing cost is lower than its equity cost when there is no information asymmetry.

The first-best equilibrium is presented in Lemma 1. With no information asymmetry, a good firm obtains favorable terms from the credit market and invests with debt financing, whereas a bad firm does not invest since its project has negative NPV regardless of the financing choice. In this benchmark, firms' financing and investment decisions achieve the optimal levels for social welfare.

Lemma 1. *With full information, a good firm chooses to invest in the project by full-debt financing (i.e., $V(g) = I$ and $D(g) = I$), whereas a bad firm chooses not to invest (i.e., $V(b) = 0$).*

4. Baseline: Exogenous Information Quality

Before we examine the effect of accounting biases on firms' endogenous information quality, we first look at a baseline setting in which the information quality (λ) is given, and firms have no effort decision on information-quality improvement. In this way, we are able to analyze the direct effects of accounting biases on firms' financing and investment decisions, which facilitates our further analysis on firms' endogenous information quality. The analysis in this baseline setting can also be regarded as the analysis of the main model by a backward induction at date 2, taking the firm's effort decision at date 0 as given.

4.1. Equilibrium in Baseline Setting

In the baseline setting, with imperfect information, the debt market updates its expectation about the

[8] Detailed analysis of this equity financing setting is available upon request.

[9] In those studies, the debt covenants are determined before a signal is observed whereas project liquidation decisions are made based upon the signal.

firms' types based on the observed signals, which are denoted as θ_H and θ_L:

$$\theta_H \equiv P(g \mid S_H) = \frac{(\lambda+\delta)\theta}{\lambda\theta+\delta},$$

$$\theta_L \equiv P(g \mid S_L) = \frac{(1-\lambda-\delta)\theta}{1-\lambda\theta-\delta}.$$

Obviously, since the signal is informative on firm type, a high signal leads to a higher posterior probability of the firm being a good one (i.e., $\theta_H > \theta > \theta_L$). As λ increases, θ_H increases and θ_L decreases ($\partial\theta_H/\partial\lambda > 0$, $\partial\theta_L/\partial\lambda < 0$), implying that the signal is more informative in differentiating good firms from bad ones.

At date 2, the firm chooses the optimal investment and financing decisions to maximize its expected payoff. Its optimization program is

$$\max_{E(\cdot),\,D(\cdot),\,V(\cdot)} \quad \{P_T[X-Y-(1+r)E]-(1-P_T)(1+r)E\}$$

$$\text{subject to} \quad V(T)=D(T)+E(T), \qquad \text{(operating constraint)}$$

$$\Pr(z=X \mid \Omega)Y = D(T)+cD(T)(1-\Pr(z=X \mid \Omega)) \qquad \text{(financing constraint).}$$

From the financing constraint (which is the creditor's break-even condition), we have

$$Y(\Omega) = \frac{1+c(1-\Pr(z=X \mid \Omega))}{\Pr(z=X \mid \Omega)}D(T). \tag{3}$$

As shown in Equation (3), the required repayment $Y(\Omega)$ decreases in the market perception of the likelihood of project success ($\Pr(z=X \mid \Omega)$).

The following proposition shows the firm's investment and financing decisions in equilibrium upon the realization of the signal.[10]

Proposition 1. *In the baseline setting,*

(i) *if S_H is obtained, then $r > K(S_H)$ and a firm chooses to invest by full-debt financing regardless of its type (i.e., $V(T)=I$, and $D(T)=I$, $T\in\{g,b\}$);*

(ii) *if S_L is obtained, then $r < K(S_L)$, and a good firm chooses to invest by full-equity financing whereas a bad firm chooses not to invest (i.e., $V(g)=I$, $E(g)=I$, and $V(b)=0$).*

$$K(S_H) \equiv \left(\frac{1+c[1-\theta_H P_g-(1-\theta_H)P_b]}{\theta_H P_g+(1-\theta_H)P_b}\right)P_g - 1,$$

$$K(S_L) \equiv \left(\frac{1+c[1-\theta_L P_g-(1-\theta_L)P_b]}{\theta_L P_g+(1-\theta_L)P_b}\right)P_g - 1.$$

When a high signal is obtained, the posterior probability of the firm being a good one is high (i.e., θ_H is high) and the posterior probability of project success is also high. As a result, the borrowing cost per unit for a good firm, denoted by $K(S_H)$, is lower than the cost of equity (i.e., $r > K(S_H)$), and the good firm prefers to borrow and invest. Under this circumstance, there exists a pooling equilibrium, where both good and bad firms choose to invest by full-debt financing. The reason is that a bad firm has incentive to mimic the financing choice of a good firm. By pooling, a bad firm achieves a lower cost of borrowing. Moreover, with the information asymmetry, a bad firm actually achieves an even lower borrowing cost than the cost for a good firm, as it is more likely to default. With the low borrowing cost, investing becomes preferable for the bad firm. Although a bad project has a negative NPV, the bad firm obtains positive payoff by pooling with good firms to borrow and invest.[11] In this case, the bad firm's strategy is detrimental to the economic efficiency in both the financing and investment respects.

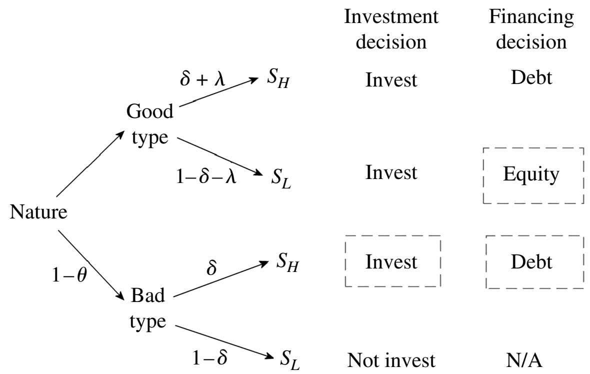
When a low signal is obtained, a good firm's borrowing cost, denoted by $K(S_L)$, is higher than the equity cost (i.e., $r < K(S_L)$), and hence the good firm chooses to invest and use full-equity financing. Under this circumstance, there exists a separating equilibrium, where good firms choose to invest with internal equity and bad firms choose to quit.[12] The reason is that a bad firm cannot pool with the good firm to take any advantage on the cost of financing. Since a bad project's return is too low to cover the cost of equity financing (i.e., $P_b X - I < rI$), the bad firm will not invest and quit. There is no inefficiency in a bad firm's financing or investing decisions. However, as a tradeoff, a good firm has to choose equity, which results in financing inefficiency. Figure 2 illustrates the equilibrium investment and financing decisions of both

[10] Note that we assume $\lambda > \lambda^*$, which implies $K(S_L) > r > K(S_H)$ (details of this threshold for λ is in the appendix), and firms' investment and financing decisions differ in the realization of the signal in equilibrium. When λ is too low ($\lambda < \lambda^*$), either $r > K(S_L) > K(S_H)$ or $K(S_L) > K(S_H) > r$, and the signals do not have any influence on firms' decisions.

[11] Here, we do not need any additional assumptions so that the bad firm will get a positive payoff by pooling with good firms to borrow and invest upon a high signal. As long as the good firms are willing to borrow upon a high signal (i.e., $P_g Y(S_H) < (1+r)I < P_g X$), we have $X > Y(S_H)$. A bad firm's expected payoff in this case is $P_b(X - Y(S_H)) > 0$. Therefore, upon a high signal, a bad firm can always achieve a positive payoff by pooling with good firms to borrow and invest. More specifically, the condition of good firms willing to borrow ($r > K(S_H)$) has implicitly incorporated the bad project's NPV component in that $K(S_H)$ is related to P_b.

