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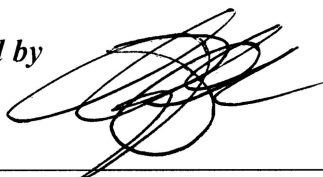
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**“A FIRM’S INFORMATION DISCLOSURE
AND THE MARKETS FOR ITS INPUTS AND OUTPUTS”**

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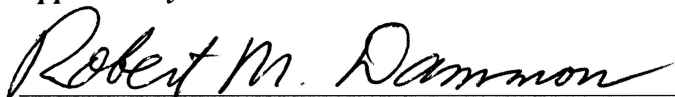


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**A Firm's Information Disclosure and the Markets for its
Inputs and Outputs**

By

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Abstract

This thesis examines the interactions between a firm's information disclosure decision and three markets: the product market, the takeover market, and the labor market, and the impact on firms' real decisions. Chapter 1 provides an introduction and overview of this thesis.

Chapter 2 considers a product-market competition setting through which to examine firms' investments in explorative initiatives and their choices of capitalization method regarding exploration related expenditures. The capitalization of exploration expenditures may contain information on whether a firm's exploration investment is successful, which may then incur imitative behavior from competitors (the information spillover effect), or intimidate competitors from investing (the pre-empting effect). These two effects are driving forces that induce firms to choose different capitalization methods. I find that if regulators require firms to capitalize only expenditures of successful explorations, firms may increase innovation. This study sheds light on the real effect that recognition of exploratory success has on firms' exploration investments.

Chapter 3 considers a setup in which the takeover market plays a disciplinary role in replacing an inefficient incumbent manager to increase firm value. We show that increasing the information quality improves takeover efficiency, but more precise information induces frequent managerial turnover and discourages the manager from working hard. We find that a perfectly informative accounting system is never optimal. Moreover, current shareholders prefer even higher information quality in the presence of antitakeover laws or provisions, since in such cases, motivating a raider to bid is particularly important for current shareholders.

Chapter 4 examines shareholder decisions on innovative investments and information quality in the presence of managerial career concerns. Managers' reputation concerns are costly to shareholders because managers must be compensated for taking career risks. I show that shareholders face a tradeoff when determining the information quality: lowering the information quality can mitigate a manager's career risk; however, it also hinders motivating managerial effort. I find that for higher managerial career concerns, shareholders with intense innovation urgency invest more in innovation and lower the information quality to protect the manager from exposure. In contrast, shareholders with lower levels of innovation urgency invest less to mitigate managerial career risk while increasing the compensation incentive to motivate higher managerial effort. My results shed light on the effects of career concerns on innovative investment, disclosure policy, and compensation incentives.

1. Introduction

Accounting information plays an important role in determining a firm stakeholders' decision making. For instance, the information disclosed by a firm may shape its potential competitors' entry decisions into its product market and it may also affect the firm's valuation in financial markets (Feltham and Xie, 1992). In addition, accounting information is critical in monitoring managers and facilitates an accurate evaluation of managerial capability in the labor market (Dewatripont et al., 1999a, Hermalin and Weisbach, 2007).

In my dissertation, I study firms information disclosure to three markets: the product market, the takeover market, and the labor market. I develop analytical models to examine how firms make real decisions and information-disclosure decisions anticipating the effect on these markets. Firms' endogenous choice of information quality has been studied in the extant literature. For example, Darrough and Stoughton (1990) and Feltham and Xie (1992) find that firms face a tradeoff between disclosing good news to the capital market and communicating bad news to competitors in the product market. Arya et al. (1998) shows that allowing earnings manipulation may benefit shareholders by saving ex-ante compensation for managers' dismissal risk. Moreover, according to Kanodia and Mukherji (1996), a firm's accounting system has real effects on its investment decisions. This suggests that the interaction between firms' real decisions and the endogenous choice of information quality deserves further examination. My study contributes to the literature by providing further insight into how a firm jointly makes information disclosure decisions and real decisions in anticipation of the reaction in the markets it interacts with.

In recent decades, regulators have often advocated improving information disclosure quality. In 2002, the Sarbanes-Oxley Act (SOX) was enacted, which mandates internal control disclosures, increases disclosure requirements, and improves transparency. As for the oil and gas industry, both the Financial Accounting Standards Board (FASB) and the International Accounting Standards Committee (IASC) have proposed to unify the capitalization method on exploration investment by enforcing the successful-efforts method and eliminating the option of the full-cost method. The reason behind this idea is that the successful-efforts method provides more accurate information regarding exploration outcomes than the full-cost method. However, controversy remains on whether higher information quality is always desirable. For example, some academicians have expressed concerns about SOX causing firms to incur an extra cost in R&D practices, resulting in less R&D investment (Lehn, 2008). Also, the successful-efforts method may induce volatile earning reports for small oil

and gas firms and possibly hinder their access to capital markets (Collins and Dent, 1979). In my study, I analyze how firms make real decisions as a response to the enforcement of an accounting regime and find that more stringent information disclosure requirements may not be necessarily beneficial to a firm since the firm may choose less efficient decisions as a response.

In Chapter 2, I examine firms investments in exploration initiatives and their choices of capitalization method in a product-market competition setting. Since the capitalization of exploration expenditures may contain information about whether a firm's exploration investment is successful, financial reports may reveal important information to competitors and thus may have real consequences in the product-market competition. On the one hand, information about successful innovation may spill over to competitors and induce them to invest in the same innovative areas; on the other hand, disclosing innovative success may preempt competitors from investing, and consequently, reinforce the innovator's competitive advantage. We show that the tradeoff between these two effects impacts both firms' investment decisions and their ex-ante choices of capitalization method. We also analyze the effect of enforcing an accounting method that requires firms to capitalize expenditures of only successful explorations. We find that enforcing this method may result in more innovation investment. The reason is that firms have an incentive to mitigate the information-spillover effect by increasing their investments. Our study sheds light on the impact that the recognition of exploratory success has on firm exploration investments.

Chapter 3 studies the interaction between firm information quality and the takeover market. We consider a model in which the takeover market plays a disciplinary role in replacing an inefficient incumbent manager to increase firm value. In corporate takeovers, financial accounting information of a target firm is useful for the acquirer to assess the target firm's value when there is information asymmetry about the true value. Although increasing the information quality improves the takeover efficiency, more precise information induces active management turnover and discourages a manager from working hard. We find that a perfectly informative information system is never optimal for either the current shareholders expected payoff maximization or the expected firm value maximization. In addition, current shareholders prefer a higher information quality level than the one that maximizes firm value. This is because the current shareholders may obtain an overbidding premium by increasing the information quality to induce a higher likelihood of receiving a high-price bid for a low-value firm. We also analyze the effect of anti-takeover laws or provisions. We find that the optimal information quality is higher after the adoption of anti-takeover laws or anti-takeover provisions. Thus, the passage of an anti-takeover law or antitakeover provision mitigates an acquirer's bidding incentive, and the acquirer should be motivated to bid by more accurate information. These results have implications for the target firms' disclosure policies in the context of the takeover market. Moreover, while the adoption of antitakeover laws always increases a firm's value, it increases the current shareholders' payoff only when the manager's

private benefit is large and the value enhancement from the takeover is small.

In Chapter 4, I develop a theoretical model to examine shareholder decisions on innovative investments and information quality in the presence of managerial career concerns. Career concerns provide managers with implicit incentives that benefit shareholders. However, these concerns are also costly to shareholders because managers need to be compensated for taking career risk. Career risk is especially significant if a manager's perceived ability is largely exposed to the labor market, as is the case when a manager is asked to implement innovative strategies. Although lowering the quality of the information disclosed by the firm can mitigate a manager's career risk, it also impedes motivating managerial effort. I show that due to the tension between mitigating the career risk resulting from innovation and motivating managerial effort, perfect information quality is not optimal for shareholders, especially when the firm is undergoing a transformation. In addition, as managerial career concerns increase, I find that when innovation urgency is intense, shareholders invest more in innovation and decrease the information quality to mitigate managerial career risk. In contrast, when innovation urgency is weak, shareholders invest less to mitigate the manager's career risk, while increasing the explicit incentive to motivate a the higher effort. My results provide possible explanations for extant mixed empirical findings on the relationship between career concerns and investment. In addition, my analysis also suggest that when we examine the impact of career concerns on innovative investments, disclosure policy, and managerial explicit incentives, we need to consider innovation urgency. Because innovation urgency is also an industry-specific characteristic, my results shed light on the aforementioned career concerns effects across industries. In addition, I find that experienced CEOs may not be coveted by extremely innovative or modestly innovative firms as much as by middle-of-the-road innovation firms.

2. Innovators and Imitators in Product-Market Competition and Accounting Reporting¹

2.1. Introduction

In this paper, we study how different capitalization methods affect firms' investments in innovative activities, and how firms choose a capitalization method to help sharpen their competitive edge. We examine a setting in which accounting reports may contain information about the result of an innovator's investments, which could be used by competitors in shaping their own investment decisions. Specifically, this information can potentially be used by competitors to imitate the innovator firm's investments, and therefore may substantially affect a firm's ability to compete in the future. To protect or enforce its competitive advantage, an innovator firm needs to consider ex ante which accounting capitalization method is optimal. We identify two driving forces that affect firms' capitalization method choice: the information spillover effect and the preempting effect. On the one hand, the information about a success in innovations may spill over to competitors and induce them into investing in the same innovative areas; on the other hand, disclosing achieved success in innovations may preempt competitors from investing and reinforce the innovator firm's competitive advantage. We show that the trade-off between these two effects impacts both firms' investment decisions and their ex-ante choices of capitalization method.

The capitalization method of exploration costs for the oil and gas industry provides a good example of the disclosure scenario in which we are interested. Oil and gas companies can currently choose between the full-cost method and the successful-efforts method to recognize their exploratory costs. If a company chooses the full-cost method, it capitalizes all of its exploration costs, including dry-hole costs. If a company chooses the successful-efforts method, it expenses the exploration costs that are related to unsuccessful exploration, and capitalizes only the expenditures related to successful exploration.

It is well documented that large oil and gas companies more often use the successful-efforts method, while smaller companies choose the full-cost method (Sunder, 1976;

¹This study is a joint work with Carlos Corona and Lin Nan.

Deakin, 1979; Dhaliwal, 1980; Bryant, 2003). The difference in the choices made by large and small oil and gas companies is usually explained by the argument that small firms cannot afford the earnings volatility induced by the successful-efforts method, because it would be harder to obtain capital if they expensed their unsuccessful exploration costs. However, this argument implies that the market cannot see through earnings volatility. That is, it implies that the market is not completely efficient. Our model provides an alternative explanation for the difference in preferences over capitalization methods that does not rely on market inefficiency. The intuition of our analysis can be illustrated by emphasizing the contrast between the situation faced by small and large firms. Suppose, on the one hand, that a very small oil drilling firm makes a single drill exploration in a given reporting period. If this firm reports its exploration expenditures by the successful-efforts method, its financial report completely reveals whether the exploration succeeded and therefore provides a lot of information to potential imitators to exploit the same area. On the other hand, say a large drilling firm drills in a hundred different areas and succeeds in ten of them. By reporting through the successful-efforts method, the large firm is not revealing much about which areas contain oil reserves to potential imitators. That is, the spillover of information through the successful-efforts method decreases with the number of areas explored by the reporting firm. However, regardless of the number of areas explored, the successful-efforts method always reveals the aggregate amount of successful explorations (i.e., the firm's competitive advantage step-up). As a result, small firms try to avoid the spillover of information to potential imitators by choosing the full-cost method. Large firms choose the successful-efforts method because their bigger investments do not reveal much information about the location of the successful drills but they intimidate competitors by revealing a competitive advantage gain.

In addition, we examine the consequences of enforcing a uniform capitalization method on firms' exploration-investment choices. The question of whether firms should be granted the option of choosing between different accounting-recognition methods for exploration expenditures has been debated for decades. In 1977, the Financial Accounting Standards Board (FASB) proposed the Statement of Financial Accounting Standards No. 19 to remove the option of the full-cost method in the oil and gas industry. However, the proposal encountered great resistance and was not enacted. Recently, this debate resurfaced again as the International Accounting Standards Committee (IASC) initiated a project to eliminate the full-cost method for extractive industries in 1998 (International Accounting Standards Committee 2000a). Again, the attempt to eliminate the full-cost method failed, and the final outcome of this project, International Financial Reporting Standard 6, still allows the choice between accounting methods. The elimination of the full-cost method raises many concerns from both extractive-industry practitioners and academicians. One reason in particular to oppose this proposed change is that the elimination of the full-cost method will hinder small firms' access to capital markets, and therefore prevent those firms from undertaking innovative investments

(Collins and Dent, 1979). However, our analysis suggests that smaller firms that are more concerned about information spillover may increase investment in innovative activities if the successful-efforts method is enforced. Under this enforcement, firms with information-spillover concerns may choose to invest more to dilute the information content in their financial reports. Also, we find that if the full-cost method is enforced, firms may invest less in their exploration activities. With the full-cost method, although an innovator firm is not concerned about information-spillover repercussions, it nevertheless loses a means of threatening its rival through the reporting of successful exploration. As a consequence, the firm may reduce its innovative investment.

The rest of the paper is organized as follows: Section 2.2 provides a review of previous studies that are relevant to our paper. In Section 2.3, we describe and analyze the main setting of our paper, in which firms have the option to choose between the full-cost and successful-efforts methods. In Section 2.4, we examine a setting in which only the successful-efforts method is allowed and a setting in which firms can only use the full-cost method. Section 2.5 concludes the study.

2.2. Literature Review

Our study is related to studies on the effect of accounting disclosure in product market competition. Darrough and Stoughton (1990) and Feltham and Xie (1992) examine firms' incentive to disclose or withhold private information in an entry game and illustrate a tension between an informed manager's desire to communicate good news (and hide bad news from) to the capital market and his desire to communicate bad news (and hide good news from) to competitors in the product market. Arya and Mittendorf (2007) illustrate how firms' incentives to withhold private information from competitors are undercut by the fact that disclosures also boost analyst following, which provides firms with new information about market conditions. Bagnoli and Watts (2010) examine a Cournot competition setting in which firms can misreport their production costs. In this study, we concentrate more on the tension between a desire to hide proprietary information to deter rivals from imitating and a desire to disclose information to rivals to achieve a preemptive advantage. In addition, we show that firms' many investments can mitigate the magnitude of undesirable information spillover. This suggests that firms can use investment decisions as a device to affect the informativeness of their accounting reports.

There are numerous empirical studies on the debate of whether extraction industries should keep the option of choosing between the successful-efforts and full-cost methods. Some studies indicate that the successful-efforts method is more informative. For example, Harris and Ohlson (1987) show that the book values of firms using the successful-efforts method have higher explanatory power about their market values than those using the full-cost method. Bandyopadhyay (1994) compares the

earnings-response coefficients of successful-efforts firms and full-cost firms around the announcement of quarterly earnings over the 1982—1990 period and finds that successful-efforts firms have higher coefficients. There are also studies that shed light on how different choices of accounting methods may influence firms' investment in exploration activities. For example, Johnson and Ramanan (1988) examine the oil and gas industry during 1970—1976 and find that firms that switch to the full-cost method exhibit a higher level of exploration activities and higher leverage. Lilien and Pastena (1982) find that revenues are positively associated with the successful-efforts choice while leverage and exploratory aggressiveness are positively correlated with the full-cost choice. Despite the abundance of empirical research in this area, there are few analytical studies on the cost and benefit of keeping the discretion between different methods regarding extractive industries' exploration expenditures. We contribute to this line of literature by providing analytical insights on this debate.

Our study is also related to studies on the aggregation in information disclosures. Arya, Frimor, and Mittendorf (2010) study the discretionary disclosure of proprietary information by multi-segment firms. They show that a disaggregate report may convey high cost in some markets to soften rival competition, but at the same time inevitably convey low cost in other markets and induce fiercer competition. As a result, they find that the optimal disclosure aggregates segment details. In our paper, aggregation is not across segments but across successful and unsuccessful investments in the same market. As a result, our paper does not need to rely on multiple markets to show the effects of disclosure aggregation. Instead, we show that firms choose between less aggregated or more aggregated disclosure policies depending on their relative size to competitors and the severity of the information spillover. Hayes and Lundholm (1996) examine a firm's disclosure of segment details when facing both a capital market and a product market and show that the firm may withhold information when product market concerns are sufficiently pronounced. In our paper, capital markets do not play a role. Instead, the product market is at center stage and aggregation is instrumental in reducing the information spillover to competitors.

2.3. The Main Model

2.3.1. Setup

We consider a setting with two firms, A and B. The firms choose their accounting disclosure methods *ex ante*. Because we want to focus on firms' innovation decisions in a competitive setting, we assume that one firm, firm A, is an innovator and makes investments in innovation. Firm A's innovation results can be reflected in its accounting report, and its rival, firm B, is deciding whether to imitate A's investment decisions by choosing the same innovation area(s) after observing the report.

Firm B’s decision on whether to imitate firm A’s innovation depends on how much information firm B is able to obtain before deciding on its own exploration investments. This information is determined in part by the accounting report issued by firm A, and therefore by the accounting regulatory regime. We further assume that the two firms later compete in a Cournot product market, and a firm’s investment in innovation, when successful, improves its ability to compete. We assume Cournot competition in our main analysis, however, the nature of competition (i.e., whether Cournot or Bertrand) does not matter because in our study, the information only affects firms’ investment decisions and information will be fully revealed before the competition. Only the competition advantage/disadvantage resulting from investments is the focus of our paper, and we do not want the nature of competition to interfere with the information. In the Appendix we also show a setting with Bertrand competition and the main results are qualitatively the same.

The way to model the sequence of events allows us to examine both the endogenous accounting choices of innovating firms and the effect of accounting regulation on exploratory investments, taking into account the resulting spillover of information in a competitive environment. We often refer to firm A as an “innovator” and to firm B as an “imitator.” Also, in our analysis and discussion, we use the oil and gas industry as a running example. In this industry, the accounting regulation regarding capital expenditures in exploratory activities has been the subject of frequent debate by both practitioners and researchers. For this reason, it provides us with realistic examples to illustrate our model and analysis. Nevertheless, our analysis can be interpreted in a much broader way and potentially be applied to a wide set of industries.²

We characterize the space of possible exploration initiatives as being subdivided into “areas” of exploration. Depending on the industry, these areas can have a different interpretation. For instance, in the extractive industry, an area can be thought of as the proximity of a mining or drilling location; in the pharmaceutical industry, an area can be understood as a line of research for a new drug for a specific disease; in the software industry, an area might be the sort of application under development, and so forth. Exploration initiatives can be kept more or less confidential depending on the industry, but they can seldom be completely private. We reflect this fact by assuming that competitors can observe the areas in which a firm explores. The extent to which the observability of explored areas is informative is also contingent on the industry under consideration. In the extractive industry, for instance, knowing the location in which another firm is exploring is potentially very informative. In the software industry, however, knowing what sort of application a firm is developing might be not as useful without more detail. Still, the information of which areas a firm is exploring might be a lot more valuable if the outcome of the exploration is also known. Depending on the accounting regulatory regime and the accounting

²For example, the software industry also encounters the problem of how to capitalize firms’ R&D expenses, and different accounting recognition rules may have real effects on firms’ innovation investments.

choices of the reporting firm, the success or failure of exploration initiatives is potentially revealed by the accounting report. Notice that in our paper the innovator and imitator compete in the same market, and the innovator's exploration-outcome disclosure should be relevant to its competitor's decisions in the market competition for similar products.

We assume that there are plenty of exploration "areas" in which firms can invest. We assume that a firm can potentially invest in several areas, and that the exploration outcome in each of these areas is binary—success or failure. We denote the probability of an investment success in a specific area by h . We assume that this probability is public information and independent across different areas. To avoid unnecessary complexity in the Bayesian updating, we further assume that if an exploration in an area is successful, then any subsequent exploration in that area is also successful with certainty. For instance, if a firm finds an oil reserve in a certain area, any other firm exploring this same area profits from drilling the same oil reserve. On the other hand, if a firm fails to succeed in exploring an area, other firms also fail when exploring the same area. To reflect the competitiveness gain obtained through a successful exploration, we assume that a success increases the contribution margin per unit of firm A by a fixed quantity $a > 0$. If firm B succeeds in exploring a different area, it obtains the same benefit. However, if it explores in an area in which firm A already succeeded, firm B only increases its contribution margin per unit by γa , with $0 < \gamma < 1$. One can think of γ as incorporating the fact that the extent to which the success by the innovator can be imitated by the follower varies from industry to industry. For instance, in extractive industries, γ may reflect the fact that the first firm that succeeds in a specific area may take the best "spots," while subsequent entrants can only take the leftovers. In the technology industry, γ may reflect the fact that the pioneering firm may obtain an advantage in the form of a reputation for innovation or for technical sophistication in the mind of consumers. For example, Apple's innovation on its products such as the iPhone and iPad gave the company an edge over its rivals. Even though several competing companies subsequently launched similar products, consumers still regard Apple's products as the best and are willing to pay a premium price for them.

To consider the effect of firm size on accounting discretionary choices and investment decisions, we reflect the size of a firm in the model by assuming that larger firms have a lower cost of investment. This is to reflect the reality that, for example, it is easier for large firms to access capital than for small firms, and large firms may also enjoy the benefit of economies of scale. Regardless of size, however, we assume that all firms have a convex cost of investment; that is, the capital necessary to explore each additional area is more expensive. We denote firm i 's cost of investing in the j^{th} area by k_j^i . For instance, the cost of exploring a second area for firm A is k_2^A . The investment-cost convexity then implies that $k_j^i < k_{j+1}^i$.

In the main setting, for simplicity we assume that firm A is able to invest in up to two areas and firm B can invest in up to one area. Firm A's first exploration costs is $k_1^A > 0$, and its second exploration costs is k_2^A , where $k_2^A > k_1^A$. Firm B's cost of

investing in one area is $k_1^B > 0$, and the cost of investing in a second area is ∞ . In the Appendix we also include the analysis for the opposite situation in which firm A can invest in up to one area and firm B can invest in up to two areas. The opposite situation does not bring much additional insight, because it is very similar to the case in the main setting when firm A's second exploration cost is very high, but we include the analysis in the Appendix for completeness.

In the oil and gas industry, there has long been a debate regarding the recognition of the cost of exploring for oil and gas reserves. Currently, oil and gas companies can choose between the full-cost method or the successful-efforts method to recognize these costs. These two capitalization methods are informatively different and therefore provide us with a case of a specific regulatory choice that potentially affects the amount of information spillover between competing firms.³ We examine three regulatory regimes. In this section, we examine the case in which firms are allowed to choose between the two capitalization methods. In Section 2.4, we examine the consequences of enforcing the successful-efforts method and the consequences of enforcing the full-cost method.

Date 1	Date 2	Date 3
Firm A chooses a capitalization method and makes an innovative investment decision.	Firm A observes the outcome and reports. Firm B makes an investment decision after observing A's report.	The outcomes of both firms' investments are revealed. The two firms compete in a Cournot market.

Figure 2.1.: Time line.