[12] Under the condition of $r < K(S_L)$, to sustain this equilibrium, we need an off-equilibrium belief of the creditor that if a firm deviates from the equilibrium and chooses to borrow, the posterior probability of the firm being a good one must be less than $\dot{\theta}$, where $\dot{\theta} = (((1+c)I)/(X+cI)-P_b)/(P_g-P_b) > 0$. This off-equilibrium belief is robust to the intuitive criterion because for any given posterior belief, a bad firm is more willing to borrow than a good firm. If a good firm deviates and chooses to borrow and the creditor also believes that only good firms choose to borrow, a bad firm is always willing to borrow and pool with good firms.

Figure 2 **Equilibrium Financing and Investing Decisions**



good and bad firms, where the suboptimal decisions are indicated by the dotted boxes.

4.2. Efficiency Implication of Accounting Biases—Baseline Setting

In our model, both the firm and the debt market are risk neutral, and the debt market is assumed to be perfectly competitive. Therefore, the social welfare or the overall efficiency can be represented by the ex ante expected payoff of a representative firm. A deviation from the firm's optimal strategy to maximize its ex ante expected payoff in the full-information benchmark setting results in financing and investment inefficiency.

Regarding the financing efficiency, the downward (upward) bias has two countervailing effects:

- First, a bad firm may obtain a high signal and choose to borrow, which leads to more expected bankruptcy loss from the bad project's failure. The downward (upward) bias decreases (increases) the probability that the bad firm obtaining a high signal and hence improves (reduces) the financing efficiency.
- Second, a good firm may obtain a low signal and choose equity financing. The downward (upward) bias increases (decreases) the probability that the good firm obtains a low signal and hence reduces (improves) the financing efficiency.

In contrast, regarding the investment efficiency, the downward (upward) bias has only one positive (negative) effect:

- Upon a high signal, a bad firm chooses to pool with good firms to borrow and invest. The downward (upward) bias decreases (increases) the probability that the bad firm obtains a high signal and hence improves (reduces) the investment efficiency. The bias has no effect on good firms' investment decisions.

More specifically, the ex ante expected payoff of a representative firm, denoted by Π, is

$$\Pi = \theta\big[(\delta+\lambda)P_g(X-Y)+(1-\delta-\lambda)[P_gX-(1+r)I]\big] + (1-\theta)\delta P_b(X-Y),$$

where the repayment amount is

$$Y = Y(S_H) = \left(\frac{1+c(1-\theta_H P_g-(1-\theta_H)P_b)}{1-\theta_H P_g-(1-\theta_H)P_b)}\right)I$$

from the creditor's break-even condition. Substituting $Y(S_H)$ into the above equation, we have the following payoff:

$$\begin{aligned}\Pi = {}& \underbrace{\theta[P_gX-I]}_{\substack{\text{Good project revenue}\\ \text{before financing cost}}} + \underbrace{(1-\theta)\delta[P_bX-I]}_{\substack{\text{Bad project revenue}\\ \text{before financing cost}}}\\ & -\underbrace{cI[\theta(\delta+\lambda)(1-P_g)+(1-\theta)\delta(1-P_b)]}_{\text{Cost of borrowing}}\\ & -\underbrace{\theta I(1-\lambda-\delta)r}_{\text{Cost of equity}}. \end{aligned} \tag{4}$$

As (4) shows, the accounting biases affect the firm's payoff not only through the cost of financing but also through the project's return before financing cost. For the cost of financing, a more downward bias (decrease in δ) reduces a bad firm's expected financing cost (i.e., $cI(1-\theta)\delta(1-P_b)$). As a trade-off, a more downward bias also reduces the probability that a good firm obtains a high signal, and hence increases the good firm's expected financing cost (i.e., $cI\theta(\delta+\lambda)\cdot(1-P_g)+\theta I(1-\lambda-\delta)r$ decreases in δ since $c(1-P_g)-r<0$). For the project's return before financing cost, a more downward accounting bias has a positive effect, because it reduces the likelihood of a bad firm investing in bad projects. This positive effect on investment efficiency is indirectly driven by its impact on the financing decision.

We find that the performance of accounting biases is related to the general profit prospects θ. A more downward (upward) bias improves the overall efficiency when θ is low (high).[13] Note that a bad firm chooses to borrow and invest upon a high signal, which leads to both investment and financing inefficiency. When bad projects are prevailing (θ is sufficiently low), the expected inefficiency driven by misclassifying a bad firm into group S_H can be severe. A more downward-biased accounting system mitigates the efficiency loss by making it harder for a bad firm to get a high signal. As a consequence, a downward-biased accounting system performs better than the neutral system, and both financing and investment efficiency is improved as the downward bias becomes larger. On the other hand, a good firm

[13] Venugopalan (2006) finds a similar result in a market setting—when the chance of "project success" is low, investment is less distorted under conservative accounting. However, in that model, the firm undertakes investment activity *before* an accounting signal is released, and conservative accounting is more informative so that it induces better investment decisions.

may be misclassified into the group of S_L and have to choose equity financing, which also leads to a financing efficiency loss. When good projects are prevailing (θ is sufficiently high), most efficiency losses are driven by good firms who have to choose equity upon a low signal. An upward bias improves the financing efficiency by making it less likely for good firms to get a low signal. Therefore, an upward-biased accounting system outperforms the neutral system, and the financing efficiency is improved as the upward bias becomes larger.

The results of the efficiency analysis are summarized in the following proposition:

Proposition 2. (i) *If $\theta < \theta^*$, a downward-biased accounting system is more efficient than a neutral accounting system, and the efficiency increases with the downward bias.*

(ii) *If $\theta > \theta^*$, an upward-biased accounting system is more efficient than a neutral accounting system, and the efficiency increases with the upward bias.*

$$\theta^* \equiv \frac{c(1-P_b)+1-(P_bX)/I}{c(P_g-P_b)+r+1-(P_bX)/I}.$$

Proposition 2 has interesting regulatory implications. It has been regulators' belief for a long time that accounting information should be neutral, and the Financial Accounting Standards Board–International Accounting Standards Board conceptual framework formulates neutrality as a desirable characteristic. However, our analysis shows that when we consider the efficiency of firms' operating decisions, a neutral accounting system is almost never optimal, and biased accounting systems are more efficient.[14]

In addition, we find that a downward accounting bias has a more pronounced effect in mitigating inefficiency when the bad project's return is more negative by reducing the chance of a bad firm investing in its negative NPV project. That is, a downward accounting bias improves efficiency in a larger parameter space (θ^* is higher when P_b is lower). We formally state this result in Corollary 1.

Corollary 1. *The threshold θ^* is higher when the bad project's NPV is lower (i.e., θ^* decreases in P_b).*

According to *Fortune*'s 2007 annual ranking of American companies, network and other communication equipment, crude-oil production, and pharmaceuticals are among the most profitable industries, with returns on revenue ranging from 15.8% to 28.8% (*Fortune* 2008). On the other hand, the food industry is among those with the lowest profits, having only a 1% return on revenue. Our analysis indicates that a more downward-biased accounting system may improve efficiency in low-profit industries such as the food industry, but a more upward-biased system can help firms lower their cost of capital because of financing inefficiency for high-profit industries such as the three mentioned above. Recently, Apple Inc. and some other companies successfully lobbied for a new revenue-recognition rule for technology companies, which is more upward biased, or at least less downward biased than the old rule.[15] This may reflect high-profit industries' preference for an upward-biased accounting system. Among many reasons for this preference, there may be a desire to be distinguished from low-profit firms and to lower the cost of financing.

5. The Endogenous Information Quality of Accounting Signals

5.1. Accounting Biases and Endogenous Information Quality

We now return to the main model and analyze the firm's decision to improve the information quality at date 0. Many studies have been done to examine the settings in which firms have some discretion about the degree of accounting biases in their financial reports (Bagnoli and Watts 2005, Gox and Wagenhofer 2009, Chen and Deng 2010). However, firms may also be able to improve the informativeness or the information quality of the signals about their future profitability, which is the focus of our analysis in this section. For example, firms may improve the internal control over financial reporting, provide more precise estimations in their financial reports, etc. These measures help outsiders better predict a firm's future performance.[16]

When firms have the option to improve the information quality at date 0, upon the realized signal $S \in \{S_H, S_L\}$ at date 1, the debt market's updated expectation about the firm's type is denoted as θ'_H and θ'_L:

$$\theta'_H \equiv P(g \mid S_H, \hat{e}) = \frac{(\lambda+\Delta\hat{\lambda}+\delta)\theta}{(\lambda+\Delta\hat{\lambda})\theta+\delta} > \theta_H,$$

$$\theta'_L \equiv P(g \mid S_L, \hat{e}) = \frac{(1-\lambda-\Delta\hat{\lambda}-\delta)\theta}{1-(\lambda+\Delta\hat{\lambda})\theta-\delta} < \theta_L,$$

[14] We thank an anonymous referee for bringing this point to our attention.

[15] In September 2009, the Financial Accounting Standards Board changed the rules regarding tangible products containing software elements that are "more than incidental" to the products' functionality. Under the new rule, companies like Apple can recognize income from sales on products like the iPod and the iPhone instantaneously instead of spreading out the revenue related to the software elements over a couple of years.

[16] We also examined a setting in which firms may save cost by decreasing information quality. We find that, by similar intuition, a downward bias provides less (more) incentive of decreasing (increasing) the likelihood of obtaining a high signal, and the results in our main setup qualitatively remain. Detailed analysis is available upon request.

where $\hat{e}$ and $\Delta\hat{\lambda}$ are the creditor's conjectures of the firm's effort and the increase in information quality; i.e., $\hat{e} = C(\Delta\hat{\lambda})$.

To analyze a good firm's incentive to improve information quality, we show below the ex post payoff function of the good firm, denoted by $\Pi_g(\Delta\lambda, K'(S_H))$, given the improvement $\Delta\lambda$ and the cost of borrowing $K'(S_H)$:

$$\Pi_g = P_g X - I - \underbrace{(\delta+\lambda+\Delta\lambda)}_{\text{Probability of } S_H} \cdot \underbrace{K'(S_H)I}_{\text{Cost of borrowing}} - \underbrace{(1-\lambda-\Delta\lambda-\delta)}_{\text{Probability of } S_L} \cdot \underbrace{rI}_{\text{Cost of equity}} - C(\Delta\lambda), \quad (5)$$

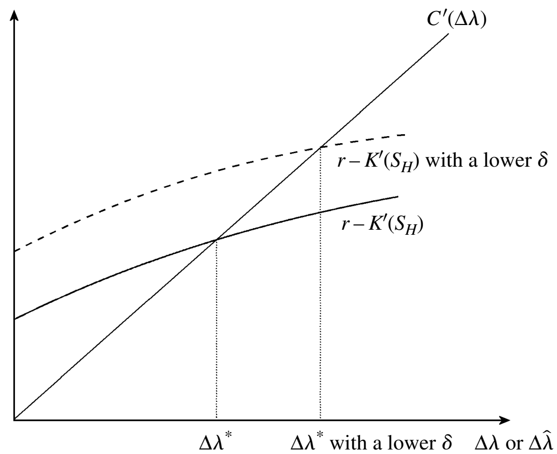
where $K'(S_H) \equiv ((1+c(1-\theta'_H P_g - (1-\theta'_H)P_b))/(\theta'_H P_g + (1-\theta'_H)P_b))P_g - 1$. The good firm chooses its optimal informativeness improvement (denoted by $\Delta\lambda^*$) to maximize its utility, which satisfies $C'(\Delta\lambda^*) = [r - K'(S_H)]I$.

As shown in (5), the improvement in information quality ($\Delta\lambda$) leads to a higher likelihood of a high signal, and thus to a higher likelihood of borrowing. Since the cost of borrowing upon a high signal is always lower than the cost of equity ($K'(S_H) < r$), the good firm benefits from a higher likelihood of borrowing. Intuitively, the good firms are always motivated to improve the information quality, since a more informative signal helps the good firms to be distinguished from the bad firms.

We further find that good firms are even more motivated to improve λ in a more downward-biased accounting system. Since the cost of borrowing $K'(S_H)$ increases in δ (i.e., $\partial K'(S_H)/\partial\delta > 0$), a more downward-biased accounting system (lower δ) leads to a lower cost of borrowing upon a high signal. As a result, a more downward-biased accounting system leads to a larger marginal saving of financing costs from improvement effort and motivates good firms to take more effort to improve the informativeness of the signal.

The equilibrium effort, or equilibrium improvement $\Delta\lambda^*$, is achieved when the marginal cost of effort ($C'(\Delta\lambda)$) equals the marginal benefit of effort ($[r - K'(S_H)]I$), where $K'(S_H)$ is determined by the market belief regarding the effort decision $\Delta\hat{\lambda}$. As illustrated in Figure 3, the two solid lines (one represents the marginal cost of effort $C'(\Delta\lambda)$, and the other represents the marginal benefit $[r - K'(S_H)]I$) intersect at point $\Delta\lambda^*$, which indicates the equilibrium effort level. When the signal becomes more downward biased (δ is lower), the marginal benefit of effort is higher and moves up to the dotted line, which represents $[r - K'(S_H)]I$ with a lower δ. The dotted line intersects with the solid line ($C'(\Delta\lambda)$) at a higher point, which indicates that the induced effort of a good firm to improve information quality increases in the degree of downward bias, and the endogenous information quality λ' increases in the degree of downward bias as well. We formally state the result in the proposition below.

Figure 3 **A Good Firm's Equilibrium Effort Decision**



Proposition 3. *The endogenous information quality increases as the accounting system becomes more downward biased; i.e.,* $\partial\lambda'/\partial\delta < 0$.

5.2. The Efficiency Implication of Accounting Biases with Endogenous Information Quality

We now examine how accounting biases affect overall efficiency when the information quality of the signal is endogenous. To better understand the efficiency implication, we first examine the optimal effort level to improve information quality to maximize the social welfare. We use $\Delta\lambda_s^*$ to denote the socially optimal improvement, which maximizes a firm's ex ante expected payoff, or social welfare, denoted by $\Pi_s(\lambda, \delta, \Delta\lambda)$:

$$\begin{aligned}\Pi_s(\lambda,\delta,\Delta\lambda) &\equiv \theta[P_g X - I] + (1-\theta)\delta[P_b X - I] - \theta I(1-\lambda-\Delta\lambda-\delta)r \\ &\quad - cI\big[\theta(\delta+\lambda+\Delta\lambda)(1-P_g) + (1-\theta)\delta(1-P_b)\big] \\ &\quad - \theta C(\Delta\lambda). \qquad (6)\end{aligned}$$

The first-order condition with respect to $\Delta\lambda$ gives us

$$C'(\Delta\lambda_s^*) = [r - c(1-P_g)]I, \qquad (7)$$

which shows that a marginal increase in $\Delta\lambda_s^*$ improves the social efficiency by inducing more good firms to borrow with the marginal benefit of $[r - c(1-P_g)]I$. Comparing $\Delta\lambda_s^*$ and $\Delta\lambda^*$, we find that $\Delta\lambda_s^* > \Delta\lambda^*$.