We examine a setting with three dates, as illustrated with the time line in Fig. 2.1. At date 1, firm A chooses whether to use the full-cost or successful-efforts method to capitalize its investment, and decides on the area(s) to explore. Firm A's capitalization method and which area(s) it chooses to explore are publicly observable. At date 2, A observes its exploration outcome and reports according to its previous choice of accounting method. We denote firm A's exploration outcome by x_A and its report by $D = (I_A, \hat{x}_A)$, where $x_A \in \{0, 1, 2\}$ is the number of areas in which the exploration was successful, $I_A \in \{1, 2\}$ is the number of areas that firm A explored, and $\hat{x}_A \in \{0, 1, 2\} \cup \{\emptyset\}$ is the reported number of areas in which the exploration was successful. Notice that under the successful-efforts method, the accounting report provides information about the aggregate successful investment. Obviously,

³Oil and gas firms that use the full-cost method usually do not write off their dry wells separately. When they write off their assets, it is usually difficult to tell whether the write offs are due to dry wells or other assets impairments. However, even if they write off the book value of their dry wells and disclose, which reveals information of the exploration results, write offs usually do not occur in a timely manner and are not useful in competitors' investment-in-exploration decisions.

the firm can only succeed in areas in which it invested; i.e., $x_A \leq I_A$. Under the full-cost method, however, the report does not distinguish between successful and unsuccessful exploration investments. The report only provides information about the size of the investment I_A , and withholds information about the outcome of that investment. Therefore, in that case, $\hat{x}_A = \emptyset$. Firm B observes A's report and makes its own exploration decision by choosing $I_B \in \{0, s, d\}$, where $I_B = 0$ means that firm B does not invest, $I_B = s$ means that firm B chooses to explore one of the same areas firm A previously explored, and $I_B = d$ means that firm B explores a different area than firm A. At date 3, the outcomes of both firms' explorations are revealed and both firms compete in a Cournot product market.⁴ That is, we assume that the initial information provided in the accounting reports is timely enough for the imitator to make investment decisions but that by the time the investment outcomes affect market competition, the outcomes have been fully revealed. We denote the exploration outcome of firm B by $x_B \in \{0, 1, \gamma\}$, where 0 means that either B does not invest or that B's exploration fails,⁵ γ means that B succeeds in an area in which A previously succeeded, and 1 means that B succeeds in a different area than the ones explored by A.

The payoff functions of firms A and B are, respectively:

$$\Pi_A = q_A(1 - q_A - q_B + a_A) - k_1^A - k_2^A \cdot t_A \quad (2.1)$$

$$\Pi_B = q_B(1 - q_A - q_B + a_B) - k_1^B \cdot t_B, \quad (2.2)$$

where $a_i = x_i \cdot a$ for $i \in \{A, B\}$ is the change in contribution margin obtained through successful exploration. In particular, $a_A = a$ if A finds oil in one area, $a_A = 2a$ if A finds oil in two areas, $a_B = a$ if B finds oil in a different area than A, $a_B = \gamma a$ if B finds oil in the same area as A, and $a_i = 0$ if firm i 's exploration fails. Also, t_A is an indicator variable that equals zero if A explores one area and equals one if A explores two areas; t_B is an indicator variable that is zero if B does not invest in exploration and equals one if B explores one area. We denote firm i 's quantity decision by q_i , and $1 - q_i - q_j + a_i$ represents firm i 's contribution margin, $i, j \in \{A, B\}$. The price of the product is decreased by both firm i 's production and the other firm's production, and we assume the products are perfectly substitutable.

In addition, we make the following scope assumptions in our analysis to rule out trivial or uninteresting cases:

Condition 2.1: *The scope of our analysis is restricted by the following bounds on the parameters of the model:*

⁴In the Appendix, we also examine a Bertrand competition and show that our results with a Cournot competition assumption are robust in a Bertrand setting in which successful exploration reduces the innovator's production cost.

⁵Because firm A cannot take advantage of this information in making its investment decisions, these two outcomes are equivalent.

AS1) $0 < h < \frac{1}{3}$;

AS2) $0 < a < \frac{1}{4}$;

AS3) $0 < \underline{\gamma} < \gamma < 1$ where $\underline{\gamma} = \frac{2a-1+\sqrt{1+4a(a+h-1)}}{2a}$;

AS4) $k_1^i < \overline{K} = \frac{4ah(1+a-2ah)}{9}$ for $i \in \{A, B\}$.

By AS1, we assume the ex-ante probability of success h is not so large that information about the innovator's success is relevant to the imitator. Regarding AS2, if $a > \frac{1}{4}$, we can show that the preempting effect will be so overwhelming that B will not invest at all when A discloses no information about its success, which is not an interesting case and provides limited insight. By AS3, we concentrate on cases in which γ is not too small. When γ is very small, the benefit from imitation is so small that B never wants to imitate A's investment. Because we are interested in B's imitating decision and this case does not bring any additional insight, we rule it out to avoid taxing readers with tedious analysis. Finally, by AS4 we assume that investment costs are not large enough to prevent firms from investing when they are only endowed with prior information. Indeed, if firm B's investment cost makes investing prohibitive when A's report provides no additional information, then A always chooses to withhold any information about its investment outcome so that B does not have a chance to obtain an increase in its contribution margin. With AS4, A always invests in at least one area and B is not completely discouraged from investing.⁶

2.3.2. Information-Spillover Effect and Preempting Effect

In this subsection, we will derive the equilibrium of our model and illustrate two effects that influence the equilibrium: the information-spillover effect and the preempting effect. If firm A reports using the successful-efforts method, its accounting report contains information about the outcome of its exploration activities, and its competitors may take advantage of the "spilled" information about A's successful explorations by imitating A's investment. We call this effect *the information-spillover effect*. Notice that even though A's report by the successful-efforts method is informative, the information spilled may not be complete. For example, when A succeeds in only some of its explored areas, B does not know which areas are successful and which are unsuccessful. B can only update about the probability of success in those areas. However, by revealing the amount of successful investment, A secures its preemptive advantage in the competition, and this advantage may intimidate firm B. We call this effect *the preempting effect*. In the following analysis, we will illustrate in detail how these two effects interact and affect the equilibrium strategies of both innovator and imitator.

⁶The detailed derivation of the thresholds $\underline{\gamma}$ and \overline{K} is in the Appendix.

To derive the equilibrium, we proceed by backward induction. At date 3, both firms' exploration outcomes are realized and publicly observed. Solving a standard Cournot game, we have firm i 's optimal production quantity $q_i^* = \frac{1+2a_i-a_j}{3}$, and firm i 's gross payoff without considering the investment/exploration cost is,

$$W_i(a_i, a_j) = q_i^*(1 - q_i^* - q_j^* + a_i) = \frac{(1 + 2a_i - a_j)^2}{9},$$

with $a_i = x_i \cdot a$, $i, j \in \{A, B\}$.

Different combinations of the two firms' exploration outcomes provide different gross payoffs for the two firms. These gross payoffs are available in Tab. A.1 in the Appendix.

2.3.2.1. Firm B's Strategies Given Firm A's Report

We first examine firm B's strategies at date 2, taking firm A's report as given. At date 2, A reports according to its choice of capitalization method that was determined at date 1. Notice that under the full-cost regime, A does not disclose its number of successes, therefore $\hat{x}_A = \emptyset$. Firm B observes A's report $D = (I_A, \hat{x}_A)$ and makes its own exploration decision $I_B \in \{0, s, d\}$ to maximize its expected payoff,

$$\max_{I_B} E[\Pi_B | I_B, D(I_A, \hat{x}_A)] = E[W_B(a_B, a_A) | D, I_B] - k_1^B \cdot t_B.$$

Because firm A may report using either the successful-efforts method or the full-cost method, we analyze B's strategies in these two cases separately. We first study the case in which A uses the successful-efforts method and then the case in which A reports with the full-cost method.

B's strategies given A's report using the successful-efforts method. If A uses the successful-efforts method to report, firm B observes exactly the number of success(es) A obtained and therefore knows the value of a_A . Nevertheless, B does not necessarily know in which area A succeeded. This happens, for instance, in the case in which A invests in two areas and reports only one success.

To analyze firm B's optimal investment choice for each possible accounting report issued by firm A using the successful-efforts method, we compare firm B's payoffs across B's investment choices for a given firm A's report, $E[\Pi_B | D, I_B]$. First, it is obvious that when firm A reports no success, exploring one of the areas explored by A does not yield any success to B and therefore B chooses to explore a different area.⁷ Indeed, the assumption $k_1^B < \bar{K}$ guarantees that B's investing in a different area dominates the no-investment strategy.

⁷Firm B's expected payoffs based on different reports from A by the successful-efforts method, $E[\Pi_B | I_B, D(I_A, \hat{x}_A)]$, are available in the Appendix.

When firm A reports a non-zero success(es) outcome, firm B's optimal investment strategy depends on both its investment cost (k_1^B) and the information-spillover effect. The information spillover, to some extent, is associated with γ . Notice that when γ is high ($\gamma \rightarrow 1$), A's disclosed information brings a large benefit to B, as B is able to imitate A's investment and obtain a large increase in its contribution margin. On the other hand, when γ is close to zero, B does not benefit from the information of A's investment outcome. The spillover effect is especially strong when A reports *full success* in its invested area(s); that is, when either A invests in one area and achieves one success or A invests in two areas and achieves two successes. In the case that A invests in two areas but reports only one success (that is, A reports *partial success*), the information content is diluted, as B cannot tell in which area A succeeded.

Our analysis shows that B's strategy depends on the relative strength of the spillover and the preempting effects. The relative strength of these effects, in turn, depends on the parameters γ and k_1^B . We illustrate B's optimal strategies given A's report by the successful-efforts method in Fig. 2.2.

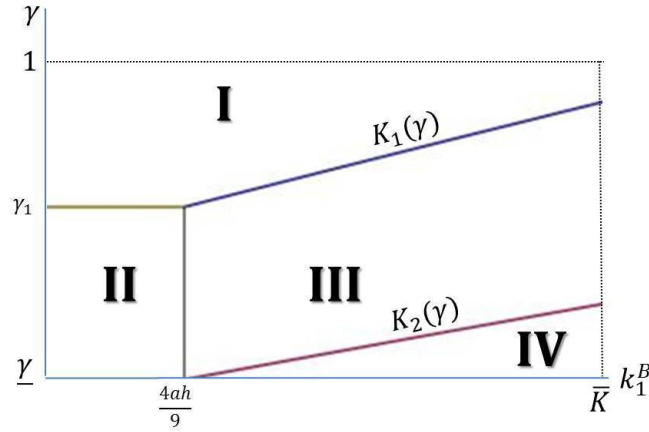


Figure 2.2.: Regions that delimit B's strategies given that A uses the successful-efforts method.

In Region I in Fig. 2.2, which is delimited by $k_1^B < \text{Min}\{\bar{K}, K_1(\gamma)\}$ and $\gamma_1 < \gamma \leq 1$, our analysis based on B's expected payoffs shows that $I_B^*(D) = s$ for $D = (1, 1), (2, 1)$, or $(2, 2)$.⁸ That is, when the information-spillover effect is significantly strong, firm B will imitate A's investment and explore a same area as firm A, as long as firm A reports any successful exploration.

In Region II, which is delimited by $k_1^B < \frac{4ah}{9}$ and $\underline{\gamma} < \gamma \leq \gamma_1$, if A reports full success, we still have the result that B invests in a same area as A. However, when A reports partial success, B only has a 50% chance of obtaining success by imitating A, and thus the benefit from imitating A is small (notice that not only γ is lower

⁸The derivations of the closed-form values of all thresholds are available in the Appendix.

than that in Region I, but also the information content from A's report is diluted when A reports partial success). Therefore, in this case, B finds that it is better to invest in a different area when firm A reports partial success.

In Region III, which is delimited by $Max\{\frac{4ah}{9}, K_1(\gamma)\} < k_1^B < Min\{\bar{K}, K_2(\gamma)\}$, B's cost of investment becomes higher than that in Region II. When A reports full success, we still have the same result as those in Regions I and II— that B will invest in a same area. However, now when A reports partial success, B will not invest at all. This is because A only discloses diluted information and has secured some preemptive advantage, while B has only a 50% chance of succeeding by imitating A and additionally has a high cost of investment. Therefore, B will choose not to invest at all.

In Region IV, which is delimited by $K_2(\gamma) < k_1^B < \bar{K}$ and $\gamma > \underline{\gamma}$, we find that B will choose not to invest even if A reports success in both of its areas ($I_B^*(D) = 0$ for $D = (2, 2)$). It is interesting that even when A reports full success in its two explored areas ($D = (2, 2)$) and B can achieve sure success by investing in either of A's areas, B's optimal strategy is not to invest at all. This result is driven by two forces. First, when A has already obtained two successes, its contribution margin per unit has increased by $2a$, and its competitive advantage is large. That is, A has secured its preemptive advantage in the future competition. Second, as γ is small but B's investment cost is high, the benefit of investing cannot outweigh the cost. Overall, even if B obtains perfect information about successful areas from A's report (the information has fully spilled over to B), the preempting effect dominates.

In Region IV when A reports success in its only investment, we find that B invests in the same area because the information spillover still dominates; however, when A reports partial success, A's secured preemptive advantage as well as B's high investment cost induce B not to invest at all.

Notice that the information-spillover effect as well as the preempting effect exist in all the above different cases and both play roles in B's investment decision. Which effect dominates in the trade-off, together with the consideration of B's investment cost, determines firm B's strategy. Our results of B's optimal strategies given A's successful-efforts reports, denoted by $I_B^*(D)$, are formally stated in Lemma 1.

Lemma 1. *Firm B's optimal strategies when firm A reports using the successful-efforts method are summarized in the following table:*

	$D = (1, 0) \text{ or } (2, 0)$	$D = (1, 1)$	$D = (2, 1)$	$D = (2, 2)$
Region I	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = s$	$I_B^*(D) = s$
Region II	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = d$	$I_B^*(D) = s$
Region III	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = 0$	$I_B^*(D) = s$
Region IV	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = 0$	$I_B^*(D) = 0$

B's strategies given A's report using the full-cost method. Now we consider the case in which A reports using the full-cost method. In this case, B does not

know in how many areas A has succeeded. Therefore, B has to make the investment decision based on its conjecture of a_A .

Comparing the expected payoffs of B based on A's report using the full-cost method, $E[\Pi_B|I_B, D = (I_A, \emptyset)]$, we obtain that $E[\Pi_B|d, (I_A, \emptyset)] > E[\Pi_B|s, (I_A, \emptyset)]$ for $I_A \in \{1, 2\}$.⁹ That is, if A reports under the full-cost regime, exploring a different area from A's area(s) is always a better strategy for B than exploring a same area as A. The intuition is that A provides no information about its exploration outcome under the full-cost regime and therefore no information has "spilled over" to B, whose belief about the probability of success stays unchanged. That is, no matter whether B decides to explore a same area as A or a different area, B's prior belief about the probability of success is h . However, if B follows A's exploration and achieves success, B will only get $a_B = \gamma a$ and benefit less from the success than from a success in a different area. In addition, with the assumption $k_1^B < \bar{K}$ for firm B, investing in a different area dominates no investment. Therefore, whenever firm A chooses the full-cost method, firm B will explore a different area. We state this result in Lemma 2.

Lemma 2. *When firm A uses the full-cost method to report, firm B chooses to invest in a different area.*

2.3.2.2. Firm A's Capitalization-Method Choices

Now we are back to date 1 to analyze A's decisions on its capitalization method and innovation investments. We denote A's choice of capitalization method to be R , $R \in \{FC, SE\}$, where FC represents the full-cost method and SE represents the successful-efforts method.

We first analyze A's optimal capitalization method given A's investment decision. Later we will compare A's expected payoffs with different combinations of I_A and R to derive A's optimal investment strategies and accounting-method choice.

A's capitalization-method choices given $I_A = 1$. We first examine the case in which A invests in one area. Notice that, according to Lemmas 1 and 2, if A uses the full-cost method, B invests in a different area; if A uses the successful-efforts method, firm B invests in a same area if A reports success and in a different area otherwise. Therefore, A's expected payoffs with the two alternative capitalization methods are as follows:

⁹The explicit expressions of firm B's expected payoffs based on firm A's report under the full-cost method, $E[\Pi_B|I_B, D(I_A, \emptyset)]$, are available in the Appendix.

$$\begin{aligned}
 E[\Pi_A|1, FC] &= h[hW_A(a, a) + (1 - h)W_A(a, 0)] \\
 &\quad + (1 - h)[hW_A(0, a) + (1 - h)W_A(0, 0)] - k_1^A \\
 &= \frac{1 - [2 + a(5 - 4h)]ah}{9} - k_1^A;
 \end{aligned}$$

$$\begin{aligned}
 E[\Pi_A|1, SE] &= hW_A(a, \gamma a) + (1 - h)[hW_A(0, a) + (1 - h)W_A(0, 0)] - k_1^A \\
 &= \frac{1 + \{2(1 + h - \gamma) + a[5 - h - (4 - \gamma)\gamma]\}ah}{9} - k_1^A.
 \end{aligned}$$

Our analysis shows that $E[\Pi_A|1, FC] > E[\Pi_A|1, SE]$. That is, A will choose the full-cost method when it invests in one area. Intuitively, when A invests in only one area, the information-spillover effect is very strong because firm B achieves a certain success by imitating A's investment as long as A reports success. Therefore, firm A prefers the full-cost method to avoid revealing any information about its success in order to prevent B from imitating.

A's capitalization-method choices given $I_A = 2$. When A invests in two areas, according to Lemmas 1 and 2, B's optimal investment strategy depends not only on A's report, but also on the severeness of the information spillover, γ , and B's cost of investment, k_1^B . To derive A's optimal reporting method, we compare A's expected payoff when choosing the full-cost method, $E[\Pi_A|2, FC]$, with that of choosing the successful-efforts method, $E[\Pi_A|2, SE]$, incorporating firm B's optimal responses in all regions depicted in Fig. 2.2. We illustrate the result in Fig. 2.3, and formally present A's optimal reporting-method choice, R^* , in Lemma 3.

Lemma 3. *A prefers the full-cost method when investing in one area ($R^* = FC$ when $I_A = 1$). When investing in two areas ($I_A = 2$), in Region FC , A prefers the full-cost method ($R^* = FC$); in Region SE , A prefers the successful-efforts method ($R^* = SE$).*

In Fig. 2.3, Region FC includes Region I and Region II in Fig. 2.2. That is, $0 < k_1^B < \text{Max}\{\frac{4ah}{9}, K_1(\gamma)\}$ and $\underline{\gamma} < \gamma < 1$. Region SE in Fig. 2.3 is the union of Regions III and IV in Figure Fig. 2.2. That is, Region SE is defined by $\text{Max}\{\frac{4ah}{9}, K_1(\gamma)\} < k_1^B < \bar{K}$ and $\underline{\gamma} < \gamma < 1$.

Notice that in Region FC , γ is big or k_1^B is small. Intuitively, B is likely to imitate A either because the benefit from imitating is large or because the cost of investment is low. Therefore, A chooses the full-cost method to avoid B's imitation. In Region SE , γ is relatively small and k_1^B is relatively large, compared with Region FC . B now has a weaker incentive to imitate A due to a high investment cost and a

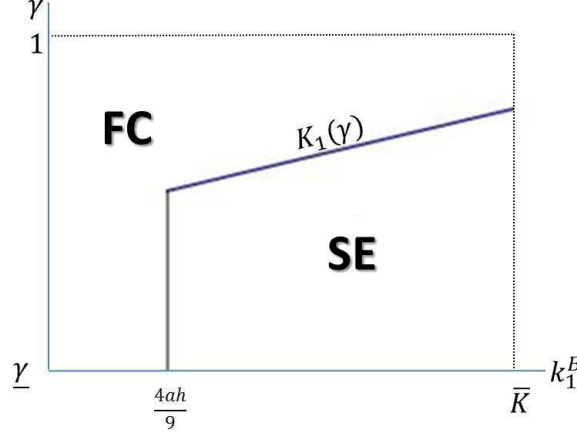


Figure 2.3.: Regions that delimit A's optimal reporting-method choices when $I_A = 2$.

low benefit from imitating, particularly when A invests in two areas because the informative content has been diluted. Therefore, A chooses the successful-efforts method in Region SE when it invests in two areas to obtain a strong preemptive advantage.

2.3.2.3. The Equilibrium

With the results we have so far, we are now able to derive the equilibrium decisions for both firm A and firm B. The equilibrium strategies are formally presented in Proposition 1.

Proposition 1. *If $k_2^A > K_A(\gamma, k_1^B)$, firm A explores one area and chooses to use the full-cost method; firm B always explores a different area.*

If $k_2^A < K_A(\gamma, k_1^B)$, firm A explores two areas, and

- *in Region FC , firm A chooses to report under the full-cost method and firm B always explores a different area;*
- *in Region $SE \cap III$, firm A chooses the successful-efforts method and B invests in a different area if A reports no success, in a same area if A reports full success, and does not invest at all if A reports partial success;*
- *in Region $SE \cap IV$, firm A chooses the successful-efforts method and B invests in a different area if A reports no success, and B does not invest at all if A reports any success out of two investments.*

We find that there is a threshold, $K_A(\gamma, k_1^B)$, such that A invests in two areas ($I_A^* = 2$) if $k_2^A < K_A(\gamma, k_1^B)$, and invests in one area ($I_A^* = 1$) otherwise. It is straightforward that firm A invests more when its investment cost is low and less

when its cost is high. When A's investment cost is so high that it is only able to invest in one area, the equilibrium strategy is quite intuitive. The information-spillover effect is very strong in this case and B will imitate A if A reports success. To avoid B's imitation, firm A will optimally choose the full-cost method; firm B thus invests in a different area.

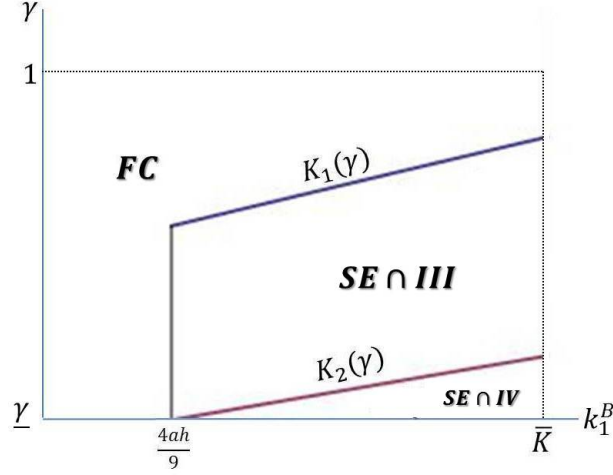


Figure 2.4.: $k_2^A < K_A(\gamma, k_1^B)$.

When A has a lower investment cost and invests in two areas, the equilibrium strategies for both firms become more complicated. We illustrate the equilibrium strategies for both firms when $k_2^A < K_A(\gamma, k_1^B)$ in Fig. 2.4. In Region *FC* in Figure Fig. 2.4 where the information-spillover effect is severe (γ is large) or it is cheap for B to invest (k_1^B is small), firm A chooses to use the full-cost method. Intuitively, because the information-spillover effect in Region *FC* is very strong or B's cost of investment is very low, B will imitate A's investment as long as A reports any success. Therefore, firm A prefers to choose the full-cost method to avoid revealing any information about its success. As a consequence, B will always invest in a different area because it does not obtain any information from A's report. In Regions *SE* ∩ *III* (the overlapped area of Region *SE* in Fig. 2.3 and Region *III* in Fig. 2.2) and *SE* ∩ *IV* (the overlapped area of Region *SE* in Fig. 2.3 and Region *IV* in Fig. 2.2), B's cost is relatively high and γ is relatively low. When γ is low, B's benefit from imitating A is small (the information-spillover effect is weak). In addition, A is able to dilute the information content of its report by investing in two areas, which makes the information-spillover effect even weaker and further reduces B's imitating incentive. Moreover, A's disclosure of its success(es) gives A the preempting advantage in the product market competition. Therefore, A chooses the successful-effort method in equilibrium. For firm B, the profitability of investment decreases due to A's competitive advantage. As a result, B may choose not to invest at all based upon A's reported success. In other words, A can intimidate B from investing by disclosing its success(es).