In our setting, a firm makes the effort decision to improve information quality only after it finds out it is a good type. When a firm observes it is a bad firm, it will not make any effort to improve λ, because a bad firm prefers a noisier signal so that it has a higher chance to pool with good firms to obtain a lower cost of borrowing. Comparing a good firm's ex post optimal effort level $\Delta\lambda^*$ with the optimal effort to maximize the social welfare $\Delta\lambda_s^*$, it is not surprising that a good firm's ex post optimal effort level is different from the socially optimal effort level. However, it may be surprising that after a firm finds out it is a good type, the firm actually inputs less effort to improve the information quality than the effort it would input if the firm had not known its type (which is equivalent to the social-optimal effort level). The reason is that higher information quality may also bring benefit to a bad firm because a bad firm enjoys a lower cost of borrowing upon receiving a high signal passively. The good firm bears all the cost of the improvement effort, but the benefit is shared between good and bad firms. Therefore, the good firm has less incentive to exert effort. Conventional wisdom may conjecture that a firm has a stronger incentive to improve information quality once it knows it is a good firm. However, it is interesting that our analysis shows that the ex post optimal effort chosen by a good firm to help distinguish itself from bad firms is actually lower than the effort level it would choose had it not known its type. We formally state this result in the following proposition.

Proposition 4. *A good firm's equilibrium effort level to improve information quality is lower than the socially optimal effort level.*

To understand why the conventional wisdom prediction is not true, it may be easier to start by examining a firm's expected payoff after it finds out it is a bad firm, which is denoted by Π_b. We have

$$\Pi_b = \delta P_b(X - Y) = \delta \cdot \left[P_b X - (K'(S_H)+1)\frac{P_b}{P_g} I\right], \qquad (8)$$

where

$$Y = Y(S_H) = \left(\frac{1 + c(1-\theta'_H P_g - (1-\theta'_H)P_b)}{1-\theta'_H P_g - (1-\theta'_H)P_b}\right) I = [K'(S_H)+1]\frac{P_b}{P_g} I$$

is the repayment amount required by the debt contract upon S_H. From (8), we can see that a bad firm's expected payoff also increases in the market's conjecture on the improvement in information quality ($\Delta\hat{\lambda}$) because $K'(S_H)$ decreases in $\Delta\hat{\lambda}$. This implies that there is a free-riding benefit for bad firms in equilibrium. In other words, the improvement in information quality not only benefits a good firm but may also benefit a bad firm. Because of the lower cost of borrowing upon a high signal, a bad firm enjoys a lower cost of financing as well if it obtains a high signal. Because good firms bear all the cost of the improvement effort, a bad firm with a high signal gets a free-riding benefit. This free-riding benefit for bad firms reduces the ex post marginal benefit for good firms from a higher information quality. As a result, a good firm's induced effort level is lower than the ex ante socially optimal effort level.

A more downward-biased accounting system limits the free-riding benefit of a bad firm, and hence increases a good firm's marginal benefit and provides a stronger incentive for a good firm to improve information quality. Intuitively, a more downward bias decreases a bad firm's probability of getting a high signal, which reduces the free-riding benefit. As a consequence, a good firm is more motivated to improve information quality, which makes the ex post induced effort level closer to the socially optimal level ($\Delta\lambda_s^*$) and improves the overall efficiency.

Proposition 5. *With endogenous information quality of the signal,*

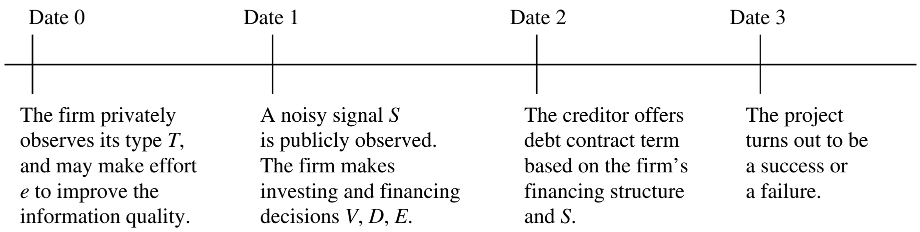
(i) *there exists a threshold $\tilde{\theta}$ such that when $\theta < \tilde{\theta}$, a downward-biased accounting system is more efficient than a neutral system, and the efficiency increases with the downward bias;*

(ii) *there exists a threshold $\bar{\theta}$ such that when $\theta > \bar{\theta}$, an upward-biased accounting system is more efficient than a neutral system, and the efficiency increases with the upward bias.*

$$\bar{\theta} \geq \tilde{\theta} > \theta^*.$$

In the baseline setting without endogenous information quality, the accounting bias influences the efficiency through a trade-off between (1) the financing-efficiency loss driven by the fact that a good firm may get S_L and have to choose equity, and (2) both the financing- and investment-efficiency losses driven by the fact that a bad firm may get S_H and choose to borrow and invest in a negative NPV project. At the knife-edge case of $\theta = \theta^*$, all the effects of the accounting bias on overall efficiency exactly offset each other, and the efficiency is not affected by the accounting bias. Here, with endogenous information quality, besides those direct effects in the baseline setting, a more downward accounting bias has one more positive indirect effect: it motivates a good firm to make a higher level of improvement effort, which indirectly improves the financing efficiency. With this incremental benefit, at $\theta = \theta^*$, the firm's ex ante payoff increases with the downward bias. A downward accounting bias is desirable in a larger parameter region. For a similar reason, with endogenous information quality, an upward accounting bias is desirable in a smaller parameter region, because it aggravates the free-riding

Figure 4 **Timeline of the Observable Financing Structure Setting**



problem and demotivates good firms from making the effort to improve information quality.[17]

6. Extension: Perfectly Observable Financing Structure

In our main setting we assume that a firm's financing decisions are not observable when the creditor offers the debt contract term upon the accounting signal. This reflects the scenario that a firm approaches a bank asking for available debt contract terms for potential loans and the bank offers loan terms based on the firm's financial accounting information. Based on available loan terms, the firm decides whether to invest, and if invest whether to borrow or to finance the investment through other measures such as equity. In this extension, we examine a different setting in which a firm's financing structure for its investment is public and perfectly observable when the creditor offers the debt contract. That is, how much of the investment is funded by equity (denoted by αI) and how much by borrowing (denoted by $(1-\alpha)I$) are observable and contractible. This may correspond to the scenario that a bank requires a firm seeking loans to reveal its financing plan for its investment. We think both scenarios are realistic. The observable financing structure setting differs from the main setting in that a good firm may be able to signal its type through its financing structure. The time line of this observable-financing-structure scenario is illustrated in Figure 4.[18]

We use the undefeated refinement to select the plausible equilibria.[19] We find that firms' investment and financing decisions in equilibrium are as follows:

Proposition 6. *When the financing structure $(D(\cdot), E(\cdot))$ is perfectly observable,*

(i) *if S_H is obtained, then $r' > K(S_H)$, and a firm chooses to invest by full-debt financing regardless of its type (i.e., $V(T) = I$, and $D(T) = I$, $T \in \{g, b\}$);*

(ii) *if S_L is obtained, then $r' < K(S_L)$, and a good firm chooses to invest by partial-debt and partial-equity financing whereas a bad firm chooses not to invest (i.e., $V(g) = I$, $E(g) = I\hat{\alpha}$ and $D(g) = I(1-\hat{\alpha})$, and $V(b) = 0$).*

$$r' \equiv (1-\hat{\alpha})c(1-P_g) + \hat{\alpha}r,$$

$$\hat{\alpha} \equiv \frac{P_b(X/I) - P_b((1+c(1-P_g))/P_g)}{1+r-P_b((1+c(1-P_g))/P_g)}.$$

When financing structure is observable and a good firm chooses a sufficiently large proportion of equity ($\alpha > \hat{\alpha}$), bad firms will quit because equity financing is too costly for bad firms with negative NPV projects. Note that here in the separating equilibrium the good firm's financing cost upon a bad signal is the partial-debt partial-equity cost, $r' \equiv (1-\hat{\alpha}) \cdot c(1-P_g) + \hat{\alpha}r$. This is different from the main setting in which the good firm's financing cost upon a bad signal is just r.