Notice that by using the successful-efforts method, firms communicate two types of information: the probability of success for imitation as well as the increase in the contribution margin per unit by the innovator's success(es). When a firm with limited investments uses the successful-efforts method, the small size of its investments makes its accounting report very informative regarding the probability of success for potential imitation. Firms that can afford many investments, however, are able to make their accounting reports much less informative for potential imitators. That is, the information-spillover problem is more severe for firms that can only afford limited innovative investments. The other information—the information about the increase in the contribution margin per unit (i.e., the increase in competitive advantage)—provides firms a preemptive advantage. Firms, especially those that can afford many investments, are motivated to choose the successful-efforts method to disclose the latter kind of information to intimidate competitors.

The predictions in Propositions 1 are consistent with firms' different choices between the successful-efforts and the full-cost methods in the real world. Previous studies have shown that large oil and gas companies usually choose the successful-efforts method, while small oil and gas companies prefer the full-cost method (Sunder, 1976; Deakin, 1979; Dhaliwal, 1980; Bryant, 2003). Conventional wisdom regarding this difference in preferences usually focuses on the consequences of reported earnings. That is, the successful-efforts method may induce more volatile earnings and small firms cannot afford the market consequences of this volatility. Our analysis provides another explanation from the competition point of view regarding information spillover. Firms constrained in capability to invest in many innovations are more reluctant to choose the successful-efforts method because they suffer from severe information spillover. Their competitors, especially those with cost and investment advantages, can easily imitate the constrained firms' exploration and reduce the constrained firms' competitive advantage from innovation. On the other hand, firms that are able to afford large innovative investments prefer the successful-efforts method because they can afford to make large investments that dilute the information content of their reported success(es) and are willing to disclose their success to secure their preemptive advantage.¹⁰

¹⁰The SEC and FASB also require oil and gas companies to disclose the information of their proved reserves in footnotes. However, this kind of disclosure can hardly substitute for the capitalization of exploration costs under the successful-efforts method.

First, footnote disclosure of proved reserves is far less timely in revealing firms' successes in exploration activities than the capitalization of exploration cost. An exploratory well should be capitalized on or shortly after the completion of drilling if oil and gas reserves are found, even though the classification of those reserves as proved cannot be made when drilling is completed. The FASB allows firms to determine whether the reserves are proved reserves in one year after the capitalization (FASB Current Text Section Oi5, paragraphs 122-125; SFAS No. 19, paragraphs 31-34), which may result in a large gap in timing between the capitalization of exploration cost and the footnote disclosure of proved reserves.

In addition, the information of proved reserves disclosed in footnotes is not audited, while the capitalization of exploration cost is audited (SFAS No. 69).

Furthermore, the change in proved reserves may not contain the same information content

2.4. The Regulatorily-Enforced Accounting Method

The debate about whether oil and gas companies should retain the option of choosing different accounting methods for their exploration costs has continued for over four decades. In 1977, the SEC proposed FASB 19, which aimed to enforce the successful-efforts method and eliminate the full-cost method. This proposal was rejected by many companies as well as some scholars and was eventually abandoned by the SEC. Recently, the trend of converging the GAAP with the IFRS has brought this long-standing debate to the spotlight again, as the IFRS does not support the full-cost method.

To shed light on the costs and benefits of eliminating companies' choices between different accounting methods regarding their exploration costs, we examine a setting in which the successful-efforts method is enforced. For completeness of analysis, we also look at a setting in which the full-cost method is the only reporting option. We focus on how the elimination of accounting-method choices influences firms' investments in exploration/innovation. We find that sometimes the enforced successful-efforts method induces more investment in innovation, while the enforced full-cost method always results in less investment in innovation.

2.4.1. The Enforced Successful-Efforts Method

We first compare firm A's investment decisions under the enforced successful-efforts regime and decisions under the discretionary regime. Since we are more interested in analyzing the impact of accounting regulations on innovative investments as opposed to imitative activities, we focus on firm A's investment decisions.

We derive A's optimal investing strategy under the successful-efforts regime by comparing A's expected payoffs of 1, 2, and 0 investments. We find that there is a threshold for A's cost of the first investment, K_1^A , and a threshold for A's cost of the second investment, $K_A^{SE}(\gamma, k_1^A, k_1^B)$, such that when the successful-efforts method is enforced, firm A explores two areas if $k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$, explores one area if $k_1^A < K_1^A$ and $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, and does not invest at all if $k_1^A > K_1^A$ and $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$.¹¹ We formally present A's optimal investing strategies in Lemma 4. We also illustrate A's investment strategies in Fig. 2.5 and Fig. 2.6.

Lemma 4. *If the successful-efforts method is enforced,*

- *when $k_1^A < K_1^A$, firm A invests in one area if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, and invests in two areas if $k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$;*

as the capitalization of exploration cost regarding the successes of a firm's exploration. The change may be due to many factors other than the expansion or discovery of new reserves, such as modified estimation of existing wells, changes in technology, and changes in market prices (SFAS No. 69).

¹¹The values of K_1^A and $K_A^{SE}(\gamma, k_1^A, k_1^B)$ are available in the Appendix

- when $k_1^A > K_1^A$, firm A does not invest if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, and invests in two areas if $k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$.

Notice that when the successful-efforts method is enforced, A suffers from information spillover. In particular, when A has a high cost of investments, $k_1^A > K_1^A$ and $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, it can not afford to increase investment to dilute the information content in its report. Therefore, A chooses not to invest.

Recall that Proposition 1 shows that under the discretionary regime, firm A invests in two areas with cost $k_2^A < K_A(\gamma, k_1^B)$ and in one area if $k_2^A > K_A(\gamma, k_1^B)$. We now examine the accounting-reporting regime's effect on A's investment strategy by comparing A's investment in Lemma 4 with that in Proposition 1.

Firm A's optimal investment decision when $k_1^A < K_1^A$ is illustrated in Fig. 2.5. When $k_1^A < K_1^A$, we can prove that $K_A^{SE}(\gamma, k_1^A, k_1^B) > K_A(\gamma, k_1^B)$. Therefore, when the accounting-reporting regime switches from the discretionary regime to the enforced successful-efforts regime, firm A's investment decision will not change if $k_2^A < K_A(\gamma, k_1^B)$ or $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$. However, if $K_A(\gamma, k_1^B) < k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$, firm A increases its investment from one area to two areas.

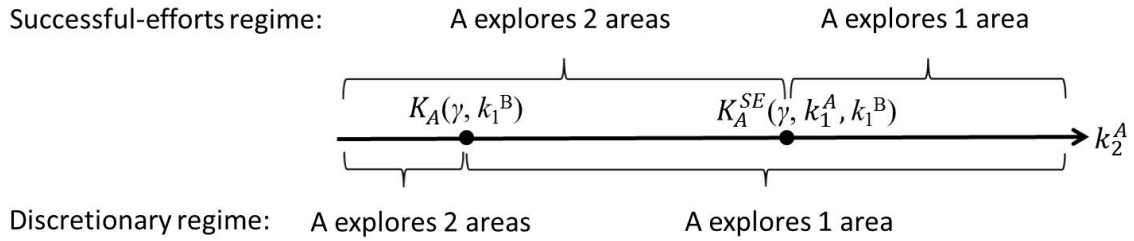


Figure 2.5.: Investment decisions under the enforced successful-efforts regime vs. under the discretionary regime when $k_1^A < K_1^A$.

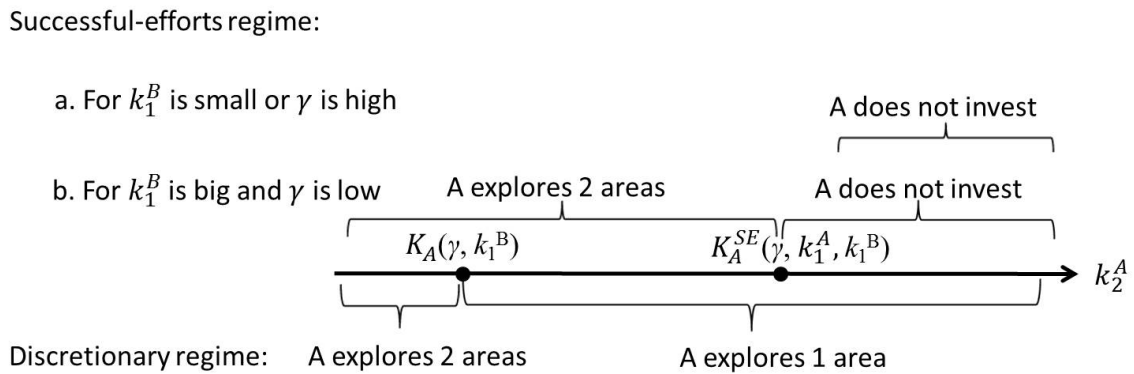


Figure 2.6.: Investment decisions under the enforced successful-efforts regime vs. under the discretionary regime when $k_1^A < K_1^A$.

Firm A's optimal investment when $k_1^A > K_1^A$ is illustrated in Fig. 2.6. In the case of $k_1^A > K_1^A$, we can prove that $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$ if γ is large or k_1^B is small. Therefore, firm A does not invest when the successful-efforts regime is enforced. Intuitively, when the information spilled from A's report is highly useful or when B's investment cost is low, B has a strong incentive to imitate A. On the other hand, firm A has high investment costs and can not afford to dilute the informative content in its report by increasing its investment. Thus, A will choose not to invest to avoid information spillover.

When $k_1^A > K_1^A$, we can also prove that $K_A^{SE}(\gamma, k_1^A, k_1^B) > K_A(\gamma, k_1^B)$ if γ is small and k_1^B is large. As depicted in Fig. 2.6, when the accounting-reporting regime switches from the discretionary regime to the successful-efforts regime, firm A's investment decision does not change if $k_2^A < K_A(\gamma, k_1^B)$, and decreases from one area to no investment if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$. However, A's investment increases from one area to two areas if $K_A(\gamma, k_1^B) < k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$.

It is surprising that A may increase innovation investment under the enforced successful-efforts regime. One may predict a decline in firm A's investment when the successful-efforts method is enforced, because now firm A does not have the choice of using the full-cost method to prevent information spillover to its competitor. However, our analysis shows that A may increase its investment under the enforced successful-efforts regime, which is directly due to the information-spillover effect. As long as A's cost of investments is not very high, to protect its competitive advantage, it may have to invest more to dilute the information content in its report and mitigate the damage from information spilled to its rival.

We summarize our results in Proposition 2.

Proposition 2. *Compared with the investment under the discretionary regime,*

- *if $k_2^A < K_A(\gamma, k_1^B)$, firm A's investing strategy stays unchanged under the enforced successful-efforts regime;*
- *if $K_A(\gamma, k_1^B) < k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$, firm A invests more under the enforced successful-efforts regime;*
- *if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, firm A invests less under the enforced successful-efforts when $k_1^A > K_1^A$, and invests at the same amount when $k_1^A < K_1^A$.*

2.4.2. The Enforced Full-Cost Method

Although regulators have no intention of imposing the full-cost method (in fact, regulators always try to eliminate the full-cost choice), for completeness of the analysis we also examine the case in which firms can only use the full-cost method to recognize their exploration costs.¹² We think it may still provide us insight on

¹²In practice, because a firm can still preempt rivals by revealing favorable information through other channels—such as disclosures in footnotes of financial reports or disclosures through

regulatory implications. To derive A's optimal investment strategies under the enforced full-cost regime, we need to compare A's expected payoffs $E[\Pi_A|I_A, FC]$ with $I_A \in \{1, 2\}$, incorporating firm B's optimal responses in Lemma 2. We find that there is a threshold of A's investment cost, K_A^{FC} , such that firm A invests in two areas with a cost $k_2^A < K_A^{FC}$ and invests in only one area if $k_2^A > K_A^{FC}$. We can prove that $K_A(\gamma, k_1^B) \geq K_A^{FC}$ for any γ and k_1^B . As shown in Fig. 2.7, when switching from the discretionary regime to the full-cost regime, firm A's investment decision does not change if $k_2^A > K_A(\gamma, k_1^B)$ or $k_2^A < K_A^{FC}$. However, when $K_A(\gamma, k_1^B) > k_2^A > K_A^{FC}$, firm A will reduce its investment from two areas to one area. We formally state the result in Proposition 3.

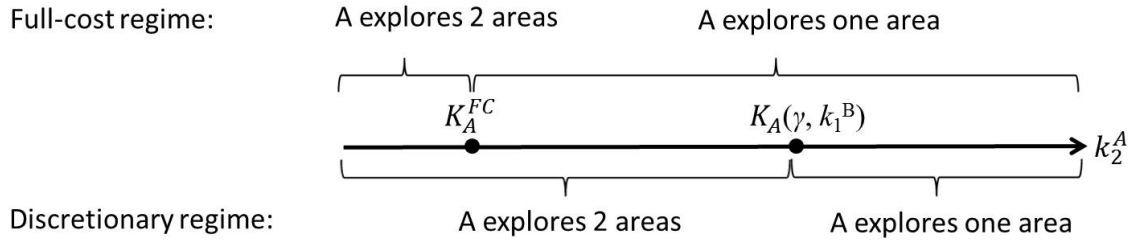


Figure 2.7.: Firms' investment decisions under the enforced full-cost regime vs. under the discretionary regime.

Proposition 3. *Compared with the investment in the discretionary regime, firm A invests less in innovation under the enforced full-cost regime.*

It may also seem counter-intuitive that A would invest less under the enforced full-cost regime. With the full-cost method, firm A is not concerned about the damage from information spillover to its competitor. However, A also loses its capability to preempt its rival by reporting its success using the successful-efforts method. That is, although there is no information spillover, the benefit from the preempting effect disappears as well. Thus, A is more reluctant to invest in innovation and its equilibrium investment declines.

2.5. Empirical Implications

Our study provides empirical implications that are either consistent with the extant empirical evidence or that may be tested by future empirical research. First, our model shows that firms that are constrained in their ability to invest substantially in innovative activities are concerned mainly about the information spillover of their accounting disclosures; as a result, they tend to choose the full-cost method. Firms

media—the enforced full-cost method may not eliminate the preempting effect. Nevertheless, we still examine this hypothetical setting for completeness of the analysis.

that are less constrained in their ability to invest, however, place more weight on the preempting effect of their accounting disclosures, and thus prefer the successful-efforts method. These predictions are consistent with firms' real-world choices between successful-efforts and full-cost methods. It is well documented that large oil and gas companies usually choose the successful-efforts method, while small oil and gas companies prefer the full-cost method (Sunder, 1976; Deakin, 1979; Dhaliwal, 1980; Bryant, 2003). Although extant empirical studies have examined the determinants of different accounting-disclosure choices in the oil and gas industry, to our knowledge there is no direct empirical test of whether market competitive forces have implications on firms' choices over different disclosure methods.

Second, our model also sheds light on the consequences of enforcing uniformity in the accounting treatment of exploratory investments. For instance, conventional wisdom may suggest that enforcing the successful-efforts method will hinder small firms' access to capital markets, and therefore prevent those firms from undertaking innovative investments (Collins and Dent, 1979). However, our model indicates that competitive concerns may actually lead to an increase in innovative investments. Indeed, if the successful-efforts method is enforced, firms with a serious concern for a potential information spillover may respond by undertaking larger investments to dilute the information content of their accounting disclosures. The extant empirical evidence on the potential effects of enforcing the successful-efforts method is very scarce. Deakin (1979) analyzes the data of oil and gas companies around the proposal of SFAS 19, which aimed to eliminate the full-cost method, and finds that the full-cost firms responded with more aggressive investments in exploration than the firms that used the successful-efforts method (although the difference is not significant). This very limited evidence seems to point in the direction of our prediction that some firms may increase their investments in exploration to dilute the information-spillover effect when the successful-efforts method is enforced (Proposition 2). The lack of significance may be due to the test's inability to distinguish between firms that are able or unable to afford larger investments. More powerful tests may actually test the predictions of our model more accurately.

Our study also provides a potential explanation for several additional puzzling empirical findings. Dyckman and Smith (1978) examine the movement of successful-efforts and full-cost firms' stock returns around the FASB's release of the Exposure Draft (ED) in 1977, which proposed the enforcement of the successful-efforts method. They find a decline in stock prices for both full-cost firms and successful-efforts firms in response to the issuance of the ED. This is contrary to the conventional belief that successful-efforts firms should not have been affected by the mandated change in the accounting method because the new regulation implied no change in their reporting. According to our study, innovators who choose the full-cost method under the discretionary regime may increase their investments when the successful-efforts method is enforced. This, in turn, may result in a more competitive product market in which all firms obtain a lower profit. This prediction provides a potential explanation for the empirical finding that both full-cost and successful-efforts firms'

stock prices declined in response to the ED. An analogous reasoning can potentially explain another empirical finding by Dyckman and Smith. Dyckman and Smith show that successful-efforts firms that invested more on exploration suffered a larger decline in their stock price than successful-efforts firms with smaller exploration investments. Using our argument that enforcing the successful-efforts method would yield a more competitive environment, one can infer that the return of exploration investments should decline accordingly; therefore the successful-efforts firms with larger exploratory investments should be more negatively affected. Finally, Dyckman and Smith find that contrary to the case of successful-efforts firms, the decline in average returns for the full-cost firms that invest less in explorative activities is larger than those for full-cost firms that invest more in exploration. Our study may also help to explain this empirical finding. Our model implies that firms that invest more in exploration are less affected by the information-spillover effect than firms that invest less in exploration. Therefore, full-cost firms with more exploration investments will suffer less when the regulator enforces the successful-efforts method. In other words, firms with less exploration investments are forced to distort their investment decisions more to avoid information spillover.

2.6. Conclusions

In this study, we examine firms' investments in innovative/explorative initiatives and their choices of capitalization method in a product-market competition setting. Because the capitalization of exploration expenditures may contain information about whether a firm's exploration investment is successful, financial reports may reveal important information to competitors and thus have real consequences on product-market competition. In our paper, we identify two driving forces that induce firms to choose different capitalization methods: the information-spillover effect and the preempting effect. We also find that enforcing an accounting method that requires firms to capitalize expenditures of successful explorations may increase innovation investment. Our study sheds light on the impact that accounting capitalization of exploratory costs has on firms' exploration investments.

3. The Corporate Governance Role of Information quality and Corporate Takeovers¹

3.1. Introduction

Financial accounting information provides direct input in the design of corporate governance mechanisms to facilitate the monitoring of managers (Bushman and Smith, 2001; Armstrong, et al., 2010). A large body of accounting research in corporate governance examines the interaction between a firm's information environment and a variety of corporate governance mechanisms. However, it is difficult to establish a precise link between the information environment and governance structures, because these two constructs are both endogenously chosen by firms (Armstrong, et al., 2010; Defond et al., 2005). In this paper, we provide a theoretical model to examine the governance roles of endogenous information quality and an important external governance mechanism, the corporate takeover market, in which a third party (an acquirer) can take control of the firm and replace inefficient managers (Jensen, 1988; Scharfstein, 1988).

Recently the role of financial reporting in facilitating takeover markets has gained attention from researchers. For example, several empirical studies examine whether the information quality of the acquirer or target firm influences the profitability and efficiency of acquisitions (Francis and Martin, 2010; Ramen et al., 2010; McNichols and Stubben, 2011; Martin and Shalev, 2009). In general, these studies focus on the acquirers' perspective, and find that acquisition decisions are more efficient in terms of ex-post profitability and synergies when acquirers or targets have more transparent financial reporting. The reason is that higher quality accounting information reduces the information asymmetry between the target and the acquirer company, and allows the acquirer to value the target with great precision and bid more efficiently (McNichols and Stubben, 2011). However, it is not clear whether target firms have the incentive to improve their information quality to facilitate the takeover market efficiency. Moreover, despite the growing interest of empirical studies in this area, no existing theoretical models provide analysis of the role of financial information in takeover. Our study provides analytical analysis to better

¹This study is a joint work with Jing Li and Lin Nan.

understand the interaction between the information quality and the takeover market as corporate governance mechanisms.

We model the endogenous choice of information quality of a target firm in the presence of a potential acquirer who may take over the firm and replace the incumbent manager. Consistent with the typical view of economic and legal scholars, the takeover market in our model serves two important functions for shareholders' value maximization. First, takeover can enhance firm value due to the acquirer's efficient management skills or superior knowledge about new environment (Scharfstein, 1988; Jensen, 1986). Second, the incumbent manager loses his private benefit of control after a successful takeover, which occurs more likely if the manager shirks. Thus the takeover market serves as a disciplinary mechanism to motivate the incumbent manager. However, an active takeover market may have a negative effect on the manager's incentive, because the manager's position is highly insecure when the takeover is highly efficient (Stein, 1988). The shareholders of the target firm need to take into consideration all these different effects of the takeover market in their decisions.

The takeover bid in our model is in the form of a tender offer, in which an acquirer makes a price offer and shareholders individually decide whether to tender their shares. Information asymmetry exists in the takeover bidding, as the acquirer only observes the target firm's financial information, whereas the current shareholders in the target firm have better information about firm value.² The manager's effort determines the firm value and he enjoys a private benefit of control. The manager loses his private benefit if takeover succeeds.³ We assume that the private benefit is the only payoff for the manager in order to focus on the disciplinary role of takeover market when other disciplinary mechanisms such as incentive contracts are not effective.⁴ In equilibrium, the acquirer's bidding strategy is based on her belief about the manager's effort given the accounting information; the manager maximizes

²In reality, acquirers may perform due diligence to obtain and verify information about the target before signing the final agreement. Due diligence is usually done by an independent third party such as an investment bank, attorney or accountant. More information may be obtained through due diligence and the acquirer may withdraw his offer or lower the price after the due diligence. However, our model's implications still apply as long as the information obtained through due diligence is imperfect. In addition, the quality of information system of the target, such as the effectiveness of internal control system, also determines whether or not the independent party obtains high quality information in due diligence. A low quality information system increases the acquirer's cost to conduct due diligence. As a matter of fact, empirical evidence shows it is common for bidding firms to overpay in acquisitions, despite the compliance with the due diligence process (Moeller et al., 2005).

³The manager may either be fired or simply lose his decision power in the firm, because the acquirer takes control after the takeover. Previous studies (Kini et al., 1995, 2004; Martin and McConnell, 1991) document a significant CEO turnover during takeovers, and also find a negative relation between the pre-takeover performance and post-takeover CEO turnovers. Moreover, this negative relation is more pronounced when a more active and less friendly takeover market plays an important role in managerial disciplining (Kini et al., 2004).

⁴Takeover market is considered as an external governance mechanism, which is often viewed as a "court of last resort" and is applied when internal governance mechanisms are weak or ineffective

his own expected payoff given the anticipated bidding strategy. We find that when the incumbent manager's private benefit is small and the information quality is low, the acquirer bids conservatively and follows a low-price-bidding strategy regardless of accounting signals. When the manager's private benefit is large, or the information quality is high, the acquirer updates her belief upon observing accounting signals and tends to bid more aggressively upon a good signal.