Intuitively, whether a good firm chooses to signal its type through its financing structure depends on a trade-off between the extra borrowing cost when the good firm pools with bad firms, $K(S) - c(1-P_g)$, and the signaling cost through choosing some proportion of costly equity instead of fully debt financing, $\hat{\alpha}[r - c(1-P_g)]$. When the borrowing cost for a good firm when it pools with bad firms ($K(S)$) is not much higher than the first-best borrowing cost $c(1-P_g)$, the good firm prefers to pool with bad firms

[17] To ensure that our results are not driven by the specific information structure in the main setting, we also examined a more general setup to model the accounting information structure following Gigler and Hemmer (2001), and we obtain qualitatively the same results. Detailed analysis is available upon request. In this study, we restrict attention to debt and equity financing. We acknowledge that the vast literature on capital structure identifies other contracts (e.g., convertible debt contract) that may well be more efficient in certain situations. However, our focus is on bias and precision of accounting information and optimal capital structure is well beyond the scope of this paper.

[18] In this extension, we follow the same information structure in the main setting. Same as in the main setting, we assume that the signal is informative enough to avoid trivial cases of useless signals. That is, we assume $\lambda > \lambda^{**}$, where $\lambda^{**} \equiv \max\{\delta(B'-\theta)/(\theta(1-B')), (1-\delta)(\theta-B')/(\theta(1-B'))\}$ and $B' \equiv (((1+c)/(1+r'+cP_g))P_g - P_b)/(P_g - P_b)$ (derivation of this threshold is the same as that in the main setting). We thank an anonymous reviewer for bringing this signaling setting to our attention.

[19] In this signaling model, there are a continuum of perfect Bayesian equilibria. To select plausible equilibria, we use the undefeated refinement by Mailath et al. (1993) because it is appropriate for the case in our setting. The intuitive criterion is not appropriate here because it eliminates the Pareto-dominant equilibrium, and the fact that the intuitive criterion may eliminate Pareto-dominant equilibrium is one of the main criticisms of the intuitive criterion (Mailath et al. 1993, Bolton and Dewatripont 2005, Schmidt et al. 2012).

instead of signaling through more costly equity. This is actually the case when S_H is realized. When S_H is obtained, the posterior probability of the firm being a good one is high (i.e., θ_H is high). As a result, the borrowing cost per unit for a good firm, denoted by $K(S_H)$, is lower than the financing cost in a separating equilibrium, denoted by r' (i.e., $r' > K(S_H)$), and the good firm prefers to borrow and invest. In other words, although a good firm is able to signal through its financing structure by choosing a large percentage of equity financing ($\hat{\alpha}$), it prefers to pool because the signaling cost is higher than the extra borrowing cost when pooling with bad firms. In fact, upon S_H, a pooling equilibrium in which both good and bad firms choose to invest by full-debt financing is the only undefeated equilibrium, and is also the Pareto-dominant equilibrium.

On the other hand, if the good firm has to suffer from very high cost of borrowing when pooling with bad firms and the signaling cost is lower than the extra borrowing cost upon pooling, the good firm prefers to signal by using some costly equity to drive away bad firms, and a separating equilibrium is achieved. This is the case when S_L is realized. Upon S_L, a good firm chooses a proportion of equity financing (i.e., $E(g) = I\hat{\alpha}$ and $D(g) = I(1-\hat{\alpha})$) such that a bad firm is indifferent between mimicking good firms and quitting. Since a bad project's return is too low to cover the cost of equity financing (i.e., $P_b X - I < rI$), it is too costly for a bad firm to pool with the good firm to take any advantage on the cost of borrowing, and thus a bad firm will not invest. The least-cost separating equilibrium with $\alpha = \hat{\alpha}$ is the only undefeated equilibrium upon S_L.

Given the undefeated equilibria upon S_H and S_L in this signaling game, the results in our main setting qualitatively remain the same.

Besides this setting, we also examined another setting in which the creditor offers a menu of contracts ex ante before the firm observes its type, and the firm's financing structure is observable. We find that the optimal debt contract in this screening-contract setting is identical to what we obtain in the main setting. That is, the debt contract menu in equilibrium is still designed in such a way that (i) if S_H is realized, the debt contract provides full financing (i.e., $\alpha = 0$) and all firms choose to take the contract and invest, and (ii) if S_L is realized, the debt contract only provides partial financing (i.e., $\alpha = \hat{\alpha}$) and only good firms choose to borrow. In this setting, the creditor maximizes the firm's expected payoff when designing the contract because the credit market is competitive, and the pooling equilibrium is still optimal upon a high signal. With such a contract menu in equilibrium, the results in our main setting qualitatively remain the same. In addition, in this screening-contract setting we obtain the same results with no need of equilibria refinements.[20]

7. Empirical Implications and Conclusions

We investigate the role of accounting biases in firms' financing and investment decisions, which are essential to the firms' operations. We show that a biased accounting information system functions better in improving firms' financing and investment efficiency than a neutral system. In industries with generally low-profit prospects, a more downward bias helps mitigate both investment and financing inefficiency; while for industries with generally high-profit prospects, an upward-biased accounting system helps improve financing efficiency. In addition, we also study how accounting biases interact with firms' endogenous information quality. We find that a more downward-biased accounting system motivates good firms to exert more effort to improve the information quality, which improves overall efficiency. Our analysis provides many testable predictions for future empirical research.

First, our model shows that a biased accounting system may function better than the neutral accounting system in inducing firms' optimal real decisions such as financing and investment decisions. Especially, our model predicts that for firms in industries with generally high profit prospects (θ is high), an upward-biased accounting system is more efficient. Some recent changes in accounting regulations for some specific industries may facilitate future empirical studies to test our prediction. For example, from June 2010, tech companies such as Apple, Xerox, IBM, Dell, and Hewlett-Packard are allowed to use a more liberal method (i.e., more upward-biased accounting method) to recognize their sales revenue for software that are bundled into their products. Similarly, as an exception to the general rule that all research and development expenditures should be expensed immediately, since 1985 firms in the software industry have been allowed to capitalize their research and development expenditures when technological feasibility has been established (Financial Accounting Standards Board 1985). Tech and network industries are among the most profitable industries and firms usually have high profit prospects (*Fortune* 2008). Future empirical tests can be implemented to examine tech firms' financing and investment efficiency before and after the change in the accounting revenue recognition regulation. Empirical researchers may look at the cost

[20] Detailed analysis is available upon request. We thank an anonymous referee for this alternative setup to help us enhance the robustness and validity of our results.

of capital and other proxies to examine the financing efficiency. For investment efficiency, Cohen and Zarowin (2008) have developed a method to measure firms' overinvestment by deriving a normal investment based on firms' fundamental factors, and future empirical studies may follow their method to examine the change in investment efficiency before and after the accounting regulation change for tech and network equipment industry.

Second, our study indicates that when the quality of the bad projects becomes worse, a downward-biased accounting system will be more efficient than a neutral accounting system in a larger parameter space. It may imply that, when there is a downturn in the economy, more conservative accounting rules may be helpful in mitigating financing and investing inefficiency. This prediction may not be easy to test directly. However, future empirical studies may indirectly test our model's implication by examining whether there is a tendency for the regulators to impose more conservative rules upon economy downturns, and whether more conservative accounting practices become norm for industries hit by recessions. For example, according to the data provided by the financial information firm Sageworks, building and construction material industries and motor vehicle dealers are among the industries hit hardest by the recent recession from 2007 to 2010. Empirical studies may be implemented to test whether the industry accounting norm became more conservative for these industries during the recession by examining the changes in the most common accounting choices for firms in these industries when they recognize revenues and expenses, estimate allowances, etc.

Third, we find that the endogenous information quality is higher as the accounting information system becomes more downward biased. This result provides interesting predictions for future empirical studies. For example, future empirical studies can compare the earnings qualities and the qualities of internal corporate governance for firms in tech and network equipment industries before and after the change toward a more upward-biased accounting system around 2010. According to our prediction, the quality of accounting information and the internal corporate governance should be both higher before the change. Another potential future empirical study can be implemented to examine the different consequences of GAAP versus IFRS. Many believe that IFRS is less conservative than U.S. GAAP. One may compare the financial reporting quality of firms following U.S. GAAP with the quality of comparable firms using IFRS to study whether firms following U.S. GAAP show higher quality of financial information, after controlling for other factors that may influence the information quality (e.g., litigation costs in different countries, characteristic of different industries, etc.).

Accounting biases are pervasive. We believe it is important to understand their real effects on firms' operating decisions and information quality. Our study contributes to the literature by demonstrating the interaction among accounting biases, financing and investment decisions, and endogenous information quality. We hope that our study sheds light on accounting biases and their real consequences.

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Appendix

Proof of Lemma 1. The proof is directly derived from the analysis in the context. □

Proof of Proposition 1. The signal $S \in \{S_H, S_L\}$ separates all firms into two groups. In each group, the market updates its expectation of project success upon the accounting signal; i.e., θ_H or θ_L. Because good firms have positive NPV projects, they always invest in the project and choose to either borrow or use equity. Bad firms, however, have negative NPV projects. Therefore, they either pool with good firms to borrow and invest, or quit.

Suppose both good and bad firms choose to borrow and invest. Given the conjecture of the firm's financing strategy, the creditor's posterior belief on the probability of investment success upon the signal S is $\Pr(z = X \mid S) = \Theta P_g + (1-\Theta)P_b$, where $\Theta \in \{\theta_H, \theta_L\}$, and Θ is determined by accounting signal realization S. From the creditor's break-even condition, the required repayment to the creditor on project success is

$$Y(S) = \frac{1 + c(1 - \Theta P_g - (1-\Theta)P_b)}{\Theta P_g + (1-\Theta)P_b} D.$$

From (2), for a good firm, the optimization program turns out to be

$$\max\left\{P_g X - (1+r)I + \left[r - \left(P_g \frac{1 + c(1 - \Theta P_g - (1-\Theta)P_b)}{\Theta P_g + (1-\Theta)P_b} - 1\right)\right] D\right\}. \quad (9)$$

The first-order condition shows that a good firm will choose full-debt financing ($D = I$) if

$$r > P_g \frac{1 + c(1 - \Theta P_g - (1-\Theta)P_b)}{\Theta P_g + (1-\Theta)P_b} - 1.$$

If good firms choose full-debt financing, bad firms will also choose to invest. For a bad firm, the optimization program is

$$\max\left\{P_bX-(1+r)I+\left[r-\left(P_b\frac{1+c(1-\Theta P_g-(1-\Theta)P_b)}{\Theta P_g+(1-\Theta)P_b}-1\right)\right]D\right\}. \quad (10)$$

If

$$r>P_g\frac{1+c(1-\Theta P_g-(1-\Theta)P_b)}{\Theta P_g+(1-\Theta)P_b}-1,$$

r must be higher than

$$P_b\frac{1+c(1-\Theta P_g-(1-\Theta)P_b)}{\Theta P_g+(1-\Theta)P_b}-1,$$

which indicates that bad firms will also choose to borrow; i.e., $D=I$. The hurdle rates (i.e., $P_g((1+c(1-\Theta P_g-(1-\Theta)P_b))/(\Theta P_g+(1-\Theta)P_b))-1)$ are determined by the realized accounting signals, which are denoted by

$$K(S_H)\equiv P_g\frac{1+c[1-\theta_HP_g-(1-\theta_H)P_b]}{\theta_HP_g+(1-\theta_H)P_b}-1 \quad \text{and}$$

$$K(S_L)\equiv P_g\frac{1+c[1-\theta_LP_g-(1-\theta_L)P_b]}{\theta_LP_g+(1-\theta_L)P_b}-1.$$

When S_H is obtained, we have $r>K(S_H)\equiv P_g((1+c[1-\theta_HP_g-(1-\theta_H)P_b])/(\theta_HP_g+(1-\theta_H)P_b))-1$; therefore, we achieve a pooling equilibrium in which both types choose full debt and invest.

When S_L is obtained, we have $r<K(S_L)\equiv P_g((1+c[1-\theta_LP_g-(1-\theta_L)P_b])/(\theta_LP_g+(1-\theta_L)P_b))-1$. Good firms choose to invest with full-equity financing ($D=0$), and bad firms have to quit because they have no chance to pool with good firms and the project return is negative with full-equity financing. □

Analysis of λ^*. From Proposition 1, the firm's financing decision varies in the accounting signal only if the firm chooses debts upon a good signal ($r>K(S_H)$) and equity upon a bad signal ($K(S_L)>r$). The condition $r>K(S_H)$ is equivalent with

$$\theta_HP_g+(1-\theta_H)P_b>\frac{(1+c)P_g}{P_gc+1+r},$$

which is

$$\theta_H=\frac{\theta(\lambda+\delta)}{\theta\lambda+\delta}>\frac{((1+c)/(1+r+cP_g))P_g-P_b}{P_g-P_b}.$$

If we define $B\equiv(((1+c)/(1+r+cP_g))P_g-P_b)/(P_g-P_b)$, the above inequality is equivalent with

$$\lambda>\frac{\delta(B-\theta)}{\theta(1-B)}.$$

Similarly, the condition $K(S_L)>r$ is equivalent with

$$\lambda>\frac{(1-\delta)(\theta-B)}{\theta(1-B)}.$$

It is obvious that the signs of $\delta(B-\theta)/(\theta(1-B))$ and $(1-\delta)(\theta-B)/(\theta(1-B))$ are opposite. In other words, one of them must be negative. Overall, we show that iff $\lambda>\lambda^*$, the firm's financing decision differs in the realization of signals, where

$$\lambda^*\equiv\max\left\{\frac{\delta(B-\theta)}{\theta(1-B)},\frac{(1-\delta)(\theta-B)}{\theta(1-B)}\right\} \quad \text{and}$$

$$B\equiv\frac{((1+c)/(1+r+cP_g))P_g-P_b}{P_g-P_b}. \quad □$$

Proof of Proposition 2. Given θ, the ex ante payoff before the firm gets to know its type, denoted by Π, is

$$\begin{aligned}\Pi=&\underbrace{\theta[P_gX-I]}_{\substack{\text{Good project revenue}\\\text{before financing cost}}}+\underbrace{(1-\theta)\delta[P_bX-I]}_{\substack{\text{Bad project revenue}\\\text{before financing cost}}}\\&-\underbrace{cI[\theta(\delta+\lambda)(1-P_g)+(1-\theta)\delta(1-P_b)]}_{\text{Cost of borrowing}}\\&-\underbrace{\theta I(1-\lambda-\delta)r}_{\text{Cost of equity}}.\end{aligned} \quad (11)$$

Taking the derivative of (11) with respect to the bias degree δ, we have

$$\frac{\partial\Pi}{\partial\delta}=(1-\theta)[P_bX-I]+\theta rI-cI[\theta(1-P_g)+(1-\theta)(1-P_b)]. \quad (12)$$

Then, Π decreases (increases) in δ (i.e., $\partial\Pi/\partial\delta<(>)0$) when $\theta<(>)\theta^*$, where $\theta^*\equiv(c(1-P_b)+1-(P_bX)/I)/(c(P_g-P_b)+r+1-(P_bX)/I)$. □