We examine the optimal levels of information quality that maximize the current shareholders' expected payoff and the expected firm value respectively. The expected firm value consists of two parts: the expected firm value without takeover (which depends on the manager's effort level) and the expected value enhancement from takeover. For the current shareholders, their expected payoff is the expected firm value plus the expected overbidding premium. Increasing information quality enhances the overall takeover efficiency because the acquirer now bids upon more precise signals. As a result, higher information quality directly increases the expected value enhancement from takeover market. However, a more efficient takeover market also discourages the manager's effort and leads to a lower expected firm value without takeover. Because of this negative effect on the manager's effort when increasing the information quality, we find that a perfectly informative information system is never optimal for either the current shareholders' expected payoff maximization or the expected firm value maximization.⁵

From the current shareholders' perspective, however, they care not only about the expected firm value, but also the overbidding premium from the takeover. The overbidding premium in our model depends on the probability of a low-value firm generating a good signal and the aggressiveness of the acquirer's bidding strategy upon a good signal. The overall incremental overbidding premium is positive from increasing the information quality above the level that maximizes the expected firm value. We thus find that current shareholders prefer a higher level of information quality than the one that maximizes the expected firm value, especially when the value enhancement from takeover is relatively large. The result sounds counter-intuitive that the optimal information quality that maximizes firm value is lower than the one preferred by the current shareholders, because the common view is that increasing financial reporting quality is always beneficial for investors who care about the fundamental firm value. In takeover market, when there exists discrep-

(Jensen, 1986). A primary motive for relying on the takeover market as a disciplinary mechanism is to replace entrenched and inefficient managers who cannot be motivated effectively otherwise (Kini et al., 2004).

⁵This result of the imperfect optimal information precision echoes other studies with similar conclusions in different settings that more information or higher quality information may not always be better. For example, Kanodia, et al. (2005) show that some degree of accounting imprecision can be value enhancing in a setting with information asymmetry regarding investment profitability; Arya, et al. (2004) show that additional information may not always be helpful when existing information is inter-temporally aggregated; Arya and Mittendorf (2011) find that more detailed information may not always be beneficial in evaluating managers' performance given career concerns.

ancy of interests between current shareholders and future shareholders, a lower level of information quality actually maximizes firm value. Notice that increasing information quality indeed always improves the overall takeover efficiency; however, this does not imply a higher firm value.

We also examine the impact of anti-takeover law adoption on the information quality of the firm, assuming that anti-takeover laws make takeovers more difficult and decreases the private benefit that the acquirer receives after takeover.⁶ We find that after the adoption of anti-takeover laws, the optimal information quality levels that maximize the current shareholders' expected payoff and the expected firm value are both higher. In addition, anti-takeover laws always improve the firm value, but improve the current shareholders' expected payoff only when the value enhancement from takeover is small and the manager's private benefit is large. Our model therefore may provide an explanation for the recent empirical finding that the informativeness of financial statements increases after the passage of anti-takeover laws or anti-takeover provisions (Armstrong, et al., 2012; Fu and Liu, 2008).

Most theoretical studies on the role of accounting information in corporate governance have been done in the area of executive compensation and performance measures in agency-based models.⁷ Not many studies examine the role of accounting information with respect to other corporate governance mechanisms.⁸ Our paper establishes the link between financial disclosure and the takeover mechanism in corporate governance of the target firm.⁹

Our paper adds to the literature on the endogenous choice of information quality or precision of public signals in various settings. For example, Penno (1997) shows the effect of ex-ante information quality on the firm's voluntary disclosure choice. Fan and Zhang (2011) study optimal accounting policies such as aggregation and

⁶In the 1980s, many states passed anti-takeover laws which increased the legal barriers to takeovers as a response to an active takeover market in the 1980s. Many firms also adopted anti-takeover provisions to reduce the threat of takeovers to protect managers from the pressure to make short-horizon investments. However, there have been controversies whether anti-takeover laws or provisions enhance or destroy shareholders' value (DeAngelo and Rice, 1983; Jarrell and Poulsen, 1988; Malatesta and Walkling, 1988; Mahoney and Mahoney, 1993; Ryngaert, 1988; etc.)

⁷Bushman and Smith (2001) and Armstrong, et al. (2010) both provide detailed reviews of this literature.

⁸For example, Laux and Laux (2009) examine the board of directors' strategies for setting CEO incentive pay and overseeing financial reporting and their effects on the level of earnings management.

⁹Prior studies examine the role of information and disclosure in takeovers in other settings. For example, Grossman and Hart (1980b) show that when the acquirer has more information about the firm value after takeover, imposing a more stringent disclosure law can reduce the level of dilution by the acquirer, which may overly hinder the takeover bid process and have an adverse effect on managerial efficiency. Marquez and Yilmaz (2008) analyze tender offers where privately informed shareholders are uncertain about the acquirer's ability to improve firm value and only shareholders with bad information will tender. They show that private information affects not only the efficiency of the takeover process, but also the surplus allocation between the acquirer and the shareholders.

conservatism when a firm can control the quality of accounting information with some cost. Nan and Wen (2012) investigate the effect of accounting biases on firms' financing decisions and the role of accounting biases in endogenous information quality.

Our paper also contributes to the broad literature that examines how financial reporting facilitates disciplining the management or other parties through capital market in general. For example, Kanodia and Lee (1998) examine the optimal information precision when the capital market relies on the accounting information to discipline the manager's investment choice. Huddart, et al. (1999) examine how public disclosure requirements influence listing decisions by corporate insiders. Dye and Sridar (2007) study the allocational effects associated with the precision of accounting estimates when the precision of estimates is a choice variable for firms.

The remainder of the paper proceeds as follows: Section 3.2 presents the main model setup and the acquirer's bidding strategy, Section 3.3 examines the equilibria and analyzes the impact of anti-takeover laws or provisions on shareholder decisions and firm value, and Section 3.4 concludes the paper.

3.2. The Model

3.2.1. Model Setup

We consider a two-period model with dates $t = 0, 1, 2$. All agents are risk-neutral. At date 0, the current shareholders choose the quality of the financial reporting system, $d \in [\frac{1}{2}, 1]$. d determines the precision of the noisy signals generated by the financial reporting system, which we will elaborate in the next paragraph. After d is determined, an incumbent manager makes an effort e that will affect the firm's future value v . For convenience, we refer to the manager as "he." The manager's effort is not contractable. For simplicity, we assume that the effort $e \in [0, 1]$. The cost of the manager's effort is a convex function, $\frac{1}{2}e^2$. We assume that the firm value is binary, $v \in \{0, 1\}$. If the manager shirks, the expected value of the firm will be lower. Specifically, we assume that the probability of generating a high firm value ($v = 1$) is e (i.e., $\text{prob}(v = 1|e) = e$), and the probability of generating a low firm value ($v = 0$) is $1 - e$ (i.e., $\text{prob}(v = 0|e) = 1 - e$). The manager enjoys a private benefit of m if the firm is not taken over. It is reasonable to assume that the private benefit of the manager is smaller than the maximum firm value; i.e., $0 < m < 1$. We assume that m is the only benefit of the manager to compensate for his effort, because we want to concentrate on the disciplinary role of the takeover market instead of other incentive mechanisms. Current shareholders can discipline the incumbent manager through the threat of takeover market. If the takeover succeeds, the incumbent manager is deprived of his private benefit.

At time 1, the firm value v is privately observed by the current shareholders. The outsiders do not observe the firm value, but receive a noisy signal y about the firm

value, which is generated from the financial reporting system.¹⁰ We assume that the signal is binary, $y \in \{G, B\}$, where G represents a good signal and B represents a bad signal. The information quality of the financial reporting system, d , determines the information properties of the signals. We assume that:

$$\begin{aligned} \text{prob}(y = G|v = 1) &= \text{prob}(y = B|v = 0) = d, \\ \text{prob}(y = B|v = 1) &= \text{prob}(y = G|v = 0) = 1 - d. \end{aligned} \quad (3.1)$$

That is, a higher-quality information system produces more informative signals.

At time 2, there is a potential acquirer in the market that makes a tender offer to the current shareholders. For convenience, we use "she" to refer to the acquirer. The acquirer can improve firm value after taking control of the firm. We assume that the value enhancement, v_0 , is smaller than the maximum firm value before takeover (i.e., $0 < v_0 < 1$), and v_0 is common knowledge.¹¹ After observing the signal y , the acquirer may make a tender offer p . If the takeover succeeds, the incumbent manager is replaced and the new firm value becomes $v + v_0$. If the takeover fails, the firm value remains as v . We assume that the acquirer enjoys some private benefit after taking control of the firm, and assume that her private benefit is b .¹² We also assume that the bidder's private benefit is smaller than the maximum firm value; i.e., $0 < b < 1$.¹³ The private benefit is common information.

¹⁰We assume that the current shareholders obtain the perfect information about firm value for simplicity. A variation of our model could assume that shareholders observe a noisy signal about firm value, but the acquirer receives a noisier signal than what shareholders observe. This variation will lead to similar results to our current model.

¹¹The value enhancement assumption is consistent with the view that the takeover market enables a control shift to a new management team that can run the firm more efficiently or has new ideas that improve the firm value when the environment changes (Scharfstein, 1988; Shleifer and Vishny, 1986).

In our model, the value enhancement from takeover is independent of the manager's effort. If we allow the value enhancement varies with the firm value, for example, the value enhancement is smaller for the high-value firm, our main results qualitatively remain. The reason is that when takeover adds less value to the high-value firm, increasing information quality benefits less in terms of encouraging more aggressive bidding in order to realize the value enhancement from successful takeover, and on the other hand, increasing information quality may weaken the manager's effort significantly.

¹²Without private benefit from the takeover, the acquirer does not have any incentive to make the offer because of the free-rider problem described by Grossman and Hart (1980a). Our assumption of private benefit of the acquirer is consistent with Grossman and Hart (1980a) and other studies which assume the acquirer can divert the firm value after takeover and thus the minority shareholders cannot receive the whole firm value. Our assumption is a simplified version that makes the acquirer willing to make the takeover bid. There are other models that resolve the free-rider problem without assuming such a divergence of payoff after takeover, for example, Shleifer and Vishny (1986), Bagnoli and Lipman (1988), etc.

¹³If the acquirer's private benefit is too large ($b > 1$), the acquirer would always bid high price regardless of accounting signals in order to capture the large private benefit from successful takeover. In that case, accounting information quality becomes irrelevant.

In our model shareholders are rational and no shareholder can affect the outcome of the takeover bid.¹⁴ Therefore the bidding price needs to be at least greater or equal to the firm's post-takeover value $v + v_0$. Otherwise, a single shareholder could always hold on to his or her shares and obtain the value enhancement, assuming his or her tender decision will not affect the outcome of the takeover bid. The takeover is successful if more than 50% of shareholders tender the offer. Given that shareholders in our model are identical, either 100% of them tender or none tenders.

Fig. 3.1 summarizes the timeline of our model.

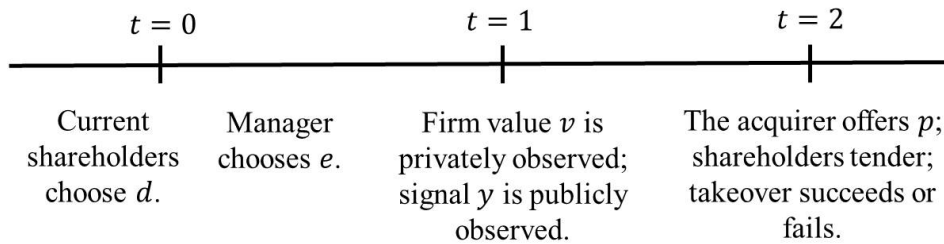


Figure 3.1.: Timeline

3.2.2. The Acquirer's Bidding Strategy with Asymmetric Information

Now we discuss the acquirer's bidding strategy when the target firm value v is not revealed to the outside acquirer, but privately observed by shareholders. Upon an imperfect signal y , the acquirer updates her belief about the true value of the firm after observing y and makes an offer. With the firm's value v being binary (either 0 or 1), it is easy to see that the acquirer will offer either a low price, $p_l = v_0$, or a high price, $p_h = 1 + v_0$. When p_l is offered, the shareholders will tender all shares if the firm value is low, but when the firm value is high shareholders will not tender as p_l is strictly smaller than the current firm value $v = 1$. When p_h is offered, shareholders always tender regardless of firm value and the takeover always succeeds.

The acquirer's payoff from the takeover, if successful, is $v + v_0 - p$. We use $\pi_r(p, y)$ to represent the acquirer's expected payoff by offering a tender price of p after observing signal y . We define $h(y)$ as the posterior probability of firm value being high given

¹⁴No shareholders in our model are influential enough to affect the takeover outcome, but they can be blockholders that have access to more information than outsiders. In reality, for example, holding 5% of shares is sufficient to get some access to insider information, but not enough to determine the takeover outcome. Our model may fit best for takeovers of private targets or small targets with high information asymmetry. Empirical evidence shows that acquisitions of private targets are prevalent in corporate takeovers (Fuller, et al., 2002).

y , i.e., $h(y) \equiv \text{Prob}(v = 1|y)$. The acquirer's expected payoffs from bidding a low price and a high price are, respectively,

$$\begin{aligned}\Pi_r(p_l, y) &= [1 - h(y)]b, \\ \Pi_r(p_h, y) &= [1 - h(y)](b - 1) + h(y)b.\end{aligned}$$

When the acquirer offers a low price after observing a signal, her expected payoff is the private benefit from successfully taking over a low value firm. When the acquirer offers a high price, because she does not have perfect information of the current firm value, she is possibly to overbid when the firm value is low. However, bidding high price makes takeover successful for sure, and the acquirer can always enjoy her private benefit. The acquirer's expected payoff by bidding high price is the private benefit from both types of firms, less the expected overbidding loss.

It is easy to see that $\pi_r(p_h, y) > \pi_r(p_l, y)$ if and only if $h(y) > \bar{h} \equiv \frac{1}{1+b}$. Essentially, the acquirer decides whether or not to offer a high price, considering the tradeoff between the private benefit she may obtain from the high-value firm and the expected overbidding loss from the low-value firm. The acquirer is more willing to offer a high price when the posterior belief of firm value being high is greater, i.e., when $h(y)$ increases. Furthermore, the threshold \bar{h} decreases with b , which implies that the acquirer is more likely to bid a high price when her private benefit increases.

We define the acquirer's bidding strategy as a pair of probabilities (α, β) , where α is the probability of offering a high price ($p = p_h$) after observing a good signal (i.e., $y = G$), and β is the probability of offering a high price after observing a bad signal (i.e., $y = B$). Lemma 5 summarizes the acquirer's bidding strategy, (α, β) :

Lemma 5. *The acquirer's bidding strategy after observing a signal y is given by:*

S1: $\alpha = \beta = 1$, if $\bar{h} < h(B) < h(G)$.

S2: $\alpha = 1$, $0 < \beta < 1$, if $h(B) = \bar{h}$.

S3: $\alpha = 1$, $\beta = 0$, if $h(B) < \bar{h} < h(G)$.

S4: $0 < \alpha < 1$, $\beta = 0$, if $h(G) = \bar{h}$.

S5: $\alpha = \beta = 0$, if $h(B) < h(G) < \bar{h}$.

Lemma 5 suggests that the informativeness of signals is critical in determining an acquirer's bidding strategy. $h(G)$ and $h(B)$ are the acquirer's posterior beliefs about the probability of facing a high-value firm upon good and bad signals respectively. Since the signal is informative ($d > \frac{1}{2}$), the probability of a high firm value is higher upon a good signal than upon a bad signal (i.e., $h(G) > h(B)$). The acquirer's probability of bidding a high price upon observing a signal increases with the updated belief about the likelihood of a high-value firm. When the acquirer's posterior

beliefs upon both signals are high enough, the acquirer always offers a high price ($S1$). When the acquirer's posterior beliefs are both low, the acquirer always offers a low price ($S5$). When the acquirer's posterior belief is high upon a good signal and low upon a bad signal, the acquirer follows a separating bidding strategy ($S3$). In the other two cases, the acquirer's posterior belief on either a good signal or a bad signal is on the edge ($h(y) = \bar{h}$), the acquirer is indifferent between a high price and a low price, and thereby follows a mixed strategy upon the signal ($S2$ and $S4$).

Although there are five cases in Lemma 5, as we will show in the next section, not all of them are in equilibrium. This is because the posterior probability $h(y)$ depends on the acquirer's conjecture of the manager's effort, whereas her conjecture has to be consistent with the manager's optimal choice of effort to make the case sustainable in equilibrium.

3.3. Equilibrium and optimal information quality

In our model, the information quality d is determined first. The manager then chooses his effort level that affects the expected firm value. However, he may lose his incumbent private benefit if the firm is later successfully taken over by an acquirer. The acquirer does not observe the manager's effort. When offering the bidding price upon the imperfect signals, the acquirer needs to conjecture the manager's effort level to update her belief about the firm value. We first define and fully characterize the manager's equilibrium effort and the equilibrium bidding strategy of the acquirer, taking as given the information quality d . We then examine the optimal choice of information quality for both current shareholders and firm value maximization given the equilibrium.

3.3.1. Manager's effort and acquirer's bidding strategy in equilibrium

A perfect Bayesian equilibrium of the manager's effort and the acquirer's bidding strategy, given any information quality, is defined as the following:

Definition 3.1 *A set of strategies (e^*, α^*, β^*) forms a perfect Bayesian equilibrium such that:*

1. *The acquirer forms her belief about the manager's effort, \hat{e} , and her optimal bidding strategy, $(\alpha^*(\hat{e}), \beta^*(\hat{e}))$, satisfies the bidding strategies as specified in Lemma 5.*
2. *The manager's optimal effort, e^* , maximizes his own expected payoff, $\Pi_m(e, \alpha^*(\hat{e}), \beta^*(\hat{e}))$, given the anticipated optimal bidding strategy of the acquirer, $(\alpha^*(\hat{e}), \beta^*(\hat{e}))$.*
3. *The acquirer's belief in (ii) is consistent with the manager's optimal effort, $\hat{e} = e^*$.*

For any bidding strategy (α, β) , a takeover fails when the acquirer offers a low price and the true value of the firm is high. Recall that the probability of a high firm value given the manager's effort e is $prob(v = 1|e) = e$. Therefore, the probability of takeover success, $Prob[T]$, is written as

$$\begin{aligned} Prob[T] &= 1 - e + e(\alpha Prob[y = G|v = 1] + \beta Prob[y = B|v = 1]) \\ &= 1 - e + [d\alpha + (1 - d)\beta] \end{aligned} \quad (3.2)$$

The manager's expected payoff for choosing an effort level of e given the acquirer's bidding strategy, $\Pi_m(e, \alpha, \beta)$, is thus given by:

$$\Pi_m(e, \alpha, \beta) = (1 - Prob[T])m - \frac{e^2}{2} = e \cdot (1 - [d\alpha - (1 - d)\beta])m - \frac{e^2}{2}. \quad (3.3)$$

Given the acquirer's strategy (α, β) , the manager's optimal effort that maximizes his expected payoff in Eq 3.3 is

$$e^*(\alpha, \beta) = m - [d\alpha - (1 - d)\beta]m \quad (3.4)$$

The takeover market affects the manager's effort incentive in two ways. First, the takeover market disciplines the manager to make effort when the low value firm is taken over, as represented by the first term in Eq 3.4. The manager is motivated to exert effort to reduce the probability of the low firm value and thus reduces the takeover probability directly. Second, the takeover threat discourages the manager's effort incentive when the high value firm may also be taken over. This negative effect of takeover market is represented by the second term, $-[d\alpha - (1 - d)\beta]m$, in Eq 3.4.

We now discuss the acquirer's belief, which in equilibrium needs to be consistent with the manager's effort choice in Eq 3.4. Denote the acquirer's belief about the manager's effort is \hat{e} . After observing the signal y , the acquirer updates her belief about the probability of a high firm value given the information structure in Eq 3.1:

$$\begin{aligned} h(G, \hat{e}) &= \frac{\hat{e}d}{\hat{e}d + (1 - d)(1 - \hat{e})}, \\ h(B, \hat{e}) &= \frac{\hat{e}(1 - d)}{\hat{e}(1 - d) + (1 - \hat{e})d}. \end{aligned} \quad (3.5)$$

With the updated belief, the acquirer chooses her optimal bidding strategy (α^*, β^*) to maximize her expected payoff. Proposition 4 characterizes the full equilibrium:

Proposition 4. *Given the information quality d , there exist two mutually exclusive, commonly exhaustive conditions, C1 and C2, such that:¹⁵*

if C1 holds, the manager chooses $e^ = m$, and the acquirer chooses $\alpha^* = 0$ and $\beta^* = 0$ (**low-price-bidding equilibrium**);*

if C2 holds, the manager chooses $e^ = \frac{1-d}{1-d(1-b)}$, and the acquirer chooses $\alpha^* = \frac{1}{d} \frac{bdm - (1-d)(1-m)}{(1-d)m + bdm}$ and $\beta^* = 0$ (**mixed-price-bidding equilibrium**).*

C1 and C2 are conditions about m and d :

C1: $m \leq \frac{1}{1+b}$ and $d < \frac{1-m}{1-m+bm}$,

C2: $m > \frac{1}{1+b}$, or $m \leq \frac{1}{1+b}$ and $d \geq \frac{1-m}{1-m+bm}$.

Proof. See Appendix. □

For the five cases in Lemma 5, it turns out that the first three bidding strategies, S1 – S3, will not be equilibrium cases. In these three cases, the acquirer is more likely to bid a high price based on a conjecture of high firm value. However, the higher likelihood of takeover success makes the manager's position more insecure and discourages the manager from working hard. As a result, the manager's optimal effort is lower, inconsistent with the acquirer's conjecture. The bidding strategies that are sustainable in equilibrium S4 and S5. That is, the acquirer either always bids a low price when the acquirer conjectures a sufficiently low effort level, or bids a low price upon a bad signal and follows a mixed strategy upon a good signal. Overall, takeover is more likely when the manager's effort is low, this is consistent with the role of takeover market in disciplining the manager.

When m is relatively small ($m < \frac{1}{1+b}$), the manager's effort incentive is low and the acquirer's conjecture about manager's effort (and thus the firm value) is low and her bidding strategy depends on the quality of signals. If the information quality is low ($d < \frac{1-m}{1-m+bm}$), the acquirer is more likely to incur overbidding loss when offering a high price. Hence her best strategy is to offer low price regardless of signals (i.e., $\alpha^* = 0$ and $\beta^* = 0$). Manager's effort is also independent of signals ($e^* = m$). If the information quality is high ($d > \frac{1-m}{1-m+bm}$), the acquirer faces less information asymmetry and is willing to bet on the high value by following a mixed strategy when the signal is good (i.e., $\alpha^* > 0$ and $\beta^* = 0$). In this case, both the acquirer's bidding strategy and the manager's equilibrium effort depend on the information quality.

When m is relatively large ($m > \frac{1}{1+b}$), the acquirer is more likely to conjecture a higher effort regardless of the quality of signals. The acquirer thus follows a mixed strategy when the signal is good, similar to the case when m is small and d is high. The information quality in this case also affect the acquirer's bidding strategy as well as the manager's equilibrium effort.

¹⁵ Although there are two possible equilibrium cases when either C1 or C2 holds, these two are mutually exclusive cases and there are no multiple equilibria in our model.