Proof of Proposition 3. The expected payoff of the good firm, denoted by Π_g, is

$$\begin{aligned}\Pi_g=&(\delta+\lambda+\Delta\lambda)P_g(X-Y)\\&+(1-\lambda-\Delta\lambda-\delta)[P_gX-(1+r)I]-C(\Delta\lambda),\end{aligned}$$

where the debt repayment Y is determined by the creditor's conjecture regarding the increase in information quality $\Delta\hat{\lambda}$. From the financing constraint, we have that $Y=Y(S_H)=((1+c(1-\theta'_HP_g-(1-\theta'_H)P_b))/(\theta'_HP_g+(1-\theta'_H)P_b))I$, where θ'_H is the creditor's updated belief about the probability of a good firm upon a high signal; i.e., $\theta'_H=(\lambda+\Delta\hat{\lambda}+\delta)\theta/((\lambda+\Delta\hat{\lambda})\theta+\delta)$. Substituting Y into the above equation, we have the expected payoff of the good firm as

$$\begin{aligned}\Pi_g=&P_gX-I-(\delta+\lambda+\Delta\lambda)K'(S_H)I\\&-(1-\lambda-\Delta\lambda-\delta)rI-C(\Delta\lambda),\end{aligned} \quad (13)$$

where

$$K'(S_H)\equiv\frac{1+c(1-\theta'_HP_g-(1-\theta'_H)P_b)}{\theta'_HP_g+(1-\theta'_H)P_b}P_g-1.$$

The good firm chooses the optimal $\Delta\lambda$ to maximize its expected payoff Π_g given the creditor's conjecture $\Delta\hat{\lambda}$. From the first-order condition, we have

$$\begin{aligned}C'(\Delta\lambda)&=[r-K'(S_H)]I\\&=\left[r+1-\frac{1+c(1-\theta'_HP_g-(1-\theta'_H)P_b)}{\theta'_HP_g+(1-\theta'_H)P_b}P_g\right]I\end{aligned}$$

$$= \left[r+1+cP_g - \frac{(1+c)P_g}{[(\lambda+\Delta\hat{\lambda}+\delta)\theta/((\lambda+\Delta\hat{\lambda})\theta+\delta)](P_g-P_b)+P_b}\right]I, \quad (14)$$

where $\Delta\lambda = \Delta\hat{\lambda}$ in equilibrium. The left-hand side (LHS) of (14) indicates the marginal cost of effort and the right-hand side (RHS) indicates the marginal benefit of effort. Now we consider how the induced effort is affected by δ. Taking the derivative of $[r - K'(S_H)]I$ (the RHS of (14)) with respect to δ, we have

$$\frac{\partial[r-K'(S_H)]I}{\partial\delta} = -\frac{\partial K'(S_H)}{\partial\delta}I < 0, \quad (15)$$

where

$$\frac{\partial K'(S_H)}{\partial\delta} = \frac{P_g\theta(1-\theta)(1+c)(\lambda+\Delta\hat{\lambda})(P_g-P_b)}{[(\lambda+\Delta\hat{\lambda}+\delta)\theta P_g+(1-\theta)\delta P_b]^2} > 0.$$

Equation (15) indicates that a lower δ leads to more marginal benefit to the good firm ($[r - K'(S_H)]I \uparrow$). Similarly, we have that $\partial[r - K'(S_H)]I/\partial(\Delta\hat{\lambda}) > 0$. If δ is lower, the RHS of (14) is higher. To keep Equation (14) in balance, $\Delta\lambda$ is higher and the LHS of (14) is also higher ($C''(\Delta\lambda) > 0$). Because in equilibrium $\Delta\lambda = \Delta\hat{\lambda}$, the higher $\Delta\hat{\lambda}$ will also increase the RHS of (14). As long as $C''(\Delta\lambda) > \partial[r - K'(S_H)]I/\partial(\Delta\hat{\lambda})$, the marginal increase in $\Delta\lambda$ will increase the LHS of (14) more than the RHS of (14). Therefore, there exists a higher $\Delta\lambda = \Delta\hat{\lambda}$ to keep Equation (14) in balance when δ is lower. That is, the endogenous information quality $\lambda' = \lambda + \Delta\lambda$ decreases in δ; i.e., $\partial\lambda'/\partial\delta < 0$. □

Proof of Propositions 4 and 5. We start to analyze the optimal effort taken to improve λ, denoted by $\Delta\lambda_s^*$, which maximizes the firm's ex ante payoff (or social welfare). As shown in (7), $\Delta\lambda_s^*$ is determined by $C'(\Delta\lambda_s^*) = [r - c(1-P_g)]I$. As shown in (14), in equilibrium the effort level taken by the good firm ex post satisfies $C'(\Delta\lambda) = [r - K'(S_H)]I$. Comparing the equilibrium effort shown in (14) with that in (7), we have by subtracting (7) from (14):

$$[c(1-P_g) - K'(S_H)]I = \left[1 - \frac{P_g}{\theta'_H P_g + (1-\theta'_H)P_b}\right](1+c)I < 0.$$

From the convexity of the cost function $C''(\Delta\lambda) > 0$, we have that the ex post equilibrium effort level is always lower than the socially optimal level.

Then, we go back to consider the effect of accounting bias on the overall efficiency. Taking the derivative of (6) with respect to δ, we have

$$\begin{aligned}\frac{\partial\Pi_s(\lambda,\delta,\Delta\lambda)}{\partial\delta} &= \{(1-\theta)[P_bX-I]+\theta rI \\ &\quad - cI[\theta(1-P_g)+(1-\theta)(1-P_b)]\} \\ &\quad + \theta[(r-c(1-P_g))I - C'(\Delta\lambda)]\frac{\partial\lambda'}{\partial\delta}. \quad (16)\end{aligned}$$

The expression $(1-\theta)[P_bX - I] + \theta rI - cI[\theta(1-P_g) + (1-\theta)(1-P_b)]$ in (16) is exactly the same as that in the basic setting (12). The rest in (16) is always negative, because from the above discussion, we have $[r - c\theta(1-P_g)I] - C'(\Delta\lambda) > 0$ and Proposition 3 indicates that $\partial\lambda'/\partial\delta < 0$. A lower δ makes the firm better off when $\partial\Pi_s(\lambda,\delta,\Delta\lambda)/\partial\delta < 0$, which is

$$\theta < \frac{c(1-P_b)+1-P_bX/I}{c(P_g-P_b)+r+1-P_bX/I+[(r-c\theta(1-P_g))-C'(\cdot)/I]\partial\lambda'/\partial\delta}.$$

Because $[(r - c\theta(1-P_g)) - C'(\cdot)/I](\partial\lambda'/\partial\delta) < 0$, we have that $(c(1-P_b)+1-P_bX/I)/(c(P_g-P_b)+r+1-P_bX/I+[r-c\theta(1-P_g)-C'(\cdot)/I](\partial\lambda'/\partial\delta))$ is always higher than $\theta^* = (c(1-P_b)+1-P_bX/I)/(c(P_g-P_b)+r+1-P_bX/I)$. Thus, there exists a threshold $\tilde{\theta}$, where $\tilde{\theta} > \theta^*$, such that when $\theta < \tilde{\theta}$, $\partial\Pi_s(\lambda,\delta,\Delta\lambda)/\partial\delta < 0$. Similarly, a higher δ makes the firm better off when $\partial\Pi_s(\lambda,\delta,\Delta\lambda)/\partial\delta > 0$, which is

$$\theta > \frac{c(1-P_b)+1-P_bX/I}{c(P_g-P_b)+r+1-P_bX/I+[(r-c\theta(1-P_g))-C'(\cdot)/I]\partial\lambda'/\partial\delta}.$$

In the extreme case, when θ is very high and approaches 1,

$$[r - c\theta(1-P_g)I] - C'(\Delta\lambda) = [K'_H - c\theta(1-P_g)]I \to 0.$$

That is

$$\frac{c(1-P_b)+1-P_bX/I}{c(P_g-P_b)+r+1-P_bX/I+[(r-c\theta(1-P_g))-C'(\cdot)/I]\partial\lambda'/\partial\delta}$$

approaches

$$\theta^* = \frac{c(1-P_b)+1-P_bX/I}{c(P_g-P_b)+r+1-P_bX/I}$$

when θ approaches 1, and hence

$$\theta > \frac{c(1-P_b)+1-P_bX/I}{c(P_g-P_b)+r+1-P_bX/I+[(r-c\theta(1-P_g))-C'(\cdot)/I]\partial\lambda'/\partial\delta}$$

is true and a higher δ makes the firm better off. From the property of continuity, we have that there exists a threshold $\bar{\theta}$, where $\bar{\theta} \geq \tilde{\theta}$, such that when $\theta > \bar{\theta}$, $\partial\Pi_s(\lambda,\delta,\Delta\lambda)/\partial\delta > 0$. □