It is also interesting to analyze how the information quality, d , affects the equilibrium. Intuitively, when the information quality increases, the signal y becomes more informative. As a consequence of higher information quality, the acquirer is more likely to follow a mixed strategy instead of always offering a low price. However, as long as the equilibrium stays in the low-price-bidding equilibrium (given $C1$ holds), a change in the information quality does not affect the equilibrium effort and bidding strategy directly. On the other hand, when $C2$ holds, the information quality d affects the mixed-price-bidding equilibrium in two ways: it changes both the equilibrium managerial effort and the acquirer's bidding strategy. The probability of bidding a high price increases because the acquirer expects a lower probability to overbid upon a good signal. As a result, the probability of takeover success increases and the takeover market becomes more efficient. However, higher information quality increases the likelihood of high value firm to be taken over, and discourages the manager's effort. We summarize these results in the following corollary:

Corollary 1. *The equilibrium manager effort (e^*) is non-increasing in the information quality, and the probability of bidding a high price (α^*) in equilibrium is increasing in the information quality; i.e.,*

$$\frac{\partial e^*}{\partial d} \leq 0, \quad \frac{\partial \alpha^*}{\partial d} > 0.$$

Our results echoes with the view of the takeover market as an effective corporate governance mechanism. The takeover market here serves as a disciplinary device to motivate the manager to choose higher effort (Jensen, 1988). If the manager shirks, it is likely that the firm value will be low and in equilibrium a low-value firm will be taken over for sure. However, our analysis also shows another effect of takeover market on the manager's effort decision. That is, if the takeover market is very efficient so that the takeover always succeeds, the manager will lose his incentive to exert effort since his position is highly insecure. This second effect is consistent with some regulators' and academic's concerns that an active takeover market may place too much pressure on the management and the manager will not pursue the best interest of shareholders (Stein, 1988).

3.3.2. Optimal information quality

So far we have analyzed the equilibrium taking the information quality as given. In this section we examine the optimal choice of information quality. The choice of information quality not only affects the probability of successful takeover and the overbidding premium, but also affects the disciplinary role of the takeover market.

In our model, as we will illustrate soon, the firm value and the current shareholders' expected payoff are not fully aligned in the presence of the takeover market. As a consequence, the optimal information quality to maximize the firm value, denoted by d_v^* , is different from the optimal quality that maximizes the current shareholders'

payoff, denoted by d_s^* . We will analyze both optimal information quality levels. The maximization of the firm value, in our view, is more consistent with regulators' perspective of protecting the interest of firms' investors, including both current shareholders and future shareholders.

To see this, let's denote $\Pi_s(e^*, p^*(y))$ to be the current shareholders' expected payoff and $\Pi_v(e^*, p^*(y))$ to be the expected firm value. The shareholders' expected payoff includes the expected value of the firm if the firm is not taken over (we denote this event as NT) and the expected price the shareholders can receive from the acquirer if the firm is taken over (we denote this event as T). The firm value is the expected value of the firm regardless of whether the firm is taken over or not. Formally, the expected firm value and the current shareholders' expected payoff are, respectively,

$$\begin{aligned}\Pi_v(e^*, p^*(y)) &= [1 - \text{Prob}(T)]E[v|e^*, NT] + \text{Prob}(T)E[v + v_0|e^*, T] \\ &= E[v|e^*] + \text{Prob}(T) \cdot v_0;\end{aligned}\tag{3.6}$$

$$\begin{aligned}\Pi_s(e^*, p^*(y)) &= [1 - \text{Prob}(T)]E[v|e^*, NT] + \text{Prob}(T)E[p^*(y)|e^*, T] \\ &= E[v|e^*] + \text{Prob}(T) \cdot v_0 + \text{Prob}(OT) \cdot 1.\end{aligned}\tag{3.7}$$

where $\text{Prob}(T)$ is the probability of takeover success, and $\text{Prob}(OT)$ is the probability of takeover success with overbidding price.

The expected firm value consists of two parts: the expected firm value $E[v|e]$ when there is no takeover, and the expected value enhancement from the takeover, $\text{Prob}(T) \cdot v_0$. The current shareholders' expected payoff equals the expected firm value plus the expected overbidding premium, $\text{Prob}(OT) \cdot 1$. The current shareholders receive a higher payoff when there is overbidding from the acquirer. However, the overbidding premium is only a wealth transfer from the acquirer (the future shareholder) to the current shareholders and should not be considered as part of the expected firm value.

In the low-price-bidding equilibrium, $E[v|e^*] = e^* = m$. Given the acquirer's low-price bidding strategy, $\alpha^* = \beta^* = 0$, only the low-value firm can be taken over. Thus the probability of takeover success is $\text{Prob}(T) = 1 - e^*$ and there is no overbidding. In this case, the current shareholders' expected payoff and the expected firm value are the same. The change in information quality does not affect the current shareholders' expected payoff or the expected firm value. As a result, the optimal information quality that maximizes both the shareholders' expected payoff and the expected firm value in the pooling equilibrium can be of any value, as long as the low-price-bidding equilibrium condition is satisfied; i.e., d_s^* and d_v^* is any value in the range of $[\frac{1}{2}, \frac{1-m}{1-(1-b)m}]$.

In the mixed-price-bidding equilibrium, $E[v|e^*] = e^* = \frac{1-d}{1-d+db}$. Given the acquirer's mixed strategy upon a good signal, when the realized value is low the takeover is always successful, while when the realized value is high the takeover succeeds only when a good signal is generated and at the same time the bidding price is high. The probability of takeover success in this case is $Prob(T) = 1 - e^* + e^*d\alpha^*$. Here, the overbidding premium occurs only when a low-value firm obtains a good signal and the bidding price is high. Therefore, the probability of successful takeover with overbidding is $Prob(OT) = (1 - e^*)(1 - d)\alpha^*$. In contrast to the case of low-price-bidding equilibrium, now the information quality affects both the current shareholders' expected payoff and the expected firm value through its impacts on both the optimal effort level of the manager and the acquirer's bidding strategy. The optimal level of information quality that maximizes firm value is $d_v^* = \frac{2v_0-m}{2v_0-m+bm}$. The optimal information quality that maximizes the current shareholders' expected payoff is $d_s^* = \frac{2v_0-m+b(2-m)}{2v_0-m+b(2+bm)}$, which is different from d_v^* because the current shareholders' expected payoff includes the overbidding premium.

As shown in Proposition 4, when the manager's private benefit is large ($m > \frac{1}{1+b}$), only the mixed equilibrium is possible. When the manager's private benefit is small ($m \leq \frac{1}{1+b}$), the equilibrium is contingent on d . Comparing the expected payoffs of current shareholders and the expected firm value in each equilibrium, we have the following proposition:

Proposition 5. *There exist interim levels of information quality, $\frac{1}{2} \leq d_s^* < 1$ and $\frac{1}{2} \leq d_v^* < 1$, that maximize the current shareholders' expected payoff and the expected firm value, respectively. Specifically,*

- when $0 < m < \frac{1}{1+b}$,

$$d_s^* = \begin{cases} [\frac{1}{2}, \frac{1-m}{1-(1-b)m}], & \text{if } 0 < v_0 \leq \frac{1-b}{2}, \\ \frac{2v_0-m+b(2-m)}{2v_0-m+b(2+bm)}, & \text{if } \frac{1-b}{2} < v_0 < 1, \end{cases}$$

$$d_v^* = \begin{cases} [\frac{1}{2}, \frac{1-m}{1-(1-b)m}], & \text{if } 0 < v_0 \leq \frac{1}{2}, \\ \frac{2v_0-m}{2v_0-m+bm}, & \text{if } \frac{1}{2} < v_0 < 1; \end{cases}$$
- when $\frac{1}{1+b} \leq m < 1$,

$$d_s^* = \begin{cases} \frac{1}{2}, & \text{if } 0 < v_0 \leq \frac{(1+b)^2m}{2} - b, \\ \frac{2v_0-m+b(2-m)}{2v_0-m+b(2+bm)}, & \text{if } \frac{(1+b)^2m}{2} - b < v_0 < 1, \end{cases}$$

$$d_v^* = \begin{cases} \frac{1}{2}, & \text{if } 0 < v_0 \leq \frac{(1+b)m}{2}, \\ \frac{2v_0-m}{2v_0-m+bm}, & \text{if } \frac{(1+b)m}{2} < v_0 < 1. \end{cases}$$

Proof. See Appendix. □

Proposition 5 shows that regardless of whether the objective is to maximize the current shareholders' payoff or to maximize the firm value, a perfect information system is never optimal. The intuition follows directly from our analysis of the equilibrium. Specifically, the information quality has the following properties:

-
- $\frac{\partial e^*}{\partial d} < 0$,
 - $\frac{\partial \text{Prob}(T)}{\partial d} > 0$,
 - $\text{Prob}(OT)$ is maximized at $d = \frac{2-m}{2-m+bm}$.

More informative signals make the takeover market more efficient as the probability of takeover success increases. However, increasing information quality weakens the managerial effort incentive. Increasing information quality up to a certain level is good for both the current shareholders' payoff and the firm value, as the takeover market becomes more efficient and can improve the firm value through efficient takeover. However, perfectly informative signals are not in the best interest of maximizing current shareholders' payoff or the firm value, since the takeover market's disciplinary role on managerial effort will be weakened when the takeover market becomes very efficient. The manager's incentive to make an effort is reduced if he anticipates a higher probability of takeover success in a better-quality information system. The results in Proposition 5 show that the potential value enhancement (v_0) is a key determinant of these tradeoffs in determining the optimal information quality. When the value enhancement is small, it is more important to motivate the incumbent manager to work hard to improve the current firm value than to grab the potential value enhancement (as well as the overbidding premium) from an efficient takeover market. Thus for both current shareholders' payoff and firm value maximization, the optimal information quality is relatively low. When the value enhancement is large, the incentive to benefit from a successful takeover becomes greater, and as a result, the optimal information quality is higher to improve the takeover efficiency.

We compare these two levels of optimal information quality in Proposition 5 and have the following results:

Corollary 2. *The optimal information quality that maximizes current shareholders' expected payoff is weakly higher than the information quality that maximizes the firm value; i.e.,*

$$d_s^* \geq d_v^*.$$

In all scenarios, the current shareholders prefer an information quality level which is never lower than the one that maximizes the expected firm value. In addition, as the value enhancement from takeover gets larger, the current shareholders prefer a strictly higher level of information quality. This difference is driven by the overbidding premium that current shareholders may receive from the acquirer. The overbidding premium in our model depends on two factors: the probability of a low-value firm generating a good signal and the aggressiveness of the acquirer's bidding strategy upon a good signal. On the one hand, increasing the information quality directly increases the probability of low firm value due to the negative effect on the manager's effort level; however, it also decreases the probability of generating an imprecise signal for the low-value firm. Thus the overall effect of

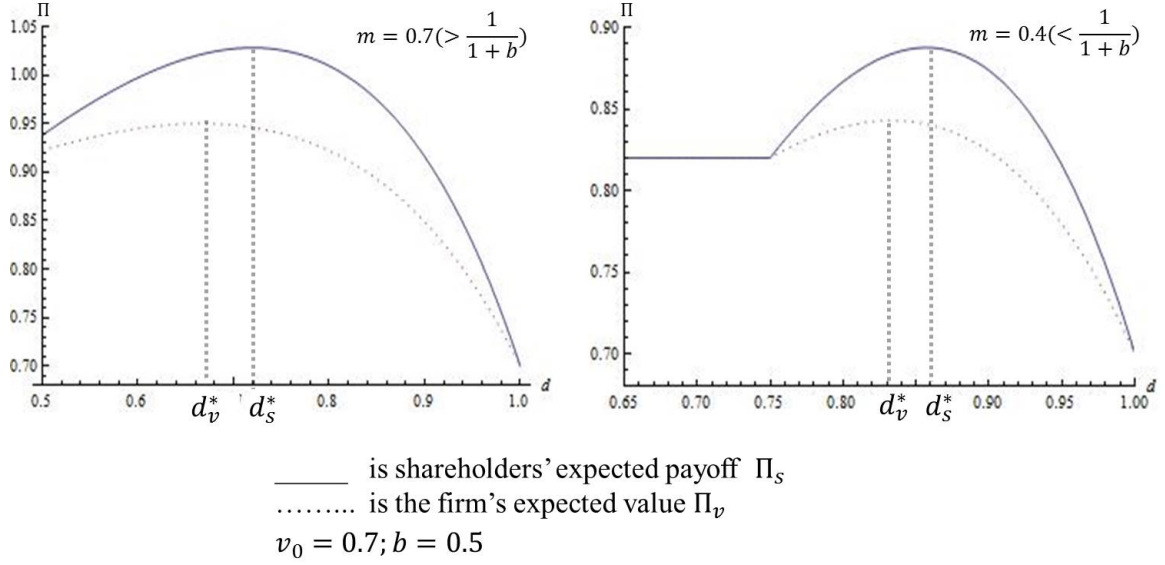


Figure 3.2.: The effect of information quality on the current shareholder's expected payoff (Π_s) and the expected firm value (Π_v).

information quality level on the probability of low-value firm generating a good signal is ambiguous. On the other hand, increasing the information quality reduces the acquirer's uncertainty about the firm value and allows the acquirer to bid more aggressively, which increases the overbidding premium. When the information quality is at the level of $d_v^* = \frac{2v_0 - m + b(2-m)}{2v_0 - m + b(2+bm)}$ which maximizes the expected firm value, the marginal overbidding premium from increasing information quality is positive since $\frac{2v_0 - m + b(2-m)}{2v_0 - m + b(2+bm)} < \frac{2-m}{2-m+bm}$. Therefore the current shareholders are better off by further increasing the information quality.

Fig. 3.2 illustrates how information quality affects the current shareholders' payoff and the expected firm value when the value enhancement is relatively large.

This result may be counter-intuitive as the common perception is that increasing the quality of financial reporting or information is always beneficial for investors who care about the fundamental firm value. Contrary to the common perception, our analysis indicates that to maximize the interests of all investors, or to maximize the expected firm value, a more stringent requirement for information quality may not be efficient in the context of takeover market, where there exists conflict of interests between current shareholders and future shareholders. Our analysis also stresses the fact that the current shareholders' interest may not fully align with the maximization of firm value.

3.3.3. Anti-takeover laws and information quality

In our model, the takeover market functions as an external disciplinary corporate governance device and the current shareholders choose the optimal information quality given the exogenous takeover market. In practice, the current shareholders or regulators may also influence the takeover market through takeover defense tools. In the 1980s, many states passed anti-takeover legislation that made takeovers more difficult and costly in response to an active takeover market of the 1980s. The anti-takeover laws usually limit acquirers' voting rights in takeovers, require acquirers to pay a fair price, or prohibit takeover activities for some period (Cheng et al., 2004). Following the adoption of anti-takeover laws, the takeover market declined in the 1990s. Besides anti-takeover legislation, a firm can also adopt anti-takeover provisions to increase the difficulty of launching a takeover bid for the firm. These anti-takeover defenses typically include corporate charter anti-takeover amendments and poison-pill securities.¹⁶

In this section we examine how the adoption of anti-takeover laws (or anti-takeover provisions) influences the information quality of the firm. Since anti-takeover laws make a takeover more difficult and costly for the acquirer, in our model we simply represent the effect of anti-takeover laws by a decrease of the private benefit of the acquirer from the successful takeover, b .¹⁷ Recall that in our model the acquirer's expected payoff from takeover depends on his private benefit, and therefore the private benefit of the acquirer will affect her bidding strategy. The acquirer is more likely to bid a low price when her private benefit is small. This in turn will change the manager's effort incentive, as it affects the manager's conjecture about the acquirer's bidding strategy and the takeover success probability. In equilibrium, a smaller private benefit of the acquirer implies that the low-price-bidding equilibrium exists in a larger parameter space. In the mixed-price-bidding equilibrium we have the following results:

- $\frac{\partial e^*}{\partial b} < 0$,
- $\frac{\partial \text{Prob}(T)}{\partial b} > 0$,
- $\frac{\partial \text{Prob}(OT)}{\partial b} > 0$.

From these results, we see that a decrease in b increases the manager's effort in equilibrium. Since the acquirer's private benefit is smaller, the manager expects that the acquirer's expected payoff from bidding a high price is lower and the chance that the acquirer bids a high price when observing a good signal is lower. Therefore, the manager is more willing to exert his effort. As a result of less aggressive bidding by the acquirer and the increased probability of being a high-value firm when the

¹⁶See Sundaramurthy (2000) for a review of literature related to anti-takeover provisions.

¹⁷Sundaramurthy (2000) discusses how each type of anti-takeover provisions can raise takeover costs for the acquirer.

manager increases the effort, the overall probability of takeover success is reduced. Moreover, the overbidding likelihood is lower, since the probability of being a low-value firm is lower as a result of a higher manager's effort and a lower probability of bidding high price.

In Proposition 6, we show the optimal information quality levels to maximize the shareholders' payoff and the expected firm value, separately, after the adoption of anti-takeover laws:

Proposition 6. *After the adoption of anti-takeover laws, the optimal information quality levels, d_s^{**} and d_v^{**} , are both higher.*

Proof. See Appendix. □

Intuitively, when the acquirer's private benefit is smaller, the expected current shareholders' payoff and firm value are reduced due to the decreased probabilities of takeover success and overbidding. To maximize the current shareholders' payoff and firm value, it turns out to be optimal to increase the information quality. This is because increasing the information quality reduces the acquirer's uncertainty about the true value of the firm and encourages more aggressive bidding from the acquirer. The implication of Proposition 6 is consistent with the empirical evidence that financial information quality improves after the adoption of anti-takeover laws or anti-takeover provisions (Armstrong et al., 2012; Fu and Liu, 2008).

It is also interesting to analyze the impacts of anti-takeover laws on the firm value and shareholder's welfare when current shareholders optimally choose the information quality. We compare these two objective functions at the optimal information quality d_s^* and d_s^{**} respectively. The following proposition summarizes the effects:

Proposition 7. *Given that the current shareholders optimally choose the information quality before and after the passage of anti-takeover laws, we have the following results:*

- *anti-takeover laws have no impact on the expected firm value when $m < \frac{1}{1+b}$ and $0 < v_0 < \frac{1-b}{2}$, and always improve the expected firm value otherwise;*
- *anti-takeover laws have no impact on the current shareholders' expected payoff when $m < \frac{1}{1+b}$ and $0 < v_0 < \frac{1-b}{2}$, otherwise anti-takeover laws improve the current shareholders' expected payoff when $\frac{1}{1+b} < m < 1$ and $1 < v_0 < \frac{1-b}{2}$, and decrease the current shareholders' expected payoff when $v_0 > \frac{1-b}{2}$.*

Proof. See Appendix. □

When the value enhancement and the manager's private benefit are both very small ($0 < m < \frac{1}{1+b}$ and $0 < v_0 < \frac{1-b}{2}$), we remain in the low-price-bidding equilibrium; thus there is no direct effect on the equilibrium effort or takeover probability by

adopting anti-takeover laws, as shown in Proposition 4. Both the current shareholders' expected payoff and the expected firm value remain unchanged after the adoption of anti-takeover laws.

Otherwise, we are in the mixed-price-bidding equilibrium. In the mixed-price-bidding equilibrium, reducing the acquirer's private benefit has a positive effect on the manager's effort and a negative effect on the takeover probability. For the expected firm value, the positive effect always dominates the negative effect and the firm value increases with the anti-takeover laws. But for the current shareholders, anti-takeover laws may either improve or reduce their expected payoff, as reducing the acquirer's private benefit also reduces the probability of overbidding takeovers. When the manager's private benefit is large but the potential value enhancement is small ($\frac{1}{1+b} < m < 1$ and $0 < v_0 < \frac{1-b}{2}$), the current shareholders care more about motivating the manager to exert higher effort to increase the current firm value than the potential value enhancement they receive from the takeover. Thus anti-takeover laws improve the current shareholders' payoff as they strengthen the manager's motivation to work. However, when the value enhancement is big ($v_0 > \frac{1-b}{2}$), the two negative effects of lower takeover efficiency and lower overbidding premium together dominate the positive effect of the manager's effort, therefore the current shareholders' overall welfare is reduced.

Our results provide one justification for the adoption of anti-takeover laws, as regulators care more about the fundamental firm value rather than the interest of the current shareholders. Our results also suggest that firms are more likely to adopt anti-takeover provisions when managers are entrenched and the takeover value enhancement is not large. Otherwise, anti-takeover provisions do not serve the shareholders' interests.

3.4. Conclusion

This paper develops a theoretical model to examine the interaction between information quality and the takeover market as the corporate governance mechanism to discipline managers. In corporate takeovers, financial accounting information of a target firm is useful for the acquirer to assess the target firm's value when there is information asymmetry about the true value. We show that when the target firm can choose the information quality level to maximize either the expected payoff of the current shareholders or the expected firm value, some imprecise information is optimal in the presence of the takeover market. In addition, we find that the information quality that maximizes the current shareholders' payoff is different from that which maximizes the expected firm value due to the overbidding premium. To be more precise, the current shareholders actually prefer a higher level of information quality in order to receive the overbidding premium through more aggressive bidding for a low-value firm. We also analyze the effect of anti-takeover laws on the optimal information quality. We find that the optimal information quality is higher after

the passage of anti-takeover laws, and the anti-takeover laws always improve the firm value but not necessarily the current shareholders' payoff. These results have implications for the target firms' disclosure policies in the context of the takeover market.

4. Innovation, Information Quality and Career Concerns

4.1. Introduction

Over the past 60 years, innovation-related expenditures have been increasing dramatically, and become a crucial strategic decision for many firms. During 1995-2007, U.S. firms' annual innovation investments comprised 12.8% of the U.S. GDP, which is more than double the number during the high-growth period after World War II (1948-1972) (Corrado and Hulten, 2010). March (1991) identifies two forms of innovation: exploitation and exploration. Exploitation aims at improving the efficiency of the current business model, while exploration seeks to develop new business opportunities. The innovation I examine in this study, better characterized as exploration, includes any radical innovation that transforms the firm, such as a broad organizational change, a strategic acquisition, entering into new markets, creating and/or adopting new technologies, etc. Boards of directors often initiate such explorative innovations when the competitive situation renders an intense urgency for transformation.¹ As pointed out by Kotter (1995), the first step in transforming a firm is cultivating a sense of urgency, followed by hiring a powerful leader to steer the change (see also Helmich and Brown, 1972). For example, after years of J.C. Penney's alarming performance, Bill Ackman, a board member and the largest shareholder, strongly suggested that the board hire Ron Johnson as CEO because of his remarkable success in Apple's retail operations. Indeed, a manager's ability is a key factor in undertaking a firm transformation (Banker et al., 2013). However, in such endeavors, the manager puts his own future career prospects at great risk. If the innovation fails, the manager may be considered ineffective, lose his job, and damage his reputation. In the J. C. Penney example, the changes that Johnson implemented caused a dramatic drop in the firm's revenues. He was shortly ousted and, since then, he has not been reported to have taken an executive job. In contrast, CEOs of firms with a clear deficiency in innovation, such as GE and CISCO, are still at the helm even though their firms have been losing profits for years (Hartung, 2012). In this sense, managers that are asked to implement innovations bear

¹The innovation urgency is different among firms, depending on the prevailing and potential crises and opportunities. For example, firms with recessive performances are desperate to make radical transformations to survive (Greve, 1998); firms facing rapid market shifts should also change business practices to adapt to the market environment; high-tech firms need to make constant innovations to maintain their reputation and maintain a competitive advantage.

a higher career risk than those simply adopting an inconspicuous stewardship role. Moreover, managers' career risk needs to be appropriately compensated. Therefore, shareholders must take into account managerial career risk when they make decisions to innovate.