Proof of Proposition 6. Suppose a good firm chooses partial equity ($E = \alpha I$) and partial debts ($D = (1-\alpha)I$) financing, and a bad firm chooses to invest using the same financing structure as a good firm with probability β, and chooses to quit with probability $(1-\beta)$, $\beta \in [0,1]$. By observing a financing structure of α percentage equity and $1-\alpha$ percentage of debts, the creditor's posterior belief is $\theta'_H \equiv (\lambda+\delta)\theta'/(\lambda\theta'+\delta)$ upon S_H and is

$$\theta'_L \equiv \frac{(1-\lambda-\delta)\theta'}{1-\lambda\theta'-\delta}$$

upon S_L, where $\theta' \equiv \theta/(\theta+(1-\theta)\beta)$. The good/bad firm's expected payoffs (denoted by Π_g and Π_b) are, respectively,

$$\begin{aligned}\Pi_g &= P_gX - I - (1-\alpha)\cdot K'(S)I - \alpha\cdot rI, \\ \Pi_b &= P_bX - I - (1-\alpha)\cdot\left[\frac{K'(S)+1}{P_g}P_b - 1\right]I - \alpha\cdot rI = 0,\end{aligned} \quad (17)$$

where

$$K'(S) \equiv \frac{1+c[1-\Theta'P_g-(1-\Theta')P_b]}{\Theta'P_g+(1-\Theta')P_b}P_g - 1,$$

and $\Theta' \in \{\theta'_H, \theta'_L\}$. Here, $K'(S)$ is a good firm's borrowing cost when bad firms play a strategy of β.

If a mixed-strategy equilibrium exists (i.e., $\beta \in (0,1)$), a bad firm is indifferent between investing and quitting ($\Pi_b = 0$), and thus the borrowing cost $K'(S)$ must be $((P_b(X/I) - \alpha(1+r))/((1-\alpha)P_b))P_g - 1$. We denote this knife-edge $K'(S)$ in the mixed-strategy equilibrium to be K^*, $K^* \equiv ((P_b(X/I) - \alpha(1+r))/((1-\alpha)P_b))P_g - 1$. Since $\beta \in (0,1)$, we have $\theta < \theta' < 1$ and thus in a mixed-strategy equilibrium $c(1-P_g) < K^* < K(S)$, where $K(S)$ is the good firm's borrowing cost in a pooling case (i.e., $K(S)$ is the $K'(S)$ when $\beta = 1$). If K^* is not in the range between $c(1-P_g)$ and $K(S)$, a mixed-strategy equilibrium does not exist. When $K^* > K(S)$, the bad firm will choose to pool with good firms; when $K^* < c(1-P_g)$, the bad firm will choose to quit. Since K^* decreases in α (i.e., $\partial K^*/\partial\alpha < 0$), for any $\alpha \in [0,1]$ chosen by the good firm, a bad firm's best response is as follows:

$$\begin{aligned}&\text{If } K^* > K(S), \text{ then } \Pi_b > 0 \text{ and bad firms choose}\\&\quad\text{to pool with good firms } (\beta = 1);\\&\text{If } K^* < c(1-P_g), \text{ then } \Pi_b < 0 \text{ and bad firms}\\&\quad\text{choose to quit } (\beta = 0);\\&\text{If } c(1-P_g) < K^* < K(S), \text{ then } \Pi_b = 0 \text{ and bad}\\&\quad\text{firms choose a mixed strategy } (\beta \in (0,1)).\end{aligned} \tag{18}$$

Given the bad firm's best response characterized in (18), a good firm's payoff is $\Pi_g = P_g X - I - (1-\alpha)\cdot K \cdot I - \alpha \cdot rI$, where $K = K(S)$ if $\beta = 1$, $K = c(1-P_g)$ if $\beta = 0$, and $K = K^*$ if $0 < \beta < 1$.

Now we analyze how Π_g changes in α. Given (18), there are three different cases: (1) If α is low, then $K^* > K(S)$ and $\beta = 1$, and $\Pi_g = P_g X - I - (1-\alpha)\cdot K(S)\cdot I - \alpha \cdot rI$. We have $\partial\Pi_g/\partial\alpha = [K(S) - r]I$. (2) If α is moderate, then $c(1-P_g) < K^* < K(S)$ and $0 < \beta < 1$, and $\Pi_g = P_g X - I - (1-\alpha)\cdot K^* \cdot I - \alpha \cdot rI$. We have $\partial\Pi_g/\partial\alpha = (1+r)I(P_g/P_b - 1) > 0$. That is, Π_g increases in α. (3) If α is high, then $K^* < c(1-P_g)$ and $\beta = 0$, and $\Pi_g = P_g X - I - (1-\alpha)\cdot c(1-P_g)\cdot I - \alpha \cdot rI$. We have $\partial\Pi_g/\partial\alpha = [c(1-P_g) - r]I < 0$. That is, Π_g decreases in α.

In each of these three regions, Π_g monotonically changes in α. Given the above analysis, it is obvious that maximum of Π_g is achieved either at $\alpha = 0$ or at $\alpha = \hat\alpha \equiv (P_b(X/I) - P_b((1+c(1-P_g))/P_g))/(1+r-P_b((1+c(1-P_g))/P_g))$, which makes $K^* = c(1-P_g)$. When $\alpha = 0$, we have $K^* > K(S)$, and the good firm's payoff is

$$\Pi_g(\alpha = 0) = \begin{cases} P_g X - I - K(S_H)\cdot I & \text{if } S = S_H,\\ P_g X - I - K(S_L)\cdot I & \text{if } S = S_L.\end{cases} \tag{19}$$

When $\alpha = \hat\alpha$, we have $K^* = c(1-P_g)$, and the good firm's payoff is

$$\Pi_g(\alpha = \hat\alpha) = P_g X - I - r'\cdot I,$$

where $r' \equiv (1-\hat\alpha)\cdot c(1-P_g) + \hat\alpha r$. If S_H is realized, we have $r' > K(S_H)$, and thus $\Pi_g(\alpha = 0) > \Pi_g(\alpha = \hat\alpha)$.[21] A good firm's maximum equilibrium payoff is achieved when investing by full-debt financing (i.e., $\alpha = 0$). Similarly, if S_L is obtained, we have $r' < K(S_L)$ and $\Pi_g(\alpha = \hat\alpha) > \Pi_g(\alpha = 0)$. A good firm's maximum equilibrium payoff is achieved when investing by $1-\hat\alpha$ borrowing and $\hat\alpha$ equity financing.

In this signaling model, there are a continuum of perfect Bayesian equilibria with $\alpha \in [0,1]$. We use the undefeated refinement developed by Mailath et al. (1993). Applying the undefeated refinement, we find that if S_H is realized, the pooling equilibrium at $\alpha = 0$ is the only undefeated equilibrium and if S_L is realized, the least-cost separating equilibrium at $\alpha = \hat\alpha$ is the only undefeated equilibrium. Given the undefeated equilibria upon S_H and S_L in this signaling game, all the results in our main setting qualitatively hold. We omit the detailed analysis because most analysis is very similar to that in our main setting except replacing r with r'. □

[21] Note that we assume $\lambda > \lambda^{**}$, which implies $K(S_L) > r' > K(S_H)$, and firms' investment and financing decisions differ in the realization of the signal in equilibrium.

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