The empirical evidence regarding the relation between CEO career concerns and firm investment decisions is mixed.² Some studies find that firms' investment decreases with the degree of managers' career concerns. For example, Pan et al. (2013) empirically find that firms with CEOs in their early tenure tend to disinvest and, later on, increase investments as the CEOs tenures extend. In contrast, Serfling (2012) finds that firms with younger CEOs invest more than those with older CEOs, but this evidence is only significant for high-growth industries. This seemingly contradicting evidence suggests that deeper insight into the interaction between managerial career concerns and innovation is needed. Moreover, although it may appear unrelated, career concerns also have an important influence on financial statement practices. Indeed, in a survey conducted by Graham et. al., (2005) more than three quarters of the managers admitted to have a strong incentive to meet earnings benchmarks due to reputation concerns rather than short-term compensation. In this sense, financial statement practices affect manager exposure to career concerns and, therefore, must also affect innovative investment decisions. The aforementioned evidence indicates that there seems to be a relation between managerial career concerns and shareholders decisions on both innovation investment and financial information quality that deserves further examination.

In this study, I develop an analytical model to examine how shareholders jointly make decisions on innovation and information quality in the presence of managerial career concerns. I assume that shareholders are risk-neutral and endowed with a level of innovation urgency, such as developing opportunities to gain a competitive advantage, resolving a current or potential crisis, etc. Depending on the innovation urgency, shareholders decide the extent to which changes are undertaken in the firm's business. The more the shareholders want to change, the more they invest. Moreover, shareholders need to hire a manager to implement such innovation. The innovative investment outcome depends on the manager's ability— more so when the change is large. In addition, the manager is risk-averse and can improve the outcome with a costly effort that is not publicly observable. This effort can be thought of as an operating effort in maintaining routine business. Shareholders offer a contract to the manager to motivate his operating effort and compensate him for career risk. In addition, shareholders can also choose the quality of accounting information. The lower the level of information quality, the less weight the labor market puts on the public signal when assessing the manager's ability and, therefore, the lower the manager's career risk. However, this also induces a noisier performance measure, thereby making motivation of the manager's effort more difficult. Together, the model determines the shareholders jointly optimal decisions on innovation, infor-

²In previous studies, it is a common perception that the degree of career concern is negatively related with CEO age and tenure.

mation quality, and compensation contract taking into consideration the manager's career risk.

I show that shareholders prefer imperfect information in order to protect the manager from career risk, especially when the innovative investment is large. I find that innovation urgency plays a critical role in determining the way shareholders cope with career concerns. When innovation urgency is intense, shareholders invest heavily and choose a low level of information quality to reduce the manager's exposure to career risk. At high levels of innovation and low levels of information quality, the outcome is very volatile and, therefore, motivating effort is very costly. However, innovation investment is inexpensive because the manager is hardly exposed to the labor market. This yields an unexpected result: the more concerned the manager is about his career prospects (e.g., the less is known about the manager's ability), the more shareholders invest in innovation. In contrast, when the level of innovation urgency is low, shareholders invest less to mitigate the manager's career risk, and focus on motivating the manager's effort with high levels of information quality and strong compensation incentives. At high levels of information quality, innovation investment is costly because it exposes the manager's ability conspicuously, whereas motivating the operating effort with explicit incentives is more efficient. This produces another unexpected result: an increase in the manager career-risk concerns induces shareholders to increase the power of explicit compensation incentives. Indeed, higher managerial career-risk concerns shift shareholders focus towards the operating effort even further. As a result, shareholders reduce innovative investment, increase information quality, and increase explicit incentives. In addition, I find that shareholders preferences over managerial degree of career concerns are not monotonic in the urgency of innovation. In fact, in firms with intermediate levels of innovation urgency, managerial career concerns are most detrimental to shareholders. Indeed, in these firms, stronger career concerns result in both lower innovative investment and managerial effort. Therefore, these firms value an experienced manager most because his ability is well known and, as a result, the manager is less concerned about being exposed to the labor market. Through a numerical example in a matching model, I show that managers with fewer career concerns, such as experienced managers, are most favored by middle-of-the-road innovation firms. In summary, I show that innovation urgency is critical in the relation between managerial career concerns and shareholders decisions on innovation, disclosure policy, managerial compensation, as well as manager selection. Moreover, the impact of innovation urgency on these relations is non-monotonic. Because innovation urgency is also an industry-specific characteristic, my results shed light on cross-industry studies on the impact of career concerns on firms investment and managerial compensation decisions.

My study sheds light on the mixed evidence in the literature with respect to the relationship between CEO career concerns and firm investment decisions. The finding of a non-monotonic relationship between career concerns and innovative investment is supported by the empirical evidence by Serfling (2012). Existing studies theoret-

ically examining the link between a firm's investment decision and career concerns are scattered. Holmstrom and Ricart i Costa (1986) show that career concerns induce a manager to underinvest in projects with returns contingent on his ability, and the distortion in investment decisions cannot be completely addressed with a compensation contract. Zwiebel (1995) and Prendergast and Stole (1996) consider a setting in which the manager has private information about his ability. Zwiebel (1995) shows that if the labor market assesses managers abilities based on their relative performance, managers may have an incentive to undertake innovative paths in order to avoid such comparison, therefore making their evaluation less accurate and less risky. Prendergast and Stole (1996) demonstrate that in order to signal high ability, managers may overweigh their private information in making investment decisions at the early stage but may ultimately become too conservative. In contrast to these papers, I focus on the tradeoff shareholders face in making decisions on innovation investment, information quality as devices to motivate effort and mitigate the manager's career risk in a setting with no information asymmetry about the manager's ability.

My study also contributes to the broad literature on the effect of career concerns on managers' compensation. Holmstrom (1999) shows that career concerns may benefit shareholders by providing implicit incentives that motivate managerial effort by linking managerial performance to future wages. Gibbons and Murphy (1992) argue that career concerns can actually substitute for explicit incentives in motivating managerial effort (henceforth, the substitution effect). However, Chen and Jiang (2006) suggest that the substitution effect may be weakened or even reversed by considering the case in which a manager can control the informativeness of the report about his ability. Autrey et al. (2003, 2006) examine the role of career concerns on incentive provision considering the availability of two signals, a public signal and a private signal. My study suggests that in addition to the direct substitution effect between career concerns and the explicit incentive, career concerns also interact with the compensation contract indirectly through a firm's innovation. Specifically, I find that when the level of innovation urgency is low, shareholders decrease innovation as career concerns increase; therefore, the business becomes relatively stable and motivating managerial effort is more efficient. As a result, my result predicts that managers' pay-performance-sensitivity increases with career concerns if the level of innovation urgency is low.

My study is also related to the literature on the relationship between career concerns and information quality. There is a line of literature that focuses on the role of career concerns in motivating managerial effort in different information environments. Dewatripont et al. (1999a) compare the different roles of career concerns incentives within various information structures. Arya and Mittendorf (2011), building upon Dewatripont et al. (1999a), study a multi-agent model and compare the aggregated and disaggregated performance measures with the existence of career concerns. There is another line of literature that implies that a less transparent information environment may be good for shareholders in the sense of reducing manager career

risk, which must be compensated ex-ante by the shareholders (as seen in Hermalin and Weisbach, 2007). Arya, Glover, and Sunder (1998) show that allowing earnings manipulation will reduce the frequency of management turnover. Therefore, shareholders save ex-ante compensation for managers' dismissal risk. In my study, I examine the tension that shareholders face between reducing information quality to protect the manager from exposure to the labor market and improving information transparency to better motivate managerial effort.

The rest of the section proceeds as follows: Section 4.2 describes the model setup and analyzes the labor market assessment of the manager's ability as well as the manager's effort input strategy. Section 4.3 characterizes the shareholders' optimal variable choices and examines the impact of career concerns on shareholders decisions and Section 4.4 concludes this study.

4.2. The model

4.2.1. The model setup

Risk-neutral shareholders are endowed with a certain level of innovation urgency m ($m > 0$), and commit to making an investment in innovation i (> 0) at a cost $\frac{c}{2} \cdot i^2$ ($c > 0$). m could be thought of as profitability of innovating. For example, innovation is urgent and profitable when the competition is intense or the market shifts radically. In this case, the shareholders have an intense urgency to change the business practice by investing in innovation. The shareholders' innovation urgency, m , and decisions on innovation, i , are public information. The assumption that shareholders make innovative investment decisions is descriptive of firms' transformation practices. Although managers may usually be given complete authority for decision makings in routine operations, investments in transformations are either initiated or at least approved by the board. The shareholders hire a risk-averse manager to lead the innovation. The manager is endowed with random ability, a , which is unknown to all. It is common knowledge that a follows a normal distribution $N(0, 1/h_a)$. $1/h_a$ represents the ex-ante uncertainty of the manager's ability. The revenue, r , is shown as:

$$r = i \cdot m + i \cdot a + e. \quad (4.1)$$

The revenue here is better characterized as the marginal revenue that the firm obtains by hiring a manager to implement the innovation. For a firm in big trouble, its marginal revenue of making changes could be very large although its current accounting revenue might be very low. Hence, the shareholders are desperate to hire a manager to make a turnaround by innovating. The revenue, r , consists of three components. The first component $i \cdot m$ captures the benefit of innovation due to

the innovation urgency. When the competitive situation renders an intense urgency for transformation (m is large), shareholders increase the magnitude of innovation. However, due to the convexity of the investment cost, the investment should be finite. The second term $i \cdot a$ is contribution of the manager's ability to the revenue. In previous studies, the sensitivity of revenue to the manager's ability is assumed to be fixed, usually normalized to 1. However this may not be descriptive on the case in which managers are asked to undertake different business. The manager's ability is more crucial in transformations compared with routine business.³ Therefore, I assume the manager's ability's effect on the revenue is magnified by the innovative investment i , representing the fact that the manager's ability is more influential on the revenue when he is asked to implement innovations.⁴ In other words, undertaking changes will largely expose the manager's ability. Besides the manager's ability, the manager's effort, e , contributes to the firm's revenue as well. e could be thought of as the operating effort in maintaining the status quo. As is standard in literature, the manager's choice of effort, e , is assumed to be unobservable to the shareholders and the labor market and incurs cost $\frac{1}{2} \cdot e^2$ to the manager.

The revenue, r , is unobservable. However, a noisy signal y about r is contractible and reported by the financial reporting system:

$$y = r + \epsilon,$$

where $\epsilon \sim N[0, \frac{1}{h}]$, and $h > 0$.

The shareholders determine the quality of the financial reporting system, h , and offer a contract, $w_1(y)$, to hire the manager. Following Gibbons and Murphy (1992), I assume the contract is short term and linear in the accounting signal, y : $w_1(y) = k_1 y + c_1$. The manager will exert effort, e , if he accepts the contract. The timeline is summarized in Fig. 4.1.

The model is a two-period model with Dates 0, 1, and 2. On Date 0, the shareholders determine the financial reporting system's quality h (> 0), commit to investing i in innovation, and offer a linear contract $w_1(y)$ to the manager. The shareholders decisions are all publicly observable.

³Banker et. al. (2013) indicate that managers in R&D intensive firms are taking relatively complex jobs, including responding to competitor's actions and environmental changes promptly, making investment decisions, managing the R&D work force, etc. As a result, the manager's ability is more important for R&D intensive firms compared to non-R&D intensive firms.

⁴The mean of the manager's ability is normalized to zero, and as a result, ex-ante the shareholders cannot benefit from the manager's ability through innovative investment. m is the only source of benefit for the shareholders by investing in innovation.

I assume that in the revenue the only source of riskiness is manager ability uncertainty so that the revenue randomness induces significant career risk. I can introduce a systematic risk, η ($\eta \sim N[0, \sigma^2]$), and rewrite the revenue as $r = i \cdot (m + \eta) + i \cdot a + e$. The main results will quantitatively hold. However, the career risk will be dampened because the labor market believes that the revenue is partially attributable to random shock rather than the manager's ability.

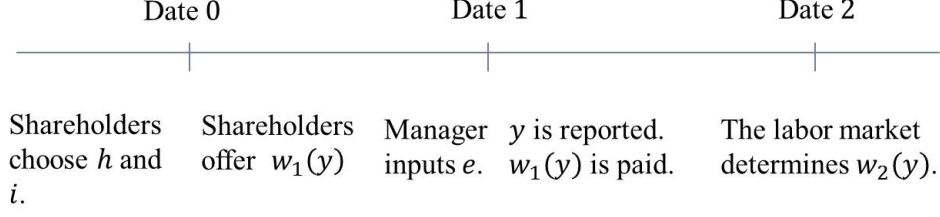


Figure 4.1.: The timeline of the setup.

On Date 1, the manager accepts the contract if his expected utility is no less than his reservation utility (i.e. his ex-ante expected ability), which is normalized to 0. The manager inputs an operating effort $e > 0$ at a cost $\frac{1}{2} \cdot e^2$. Then the signal y is reported and the shareholders pay the manager $w_1(y)$.

On Date 2, the manager can either stay with the firm or leave and look for another job. His new wage w_2 is determined by the labor market as the perception of the manager's ability based on the public signal y , namely $w_2 = E[a|y]$.⁵ The manager's career concerns are introduced here. If the signal is low, the manager would be regarded as having low ability. Therefore, in the future, the manager can only earn a low wage due to his bad reputation. For a risk-averse manager, the volatility of future wages, w_2 , causes a dis-utility, which could be thought of as career risk.

I assume the manager has an additively separable mean-variance utility function, as shown in Eq 4.2. ρ is the manager's degree of risk aversion:

$$U(w_1, w_2, e) = E[w_1] - \frac{\rho}{2} Var[w_1] - \frac{1}{2} e^2 + E[w_2] - \frac{\rho}{2} Var[w_2]. \quad (4.2)$$

I assume that the manager does not have access to the credit market. This utility function follows a study by Chen and Jiang (2006), who cite empirical evidence that managers cannot completely hedge future career risks, particularly early in their careers (Jin, 2002; Garvey and Mibourn, 2003).⁶ Many other studies assume that the principal is limited to offering a fixed contract (Arya and Mittendorf, 2011; Dewatripont et al., 1990b; Hermalin and Weisbach, 2007) such that the shareholders

⁵To be more precise, $E[a|y]$ is the manager's reservation utility on Date 2. I do not model the case in which the manager is asked to implement innovations or exert effort on Date 2. As a result, the manager's future wage should exactly equal his reservation utility. If there is an effort input or risk-taking on Date 2, then the manager's future wage should compensate for the cost of effort and risk. However, the manager's certainty equivalent of his future wage should still equal his reservation utility $E[a|y]$.

⁶The restriction here is simply to ensure that the manager cannot insure his career risks through savings or lendings, which raises the manager's career concerns. This assumption is stronger than necessary. Actually, the manager's career concerns exist as long as it is not possible to completely insure the manager's future career risk. However, it is by assuming that insurance is totally infeasible that career concerns are most succinctly captured.

cannot provide the manager insurance for his future career risk through an incentive contract.

4.2.2. The labor market's belief and the manager's optimal effort

I solve for the equilibrium by backward induction, starting with the labor market's perception about the manager's ability on Date 2. The revenue depends on the manager's effort, as well as the manager's ability. Since the manager's effort is unobservable to the labor market, to update the belief of the manager's ability, the labor market makes a conjecture of e denoted by \hat{e} . Given \hat{e} , the updated belief of the manager's ability upon signal, y , follows a normal distribution:

$$a|y \sim N\left[\frac{i/h_a}{var_y} \cdot (y - i \cdot m - \hat{e}), \frac{1/h_a \cdot 1/h}{var_y}\right],$$

where var_y is the variance of the signal y :

$$var_y \equiv Var[y] = i^2/h_a + 1/h.$$

The first term of signal y 's variance, i^2/h_a , is the variance of the revenue, which is due to the uncertainty of the manager's ability. The innovation investment has a multiplicative effect on the revenue variance. That is, innovations induce riskiness in the business, especially when the manager's ability is highly uncertain. For example, asking a less experienced manager, whose ability is less known, to transform the firm may lead to a riskier business than asking a more experienced manager to do so. The second term of var_y , $1/h$, is the noise of the accounting signal that is predetermined by the shareholder. In previous studies, the randomness of the signal is taken as given. However, in this model, the signal's volatility is contingent on shareholders' endogenous choices of innovative investment, i , and information quality, h . In other words, I am considering a setup in which shareholders decisions on information quality and investment impact the labor market's evaluation of the managerial ability. The future wages can be expressed as:

$$w_2(y, i, \hat{e}) = E[a|y] = k_2 \cdot (y - i \cdot m - \hat{e}), \quad (4.3)$$

where $k_2 = \frac{cov(a, y)}{var_y} = \frac{i/h_a}{var_y}$.

As suggested by previous studies, career concerns work as an implicit contract to the manager: the manager has an incentive to exert effort to improve the signal thereby

obtaining a better evaluation in the labor market.⁷ The slope of w_2 , k_2 is referred as the career concerns incentive. Lemma 6 captures that the career concerns incentive increases with the information quality and the uncertainty about ability, $1/h_a$.

Lemma 6. *The career concerns incentive, k_2 , increases with h and $1/h_a$.*

Proof. See Appendix. □

According to previous studies, career concerns stem from uncertainty about a manager's ability. For the manager, the more uncertain about his ability ($1/h_a$ is larger), the more to expose in the labor market. Therefore, the manager has stronger incentive to work hard to improve the signal. I show that the information quality is also critical to the career concerns incentive. The more informative the signal y about the revenue, the more weight the labor market puts on the signal to form posterior beliefs about the manager's ability. The manager's effort then results in a larger upward revision of the labor market perception. Therefore, the manager is more motivated to exert effort (k_2 is higher). Lemma 6 shows that the career concerns incentive increases with the information quality, as well as with the managerial ability uncertainty.

After considering the labor market perception about the manager's ability, I now return to Date 1. The manager chooses the optimal effort to maximize his expected utility, taking the shareholders' explicit contract, w_1 , and his future wages determined by the labor market, w_2 , as given. Formally, the manager solves $\text{Max}_e U(w_1, w_2, e)$.

From the first-order condition of the manager's utility function, one can derive the manager's optimal effort, $e^* = k_1 + k_2$. This is a standard result in literature, suggesting that the managerial effort is motivated by both the compensation incentive and the career concerns incentive. Moreover, in the perfect Bayesian equilibrium, the labor market conjecture about the manager's operating effort \hat{e} should coincide with the manager's optimal operating effort: $\hat{e} = e^* = k_1 + k_2$.

4.2.3. Managerial career risk

It can be seen from Eq 4.3 that the manager's future wages, w_2 , is contingent on the signal y . Therefore, the volatility of w_2 incurs a disutility to the manager, $\frac{\rho}{2} \text{Var}[w_2]$,

⁷In the equilibrium, the labor market's conjecture of the manager's effort is consistent with the manager's equilibrium effort, and the labor market will accordingly undo the effect of the manager's effort on the revenue. As a result, the manager's effort will not bias the labor market's belief about his ability. However, the manager still has the incentive to exert effort. According to Holmstrom (1999), "the manager is trapped in supplying the equilibrium level that is expected of him, because, as in a rat race, a lower supply of labor will bias the evaluation procedure against him."

which is referred to as career risk and denoted by C_R :

$$C_R \equiv \frac{\rho}{2} \text{Var}[w_2] = \frac{\rho}{2h_a} \frac{i^2/h_a}{\text{var}_y} = \frac{\rho}{2h_a} i \cdot k_2. \quad (4.4)$$

It can be easily proved that C_R increases with the manager's risk-averse degree, ρ , and the uncertainty about the manager's ability, $\frac{1}{h_a}$, both of which relate to the manager's personal characteristics: the risk-averse degree as well as the ex-ante uncertainty of his ability. Therefore, for the sake of illustration, I refer to ρ/h_a as the degree of career concern throughout: when the manager is more risk-averse (ρ is larger) or more uncertain about his ability (h_a is smaller), the career risk is larger. C_R can then be rewritten as a product of two terms, $\frac{\rho}{2h_a}$ and $\frac{i^2/h_a}{\text{var}_y}$, which is shown in Eq 4.4. The first term, $\frac{\rho}{2h_a}$, is the manager's degree of career concerns as discussed above. The second term, $\frac{i^2/h_a}{\text{var}_y}$, is the proportion of the total volatility of the performance measure y that is attributable to the manager's unknown ability. This could be considered as the extent to which the manager's ability is exposed to the labor market through the accounting signal. If the volatility due to the manager's unknown ability takes up a large proportion of the signal's volatility ($\frac{i^2/h_a}{\text{var}_y}$ is large), the labor market will interpret a high (low) realization of the signal as the manager having a high (low) ability. In other words, the signal is very informative about the managerial ability. In contrast, if $\frac{i^2/h_a}{\text{var}_y}$ is small, the signal is very noisy. The labor market believes that the signal is mainly driven by noise and contains little information about the manager's ability. As a result, when evaluating the managerial ability, the labor market relies less on the signal and more on the ex-ante belief of the manager's ability. As the manager's ability is increasingly exposed in the labor market, the manager bears a higher career risk. It can be verified that $\frac{i^2/h_a}{\text{var}_y}$ increases with the shareholders' two choice variables: the information quality h and the innovative investment i . The reason is that higher h suggests the accounting signal is less noisy, while higher i leads to riskier business practice in which the managerial ability uncertainty induces higher riskiness. Both higher h and higher i can increase the proportion of y 's volatility that is attributable to the manager's unknown ability, and thus induce larger exposure of the manager. In other words, the shareholder can mitigate the manager's career risk in two ways: lowering the information quality and reducing the innovation investment.

Lemma 7. *The manager's career risk, C_R , increases with the information quality and the innovative investment; i.e., $\frac{\partial C_R}{\partial h} > 0$, and $\frac{\partial C_R}{\partial i} > 0$.*

Proof. See Appendix. □

Hermalin and Weisbach (2007) indicate that in a more transparent information environment, the labor market puts more weight on the random signal when forming

perceptions about the manager's ability. Thus, the manager suffers from higher career risk. Besides the information quality, a higher level of innovation makes the manager's ability has a stronger influence on the firm's revenue, which leads to increased exposure of the manager's ability in the labor market, thus creating a higher career risk as well.

4.3. Main Results

In the previous section, I characterized the labor market determination of the manager's future wages, the manager's optimal effort, and then captured the manager's career risk. In this section, I return to Date 0 to examine the shareholders' optimal strategies about the compensation contract, w_1 , the information quality, h , and the innovative investment, i . I next characterize the impact of career concerns on the shareholders decisions on the innovative investment and the compensation incentive. I then consider a setup with heterogeneous shareholders and managers to examine how shareholders select managers to implement innovations. I provide a numerical example comprised to illustrate the endogenous matching patterns between shareholders and managers. I finally characterize the impact of imposing a highly-stringent disclosure policy on firms' innovation decisions.

4.3.1. The shareholders' optimal decisions

On Date 0, the shareholders choose the optimal decisions on the compensation contract, w_1 , the information quality, h , and the innovative investment, i , to maximize their expected payoff, π_s . The shareholders make these decisions while anticipating the labor market's reaction to the accounting signal and the manager's effort input strategy derived in Section 4.2.2. The compensation contract should satisfy the manager's participation constraint (IR) and incentive compatible constraint (IC). The shareholders' problem is:

$$\begin{aligned} \underset{\{k_1, c_1, h, i\}}{\text{Max}} \pi_s(k_1, c_1, h, i) &= E[r|e = e^*] - E[w_1(y)|e = e^*] - \frac{c}{2}i^2, \\ \text{s.t.} \quad U(w_1, w_2, e^*) &\geq 0 \text{ (IR)}, \\ e^* &= \arg \text{Max}_e U(w_1, w_2, e) \text{ (IC)}. \end{aligned} \tag{4.5}$$

In the following, I restrict attention to the cases with interior solutions by assuming that parameters ρ , h_a , m , k satisfy condition C1.

Condition C1: $\frac{2+\sqrt{2}}{2} < \rho/h_a < (1 + \sqrt{2})m$ and $c > \frac{(\sqrt{2}-1)m\rho}{h_a}$.

I am able to show the shareholders' optimal choices of k_1 , c_1 , h , and i in Proposition 8.

Proposition 8. *For a given level of innovation investment, i , the shareholders optimally choose*

- the information quality $h^*(i) = \frac{1}{\text{var}_y^*(i) - i^2/h_a}$,
- the contract $w_1^*(y) = k_1^*(i)y + c_1^*(i)$,

where $\text{var}_y^*(i) = \frac{i[\sqrt{2}h_a + (2+\sqrt{2})i\rho]}{h_a^2 + 2\rho h_a - i^2\rho^2}$, $k_1^*(i) = 1 - \frac{\sqrt{2}}{2} - \frac{3\sqrt{2}-4}{2h_a}i\rho$, $k_2^*(i) = \frac{\sqrt{2}}{2} - \frac{(2-\sqrt{2})}{2h_a}i\rho$,

and $c_1^*(i) = \frac{k_2^*(i)^2 - k_1^*(i)^2 + (k_2^*(i)^2 + k_1^*(i)^2)\rho \text{var}_y^*(i)}{2} - k_1^*(i) \cdot i \cdot m$.

$k_2^*(i)$ is the career concerns incentive.

In the equilibrium, the shareholders choose optimal innovative investment, $i^* = \frac{h_a^2 m - (\sqrt{2}-1)\rho h_a}{h_a^2 c - (3-2\sqrt{2})\rho^2}$, optimal information quality, $h^* = h(i^*)$, and optimal linear contract, $w_1^*(y) = k_1^*y + c_1^*$, where $k_1^* = k_1^*(i^*)$ and $c_1^* = c_1^*(i^*)$. The equilibrium career concerns incentive, $k_2^* = k_2^*(i^*)$.

Proof. See Appendix. □

In the equilibrium, the IR constraint of Eq 4.5 is binding. As a result, according to Eq 4.2, the expected payment to the manager by the shareholders, $E[w_1^*]$, can be calculated as:

$$E[w_1^*] = \frac{\rho}{2} \text{Var}[w_1^*] + \frac{1}{2} e^{*2} + C_R^*, \quad (4.6)$$

where $C_R^* = \frac{\rho}{2h_a} \frac{i^{*2}/h_a}{\text{var}_y^*}$ is the equilibrium career risk.⁸

The expression of Eq 4.6 is similar to the equilibrium compensation payment in a standard principal-agent model without career concerns, which covers the manager's cost of effort and the risk from the explicit contract, with the addition of the manager's career risk. This suggests that the manager's disutility of his career risk must be compensated by the explicit contract. In other words, managerial career risk is a cost to the shareholders. Therefore, shareholders must take into accounting managerial career risk when making decisions to innovate. Balkin et al. (2000) find empirical evidence that for high-tech firms, CEOs' short-term compensation is positively related to innovation. My model may provide a possible explanation for this evidence. According to Lemma 7, with other things held equal, asking the manager to increase innovation induces the manager to bear higher career risks. The higher managerial career risk must be compensated with a higher payments from the shareholders.

It can be seen from Proposition 8 that the shareholders' equilibrium decisions depend on both the innovation urgency, m , and the manager's characteristics, ρ and

⁸Note that $E[w_2]$ is the ex-ante expected value of the manager's ability, which is normalized to 0.

h_a . With the manager's characteristics held equal, it can be verified that as m increases, the shareholders' equilibrium innovative investment, i^* increases while the optimal information quality h^* decreases. It is intuitive that the shareholders increase the magnitude of innovative investment as innovation becomes more urgent and profitable (m is larger). Larger innovation magnitude induces more exposure of the manager's ability in the labor market and thus increases the manager's career risk for which the shareholders must compensate. To mitigate the manager's career risk, the shareholders choose to reduce the information quality. Therefore, the shareholders' equilibrium information quality, h^* , decreases with m . The above results are presented in Corollary 3.

Corollary 3. *The innovative investment that maximizes the shareholders' expected payoff, i^* , increases with the innovation urgency; i.e., $\frac{\partial i^*}{\partial m} > 0$. The information quality that maximizes the shareholders' expected payoff, h^* , decreases with the innovation urgency; i.e., $\frac{\partial h^*}{\partial m} < 0$.*

Proof. See Appendix. □

Corollary 3 implies that firms with a higher level of innovative investment may choose a lower level of information quality. There are plenty of empirical evidence shows that the value relevance of financial statement has been deteriorating during the recent decades and the deterioration is associated with R&D investment (Lev and Zarowin, 1999; Chang, 1998; and Srivastava, 2013). R&D investments are usually believed to lower the informativeness of financial statements in two ways: first, the financial statements cannot reflect the economic consequences of innovations (Healy and Palepu, 2001); second, the outcomes of R&D investments are highly uncertain, resulting in high volatility in both incomes and cash flows (Srivastava, 2013). My results may provide an alternative explanation from the career concerns point of view. While implementing changes in the firm's business, the manager puts his own future career prospects at great risk and requires the shareholders to compensate for the career risk. Then, the shareholders may choose less stringent policies for preparing financial statements, which works to mitigate the manager's career risk. In a survey conducted by Graham et. al., (2005) most managers agree that they have a strong incentive to meet the earnings target due to reputation concerns rather than short-term compensation, suggesting that managers' career concerns have an important influence on financial reporting practices. My finding is also supported by Lev and Zarowin (1999), who find that firms undergoing considerable business changes have a significant decline in the informativeness of financial statements. My result provides implications for future empirical research on the interaction between innovative investment and disclosure policy regarding managers' career concerns.

4.3.2. Career concerns' effect on innovative investment

In the previous section, I examined the urgency of innovation's impact on shareholders' decisions regarding innovation investment and information quality. Besides the innovation urgency, shareholders' decisions also depend on characteristics of managers' career concerns, which cost the shareholders, and should be considered when making decisions about innovation and information quality. As shown in Lemma 7, shareholders can mitigate a manager's career risk in two ways: by reducing the information quality of the accounting signal, or by reducing the magnitude of innovation. However, both methods are costly to shareholders. A lower level of information quality induces a noisier performance measure, thereby making motivation of the managerial effort more costly. Reducing the magnitude of innovation directly reduces the profit of innovation, especially when an intense innovation urgency exists. The shareholders optimally determine the level of information quality and innovative investment to maximize the expected payoff given the manager's degree of career concerns. In the following sections, I will examine managers' career concerns' impact on shareholder choices of innovative investment and information quality.

I now analyze the effect of a manager's degree of career concern on the firm's optimal innovative investment. In the extreme case in which the manager's ability is perfectly observable ($h_a = \infty$), namely, when there are no career concerns, it is easy to see that the career risk is 0. In other words, the shareholders do not need to compensate the manager extra for his career risk. The shareholders will optimally choose perfect information to most efficiently motivate the manager's operating effort and innovative investment to maximize the innovation profit $i(m + a) - \frac{\epsilon}{2}i^2$. That is, the shareholders' optimal decisions on information quality and innovative investment are independent. For example, consider the case in which the manager's ability, a , is known as 0 for certain, which is the ex-ante expected ability in the model, then the optimal innovative investment for the shareholders is $i_0 = m/c$. Corollary 4 shows that in the presence of career concerns, the shareholders invest less in innovation compared with the case in which there are no career concerns, namely $i^* < i_0$.

Corollary 4. *Shareholders underinvest in innovation in the presence of career concerns, compared with the case in which a manager's ability is perfectly observable as 0; i.e., $i^* = \frac{h_a^2 m - (\sqrt{2}-1)\rho h_a}{h_a^2 c - (3-2\sqrt{2})\rho} < i_0 = m/c$.*

Proof. See Appendix. □

The intuition for Corollary 4 is as follows: In the event that the manager is uncertain about his ability (i.e., $h_a < \infty$), the manager's degree of career concern affects shareholders' innovation decisions. Innovation increases the variability of the revenue due to the manager's ability uncertainty and consequently induces higher volatility in the signal. A volatile signal provides a bad performance measure for contracting with the manager since volatility is unrelated to the managerial effort. As a result,

according to the standard principal-agent model, the manager's equilibrium effort decreases. Thus, the benefit of motivating the manager's effort decreases with innovation investment, i . Furthermore, as mentioned earlier in Lemma 7, the manager's career risk increases with innovative investment. Both effects of innovation are costly to the shareholders. As a result, due to the manager's career concerns, there is a downward distortion in the shareholders' decisions on innovative investment.

I next analyze the relationship between the degree of career concern and the shareholders' optimal innovative investment, represented in Proposition 9. Although the shareholders invest less when the manager has career concerns than when the manager has no career concerns, interestingly, it is not always the case that shareholders' innovation investment decreases with managerial career concerns.

Proposition 9. *Shareholders' optimal innovative investment increases (decreases) with the manager's degree of career concern, if m is large (small); i.e.,*

- $\frac{di^*}{d\rho/h_a} < 0$ if $m < \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}$,
- $\frac{di^*}{d\rho/h_a} > 0$ if $m > \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}$.

Proof. See Appendix. □

It is helpful to illustrate the above results through Fig. 4.2, which shows a numerical example ($c = 2$) of the relationship between the shareholders' equilibrium choice variables (i^* , h^*/h_a , and k_1^*) and the degree of career concern, $\frac{\rho}{h_a}$. Fig. 4.2 depicts three cases contingent on different levels of innovation urgency ($m = 1.2, 1.5, 2$). In each cases, the horizontal axis is the manager's degree of career concerns and the vertical axis is the shareholders' optimal choice variables, which are i^* , h^*/h_a , and k_1^* respectively. Fig. 4.2 shows that the relationship between the shareholders' optimal choice variables and the manager's degree of career concerns is non-monotonic, depending on the level of innovation urgency. A detailed analysis is provided as follows.

As the manager is more concerned about his future career prospects, either due to having higher risk aversion or increased uncertainty about his ability, the shareholders must compensate the manager more. As discussed in Lemma 7, the shareholders have two methods of mitigating the manager's career risk: lowering the innovative investment and lowering the information quality. Recalling Proposition 8, for a given level of i , the shareholders should optimally choose the information quality, h as $h^*(i)$. Therefore, we can first examine how the shareholders choose the optimal i as a response to managerial career concerns. According to Eq 4.4, when the shareholders invest i in innovation and optimally choose $h = h^*(i)$, the managerial career risk can be written as:

$$C_R^*(i) = \frac{\rho}{2h_a} i \cdot k_2^*(i), \quad (4.7)$$

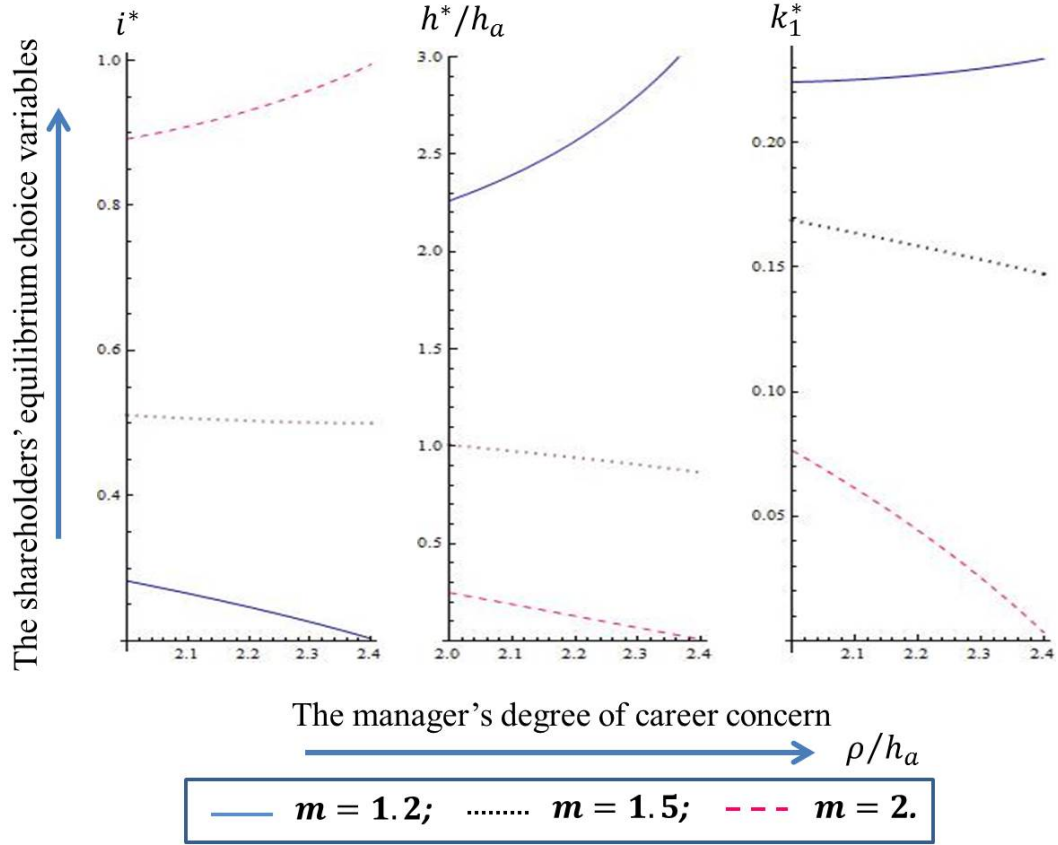


Figure 4.2.: The shareholders' equilibrium choice variables with respect to the manager's degree of career concern.

where $k_2^*(i) = \frac{\sqrt{2}}{2} - \frac{(2-\sqrt{2})}{2h_a}i$ ρ is the career concerns incentive as derived in Proposition 8.

From Eq 4.7, I derive the impact of the innovative investment on the manager's career risk as

$$\frac{dC_R^*(i)}{di} = \frac{1}{2} \frac{\rho}{h_a} (k_2^*(i) + i \frac{dk_2^*(i)}{di}) = \frac{1}{2} \frac{\rho}{h_a} (2k_2^*(i) - \frac{\sqrt{2}}{2}).$$

Because the manager's career risk is costly to the shareholders, $\frac{dC_R^*(i)}{di}$ could be thought of as the marginal cost of innovation for managerial career risk. As the manager's degree of career concern $\frac{\rho}{h_a}$ increases, the marginal cost of innovation changes by

$$\frac{d \frac{\partial C_R^*(i)}{\partial i}}{d \frac{\rho}{h_a}} = \frac{\partial \frac{dC_R^*(i)}{di}}{\partial \frac{\rho}{h_a}} + \frac{\partial \frac{dC_R^*(i)}{di}}{\partial k_2^*(i)} \frac{\partial k_2^*(i)}{\partial \frac{\rho}{h_a}} = (k_2^*(i) - \frac{\sqrt{2}}{4}) + (-\frac{2-\sqrt{2}}{2}i \frac{\rho}{h_a}). \quad (4.8)$$

The first term of Eq 4.8, $\frac{\partial \frac{dC_R^*(i)}{di}}{\partial \frac{\rho}{h_a}} (= k_2^*(i) - \frac{\sqrt{2}}{4})$, represents a direct effect of man-

agerial career concerns on the marginal cost of innovation for career risk. That is, all other things held equal, if the manager is more concerned about his future career path, the shareholders should compensate the manager additionally if they are asking him to innovate. This effect is especially severe when the career concerns incentive, $k_2^*(i)$, is large, which is the case when the information quality is high and innovation investment is small. Since this direct effect increases the cost of innovation, it provides the shareholder an incentive to to reduce i . However, the second term of Eq 4.8, $\frac{\partial \frac{dC_R^*(i)}{di}}{\partial k_2^*(i)} \frac{\partial k_2^*(i)}{\partial \frac{\rho}{h_a}} (= -\frac{2-\sqrt{2}}{2} i \frac{\rho}{h_a})$, suggests an indirect effect of managerial career concerns on the marginal cost of innovation for career risk: the increase of $\frac{\rho}{h_a}$ causes the shareholders to reduce the information quality, resulting in lower $k_2^*(i)$ ($\frac{\partial k_2^*(i)}{\partial \frac{\rho}{h_a}} < 0$). The decline in $k_2^*(i)$ protects the manager from exposure and hence dampens the marginal innovation cost for career risk. As a result, this indirect effect provides the shareholders an incentive to increase the innovative investment. The indirect effect is strong when the innovation investment level is high because intensive innovation largely exposes the manager's ability. As the manager becomes more concerned about his career path, the shareholders will dramatically reduce the information quality to protect the manager from career risk. Moreover, innovative business also generates a volatile signal, making motivating managerial effort costly, which also provides the shareholder an incentive to mitigate managerial career risk by reducing the information quality. As the manager's degree of career concern increases, the overall effect on the innovation investment is determined by which effect dominates. If the direct effect dominates, the cost of innovation becomes higher and the shareholders increase the innovative investment. If the indirect effect dominates, the cost of innovation declines, and the shareholder will increase the innovative investment.

The indirect effect dominates when the level of innovation urgency, m , is large, as shown in the case $m = 2$ in Fig. 4.2. In this case, innovation profit relatively outweighs the managerial effort in shareholders' expected payoff. The shareholders invest a lot in innovation. As career concerns become stronger, driven by either a higher degree of risk aversion or a larger ability uncertainty, the benefit of motivating the manager's operating effort declines. Because the innovative investment magnifies the revenue volatility that is attributable to the manager's ability uncertainty, the decline is exacerbated by the investment. In other words, the increase of career concerns dampens the tradeoff of reducing the information quality particularly when the innovative investment is high. Therefore, when the level of innovation urgency is high, as career concerns become stronger, the shareholders largely lower the information quality to mitigate the manager's career risk, and increase the innovative investment to most efficiently earn innovation profits.

Serfling (2012) finds that firms with younger CEOs invest more than firms with older CEOs and this evidence only prevails with respect to high-growth industries. Conventional wisdom interprets this evidence as older CEOs possibly being more conservative or having the horizon problem that they cannot benefit from a long-

term return of an investment. However, Serfling (2012) documents that older CEO compensation contains fewer stock options than younger CEO compensation, which implies that shareholders do not tend to encourage older CEOs to invest. My results explain this finding from the career concerns point of view. High growth is associated with high levels of innovative investment, which induce relatively volatile revenue. There is large ability uncertainty among young managers, which magnifies revenue volatility. This volatility impedes motivating the manager's effort and shifts shareholders' focus toward innovation. As a result, the shareholders will increase innovative investment and choose a lower level of information quality to protect managers from career risk. In contrast, an older manager's ability is well known and therefore the revenue is not as volatile. Thus, the shareholders have comparably intense incentives of motivating the manager's operating effort and obtaining innovation profit—in other words, the shareholders will not overemphasize innovation or effort. Therefore, the shareholders who hire a more experienced manager choose a lower level of innovative investment and a higher level of information quality than those who hire a less experienced manager. The above analysis suggests that the underinvestment of older CEOs in a high growth firm may actually work in shareholders' favor.

In contrast to the case with a large m , when the level of innovation urgency is not extremely intense, the direct effect dominates. In this case, the shareholders invest little in innovation and focus on motivating the manager's effort by choosing a high level of information quality. On the one hand, with low innovative investment, the firm's business is relatively safe and revenue is less volatile, which makes motivating the manager's effort is then efficient. On the other hand, due to the high level of information quality, the labor market pays particular attention to the accounting signal when evaluating the manager's ability. As a result, innovative investment expose the manager largely in the labor market and thus is very costly to the shareholders. Therefore, as the degree of career concerns increases, the shareholders dramatically reduce innovative investment to mitigate the managerial career risk and their focus shifts further toward motivating the operating effort. Many empirical findings suggest firms with managers that have large career concerns invest less. For example, Pan et al. (2013) empirically find that firms with early-tenure CEOs tend to disinvest and increase investment subsequently. Likewise, Barker and Mueller (2002) find that firms with more experienced CEOs in output functions (functions that emphasize growth through discovering new products and markets, such as marketing/sales and engineering/R&D) spend more on R&D. My results suggest that this evidence may present only in firms that are not engaged in intensive innovations.

4.3.3. Career concerns' effect on compensation incentive

I next examine how the degree of career concern affects the explicit incentive k_1^* . The relationship between CEO pay-performance-sensitivities (PPS) and CEO characteristics related to career concerns has been extensively studied. Previous studies

suggest that as a manager's tenure increases, his ability uncertainty decreases, and his career concerns incentive decreases. Consequently, shareholders increase the explicit incentive to motivate the manager's effort (namely the substitution effect). In other words, for managers with a shorter tenure or who have less experience, the career concerns incentive is relatively strong, which leads to a lower level of explicit incentive. However, I find the substitution effect does not always exist when the innovative investment decision is considered. To see this, consider the equilibrium explicit incentive, k_1^* , and career concerns incentive, k_2^* , characterized in Proposition 8:

$$k_2^* = \frac{\sqrt{2}}{2} - \frac{(2 - \sqrt{2})}{2} i^* \frac{\rho}{h_a}, \quad (4.9)$$

$$k_1^* = 1 - \frac{\sqrt{2}}{2} - (3\sqrt{2}/2 - 2) i^* \frac{\rho}{h_a}. \quad (4.10)$$

In previous studies such as Gibbons and Murphy (1992), the career concerns incentive, k_2 , depends only on the manager's characteristics represented by ρ and h_a . However, in my model, the shareholders are able to set the information quality and innovative investment in response to the manager's career concerns, both of which affect the career concerns incentive. In contrast to previous studies, I find the career concerns incentive and the explicit contract incentive to be positively correlated. This is because in my model, the shareholders are able to determine the career concerns incentive through endogenous decisions on the information quality and innovative investment. Shareholders optimally choose both the career concerns incentive and the explicit contract incentive to maximize their payoff. The shareholders pay the manager according to the explicit contract on Date 1 and the labor market pays the manager on Date 2. Since the manager cannot hedge between Date 1 and Date 2, the shareholders should optimally set the two incentives, response to the manager's career concerns in the same direction. Otherwise, if the two incentives have different movement directions with respect to career concerns, the incentives offset each other while monitoring the manager, and the managerial effort cannot be efficiently motivated.

In addition, I find that in the case of small innovation urgency, the shareholders' optimal explicit compensation incentive increases with managerial career concerns, suggesting that the substitution effect may not always hold. According to Proposition 9, when the innovation urgency is small, the shareholders reduce the innovative investment in response to an increase in managerial career concerns. The decline in innovative investment leads to a safer business and the performance measure becomes less volatile. Motivating the manager's effort then becomes more efficient. As a result, the shareholders increase the compensation incentive because their focus shifts further toward motivating the operating effort (as shown in the case of $m = 1.2$ in Fig. 4.2). The above results are summarized in Proposition 10.

Proposition 10. *In the equilibrium, the shareholders' optimal explicit incentive increases (decreases) with the manager's degree of career concern if the level of innovation urgency is small (large); i.e.,*

- $\frac{dk_1^*}{d\rho/h_a} < 0$ if $m > \frac{(6-4\sqrt{2})c\rho/h_a}{(5\sqrt{2}-7)(\rho/h_a)^2+(\sqrt{2}-1)c}$,
- $\frac{dk_1^*}{d\rho/h_a} > 0$ if $m < \frac{(6-4\sqrt{2})c\rho/h_a}{(5\sqrt{2}-7)(\rho/h_a)^2+(\sqrt{2}-1)c}$.

Proof. See Appendix. □

Proposition 10 identifies the link between PPS and career concerns through innovative investment. It suggests that career concerns impact PPS non-monotonically depending on the level of innovation urgency m . For firms with low levels of innovation urgency such as monopoly firms, the above results predict a positive relationship between managers' career concerns and PPS. The prediction may sound unexpected by suggesting that more risk-averse managers are offered higher PPS. This is because when shareholders hire a manager that is highly concerned about his career risk, the shareholders will ask the manager to implement less innovative business. The revenue is then less volatile and the performance measure is accurate. Therefore, the shareholders choose higher PPS because it is very efficient in motivating the manager's effort. However, for firms with large R&D spending such as, high-tech firms, the above results predict a negative relationship between the manager's career concerns and PPS. The reason is that as the manager's career concerns become stronger, the shareholders dramatically reduce the information quality to mitigate the managerial career risk and consequently choose a lower level of PPS since the performance measure becomes noisy. In fact, the level of innovation urgency varies among industries. Proposition 10 suggests that we should examine the relationship between managers' career concerns and PPS in cross-industry studies.

4.3.4. Shareholders and managers' matching equilibrium

So far, I have assumed that a manager is assigned to a firm at Date 0. The manager and the shareholders were assumed to be exogenously matched. In this section, I relax this assumption by considering a setup in which managers are heterogeneous in their degree of career concerns and the innovation urgency varies among firms. For instance, experienced managers could be considered less concerned about career risk because their ability is already well known from their career history. In contrast, the labor market is highly uncertain about the ability of rookie managers, which makes their career concerns very strong. Successful firms in mature industries, such as water and energy distribution industries, may have less incentive to innovate. Those in distress, facing fierce competition or in innovative industries such as high-tech, may have intense urgency to innovate in order to maintain a competitive advantage. According to my previous results, managerial career concerns

affect shareholder decisions on innovation and information quality as well as on compensation design. Therefore, in a market that consists of heterogeneous managers, shareholders should first select a manager before innovating. All shareholders prefer managers with a lower degree of career concerns, since managerial career concerns are costly. As a result, shareholders compete to hire experienced managers, and competition increases their compensation. Finally, experienced managers will be hired by the shareholders who value them most, i.e., those who are willing to offer them the highest compensation.

Consider a market that consists of N firms indexed by j and N managers indexed by k ($j, k \in \{1, 2, \dots, N\}$). Each firm j is endowed with a level of innovation urgency, m_j , while each manager k has a degree of career concerns, d_k , where $d_k \equiv \rho_k/h_a^k$. As before, m_j and d_k are public information. I still assume managers have the same expected ability ex-ante, which is normalized to 0. However, uncertainty about their ability, $1/h_a^k$, or the degree of risk aversion, ρ_k , may be different among managers. This captures the fact that managers are different in tenure or experience.

At Date 0, firms and managers match each other one-to-one: each firm hires only one manager and each manager can only work for one firm. Denote $X = [x_{j,k}]_{N \times N}$ as a matching pattern, in which $x_{j,k} \in \{0, 1\}$. If firm j hires manager k , $x_{j,k} = 1$; otherwise, $x_{j,k} = 0$. Given a matching pair (j, k) , shareholders of firm j set a level of information quality, $h_{j,k}$, commit to invest $i_{j,k}$ in innovation, and offer a linear contract $w_1^{j,k}(y) = k_1^{j,k} \cdot y + c_1^{j,k}$ to hire manager k . Because the information quality and the investment in innovation are determined before the manager accepts the contract, these two decisions could be thought of as part of the contract. In other words, the contract signed between shareholders of firm j and manager k could be denoted as $C_{j,k} = \{h_{j,k}, i_{j,k}, k_1^{j,k}, c_1^{j,k}\}$. Obviously, shareholders should optimally make decisions on $C_{j,k}$ to maximize the expected profit, which is the firm's revenue minus the shareholder's cost of innovation and the manager's cost of effort and risk. According to the equilibrium strategy as shown in Proposition 8, shareholders should make the following optimal decisions: $h_{j,k} = h^*$, $i_{j,k} = i^*$, and $k_1^{j,k} = k_1^*$, with $m = m_j$ and $\rho/h_a = d_k$. Denote the maximum value of the expected profit as $\Pi_{j,k}$. $\Pi_{j,k}$ can be calculated as:⁹

$$\Pi_{j,k} = \frac{c + m_j[m_j - 2(\sqrt{2} - 1)d_k]}{2[c - (3 - 2\sqrt{2})d_k^2]}. \quad (4.11)$$

The constant part of the compensation contract, $c_1^{j,k}$, does not affect the profit $\Pi_{j,k}$. This is because $c_1^{j,k}$ is not sensitive to managerial performance and cannot impact managerial effort. $c_1^{j,k}$ is offered so that the manager accepts the contract. With the

⁹In a setup in which the manager is exogenously assigned to a firm, in the equilibrium, the manager is breaking even at his reservation utility zero, and the shareholders enjoy all the profit. Therefore, $\Pi_{j,k}$ equals the maximum value of shareholders' expected payoff as shown in Eq 4.5.

assumption of an exogenous manager assignment, as discussed in previous sections, the manager breaks even. The shareholders optimally choose $c_1 = c_1^*$, as derived in Proposition 8, so that the manager's expected utility equals his reservation utility. However, when shareholders can endogenously select a manager, as mentioned earlier, shareholders will compete to hire experienced managers. In other words, managers may obtain more than the reservation utility, i.e., $c_1^{j,k} \geq c_1^*$. We can decompose $c_1^{j,k}$ into two parts, c_1^* and $b_{j,k}$, such that

$$c_1^{j,k} = c_1^* + b_{j,k},$$

where $b_{j,k} \geq 0$ represents the rent that manager k obtains due to shareholder competition.

Denote $\Pi_{j,k}^j$ as shareholders j 's expected payoff of hiring manager k with contract $C_{j,k}$. If the manager is assigned exogenously, the shareholders enjoy all the expected profit $\Pi_{j,k}$, and the manager breaks even at his reservation utility zero. However, when shareholders endogenously select a manager, since the manager obtains a rent $b_{j,k}$, they expect a payoff of:

$$\Pi_{j,k}^j = \Pi_{j,k} - b_{j,k}.$$

On Date 0, shareholders offer contracts to managers. I assume a contract is adjustable before managers sign it so that I can focus on the matching equilibrium. A matching equilibrium consists of a matching pattern $X = [x_{j,k}]_{N \times N}$ and a set of contracts $C = \{C_{j,k}\}$, which is defined as the following:¹⁰

Definition 4.1 A matching pattern $X^* = [x_{j,k}^*]_{N \times N}$ and a set of contracts $C^* = \{C_{j,k}^*\}$, where j, k satisfies $x_{j,k} = 1$, form a matching equilibrium such that:

1. Each manager optimally chooses his managerial effort given the contract set C .
2. Shareholders and managers receive no less than their reservation utilities, which are normalized to zero.
3. For any two matching pairs (j, k) and (j', k') such that $x_{j,k}^* = 1$ and $x_{j',k'}^* = 1$, firm j cannot offer a contract $\tilde{C}_{j,k'}$ to hire manager k' and makes both j and k' better off; i.e., there does not exist $\tilde{C}_{j,k'}$ such that $\Pi_{j,k'}^j(\tilde{C}_{j,k'}) > \Pi_{j,k}^j(C_{j,k}^*)$, and $b_{j,k'}(\tilde{C}_{j,k'}) > b_{j',k'}(C_{j',k'}^*)$.
4. For any matching pair (j, k) such that $x_{j,k}^* = 1$, firm j cannot be better off by offering manager k another contract $\tilde{C}_{j,k}$; i.e., there does not exist $\tilde{C}_{j,k}$ such that $\Pi_{j,k}^j(\tilde{C}_{j,k}) > \Pi_{j,k}^j(C_{j,k}^*)$.

¹⁰The matching equilibrium in this study is the principal-agent market equilibrium in Serfes (2007), who provided detailed discussions about the matching equilibrium.

The first condition in Definition 4.1 indicates that in the equilibrium, managers' IC constraint is satisfied, while the second condition indicates that the IR constraints for both shareholders and managers are satisfied. Under the third condition, no shareholder could hire a different manager with a different contract and benefit either party. In this sense, the matching pattern X^* is stable. The fourth condition suggests that shareholders are maximizing their payoffs by offering the manager the lowest amount the matching pattern X^* can sustain.

Serfes (2007) shows that the equilibrium matching pattern X^* is an optimal assignment between shareholders and managers such that the total expected profit, $\sum_{k=1}^N \sum_{j=1}^N \Pi_{j,k} \cdot x_{j,k}$, is maximized at $X = X^*$. According to the assignment game in Shapley and Shubik (1972), I can derive the equilibrium matching pattern $X = [x_{j,k}^*]$ by solving the following linear programming problem:

$$\begin{aligned}
& \underset{\{x_{j,k}\}}{\text{Max}} && \sum_{k=1}^N \sum_{j=1}^N \Pi_{j,k} \cdot x_{j,k}, \\
& \text{s.t.} && \\
& && \sum_{j=1}^N x_{j,k} \leq 1; \\
& && \sum_{k=1}^N x_{j,k} \leq 1; \\
& && x_{j,k} \geq 0.
\end{aligned} \tag{4.12}$$

It is a standard result (as shown in Roth and Sotomayour, 1990) that there exists a solution $[x_{j,k}^*]$ to the above linear programming problem with $x_{j,k}^* = 0$ or 1 for all j and k . After deriving the equilibrium matching pattern $X^* = [x_{j,k}^*]$, we then solve for the equilibrium contract C^* . As discussed earlier, the shareholders should optimally choose the information quality, the innovative investment, and the compensation incentive, $\{h_{j,k}, i_{j,k}, k_1^{j,k}\}$ according to the equilibrium decisions derived in Proposition 8. We then only need to solve for the set of equilibrium managerial rents $\{b_{j,k}\}$ with j, k satisfying $x_{j,k} = 1$, such that X^* is sustainable with $\{b_{j,k}\}$. According to X^* , each manager j is assigned to exactly one firm k . Therefore, I simply denote $b_{j,k}$ as b_k . Similarly, I denote firm j 's expected payoff $\Pi_{j,k}^j$ as Π^j , namely $\Pi^j = \Pi_{j,k} - b_k$. There may be multiple sets of $\{b_k\}$ that sustain X^* . I assume that shareholders have strong bargaining power and then I focus on the minimum price matching equilibrium contract, $\{b_k^*\}$, that sustains X^* with the minimum total payment to the managers. It is an established result that $\{b_k^*\}$ could be obtained by solving the following linear function (e.g. Serfes, 2007):

$$\begin{aligned}
 & \underset{\{b_k\}}{\text{Min}} && \sum_{k=1}^N b_k && (4.13) \\
 & \text{s.t.} && && \\
 & && \Pi^j + b_k \geq \Pi_{j,k}; \\
 & && \Pi^j, b_k \geq 0.
 \end{aligned}$$

By solving Linear Programming problems 4.12 and 4.13, we can derive the shareholders and managers matching equilibrium (X^*, C^*) with the minimum total payment to managers. I use a numerical example to illustrate the matching game. For example, I assume $N = 9$ (the number of players is not crucial.) Moreover, I set $c = 2$, and assume $\{m_j\}$ evenly distributed between 1.2 and 2.4, and $\{d_k\}$ evenly distributed between 2 and 2.4, where $j, k = 1, 2, \dots, 9$.

By solving the linear programming problem 4.12, I can show the equilibrium matching pattern in Fig. 4.3. The horizontal axis in Fig. 4.3 represents the shareholders' innovation urgency, m_j , and the vertical axis represents the manager's degree of career concerns, d_k . The dot with coordinate (m_j, d_k) means that the shareholders with urgency m_j hire the manager k in the equilibrium matching pattern, namely $x_{j,k}^* = 1$.

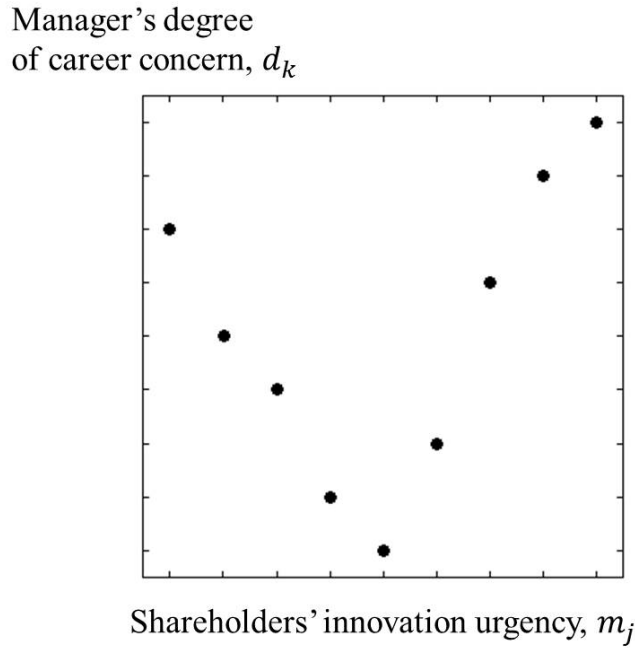


Figure 4.3.: The equilibrium matching pattern X^* .

By solving the linear programming problem 4.13, we can obtain the minimum equilibrium managerial rent, $\{b_k^*\}$, which is shown in Tab. 4.1.

(j, k)	(5, 1)	(4, 2)	(6, 3)	(3, 4)	(2, 5)	(7, 6)	(1, 7)	(8, 8)	(9, 9)
b_k^*	0.038	0.032	0.026	0.020	0.015	0.010	0.006	0.002	0

Table 4.1.: The minimum equilibrium managerial rent $\{b_k^*\}$.

It can be seen from Tab. 4.1 that in the equilibrium, the manager's rent b_k^* decreases with his degree of career concerns, d_k , because all shareholders prefer managers with lower degrees of career concerns, such as experienced managers. As a result, shareholders compete in hiring experienced managers. The more experienced the manager, the stronger the competition among shareholders and the more rent the manager can obtain. In contrast, managers who are highly concerned about career risk, such as rookie managers, are in low demand because their career concerns are costly to shareholders. As a result, these managers can only earn small rents beyond their reservation utility. The manager with the highest degree of career concerns obtains a rent of zero; that is, he only breaks even at his reservation utility.

From Fig. 4.3 we can also see that in the equilibrium, the managers with the lowest career concerns, such as the most experienced managers, are hired by firms with intermediate levels of innovation urgency. Managers are hired by shareholders who value them most, because these shareholders are willing to pay a high rent. The “value” of a manager to the shareholders is the sensitivity of the shareholders' expected payoff with respect to the manager's degree of career concerns; i.e. $-\frac{d\pi_s^*(m, \frac{\rho}{h_a})}{d\rho/h_a}$, where $\pi_s^*(m, \frac{\rho}{h_a})$ is the value of Eq 4.5 in the equilibrium.¹¹ If the shareholders' expected payoff is very sensitive to the manager's degree of career concerns, then hiring an experienced manager can make a larger difference to the shareholders than hiring a less experienced manager. As a result, the shareholders are more willing to offer high salaries to experienced managers. In contrast, if the shareholders' expected payoff is less sensitive to the manager's degree of career concerns, they do not need to hire an experienced manager who requires a high compensation.

It can be verified that the term $-\frac{d\pi_s^*(m, \frac{\rho}{h_a})}{d\rho/h_a}$ has an inverse U-shape relationship with respect to the level of innovation urgency m , and that is stated formally in the Proposition 11 below. Fig. 4.4 shows a numerical example of the relationship between $-\frac{d\pi_s^*}{d\rho/h_a}$ and the level of innovation urgency, m , by setting $c = 2$ and $\rho/h_a = 2$. One way to understand Fig. 4.4 is to consider the extreme cases in which the level of innovation urgency is very low or very high. For firms with an extremely low level of innovation urgency, the innovative investment is low, which barely exposes the manager's ability through the accounting signal. As a result, managerial career concerns have little impact on shareholder payoff. As previously shown in the case $m = 1.2$ in Fig. 4.2, in which the degree of career concern increases, the shareholders choose a higher level of information quality to motivate higher effort, and decrease

¹¹Since $\pi_s^*(m, \frac{\rho}{h_a})$ decreases with ρ/h_a , I use $-\frac{d\pi_s^*(m, \frac{\rho}{h_a})}{d\rho/h_a}$ instead of $\frac{d\pi_s^*(m, \frac{\rho}{h_a})}{d\rho/h_a}$ to measure the magnitude of sensitivity.

the innovative investment at the same time. The shareholders are worse off by the innovation decline yet are compensated somehow through the manager's higher effort. As a result, the shareholders' expected payoff does not decrease as much as the case wherein the manager's degree of career concerns increases. In the opposite case, wherein the level of innovation urgency is extremely high, as shown in the case of $m = 2$ in Fig. 4.2, in which the degree of career concern increases, the shareholders focus more on innovation and choose a lower level of information quality to mitigate the manager's career risk. The lower information quality mitigates the managerial career risk, and the incremental innovation profit partially offsets the damage from larger managerial career concerns. As a result, the shareholders' overall expected payoff does not decline significantly. Therefore, in both extreme cases, the shareholders' expected payoff is not very sensitive to the manager's degree of career concerns.

Unlike the extreme cases for intermediate values of m , there is a strong tension between motivating the manager's effort and obtaining innovation profit. As shown in the case of $m = 1.5$ in Fig. 4.2, when the manager's degree of career concern increases, the shareholders are not able to rely on either method to mitigate the career risk. Instead, they have to decrease both the information quality and the innovative investment. As a result, shareholders incur losses from both the lower effort and innovation profit. In this case, the shareholder's expected payoff is very sensitive to managerial career concerns and hiring a manager with less career concerns largely improves the shareholders' expected payoff. Proposition 11 presents the above results.

Proposition 11. *The shareholders' marginal benefit of reducing the degree of career concerns $-\frac{d\pi_s^*}{d\rho/h_a}$ has an inverse U-shaped relationship with the expected level of innovation urgency:*

$$-\frac{d\pi_s^*}{d\rho/h_a} \text{ increases with } m \text{ if } m < \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a} \text{ and decreases with } m \text{ if } m > \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}.$$

Proof. See Appendix. □

Proposition 11 together with Fig. 4.3 provide various implications for empirical studies about the relationship between managers' characteristics regarding career concerns and firms' innovation decisions. The figure shows when compared with their peers with intermediate levels of innovation urgency, shareholders with extreme values of innovation urgency have payoffs that are less sensitive to managers' career concerns. The reason is that these shareholders protect the manager from career risk by either implementing relatively safe business practices (for shareholders with low levels of innovation urgency), or disclosing less information (for shareholders with high levels of innovation urgency). However, in firms with intermediate levels of innovation urgency, stronger career concerns result in both lower innovation investment and managerial productive effort. As a result, managers' career concerns are

The sensitivity of
shareholder expected
payoff to managerial
career concerns, $-\frac{d\pi_s^*}{d\rho/h_a}$

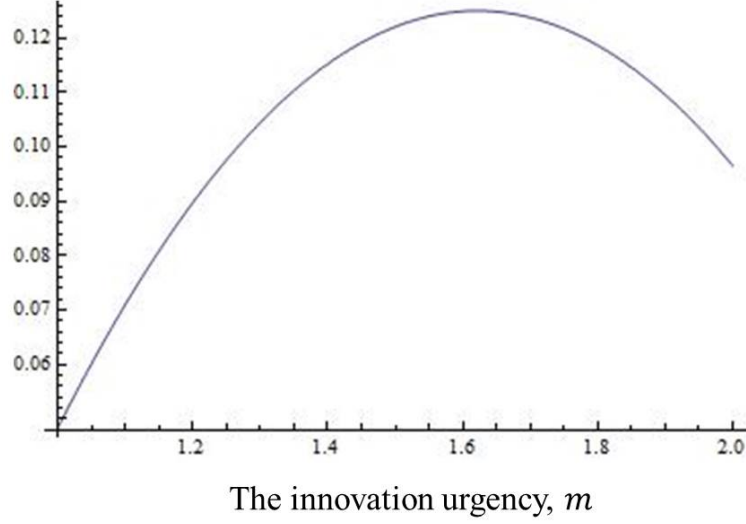


Figure 4.4.: The sensitivity of shareholder expected payoff to managerial career concerns as a function of m .

most detrimental to shareholders. In other words, these shareholders are the ones that most favor hiring an experienced manager that has a less uncertain ability and is less concerned about exposure to the labor market. Overall, my results predicts that experienced managers are hired by middle-of-the-road innovation firms.

4.3.5. What if a regulator mandates a high level of information quality?

Throughout the study, I assume that the shareholders are able to choose both the information quality and the innovative investment. However, it would be interesting to examine the case in which a regulator determines the information quality, and to study how shareholders choose the innovative investment as a response. Due to the complexity of the model, the shareholders' optimal level of innovative investment for a given level of information quality $i^*(h)$ cannot be solved in the closed-form. However, I find that the shareholders will reduce the innovative investment when a regulator enforces a level of information quality above the shareholders' optimal level, which is summarized in Proposition 12.

Proposition 12. *An improvement in the information quality from the optimal level*

for the shareholders would induce the shareholders to decrease innovative investment; i.e., $\frac{\partial \pi_s(k_1^*, c_1^*, h, i)}{\partial h} < 0$ for $i = i^*$ and $h = h^*$.

The intuition of Proposition 12 is as follows: after mandating a higher level of information quality, the signal is more informative about the manager's ability, inducing higher managerial career risk. The manager's larger exposure in the labor market requires to be compensated by the shareholders. In other words, the cost of innovation for managerial career risk increases. The shareholders should reduce the innovative investment as a response.

Proposition 12 echoes concerns by regulators and academics that the implementation of SOX may induce a decline in firms' R&D investments. SOX mandates internal control disclosures and improves transparency by increasing disclosure requirements. There is plenty of empirical evidence showing that firms' R&D investments declined dramatically since SOX was enacted (Bargeron et.al., 2009; Cohen et.al., 2013). This phenomenon is interpreted as that SOX incurs an extra reporting cost to the firm for R&D practices, resulting in less R&D investment. For example, the Biotechnology Industry Organization sent a letter to the SEC, commenting on SOX's Section 404 rules: "Many emerging biotech companies are directing precious resources away from core research and development of new therapies for patients due to overly complex controls or unnecessary evaluation of controls" (Lehn, 2008). My results provide a possible explanation for this evidence regarding the manager's career concerns. After the implementation of SOX, firms disclosure is more informative, which helps the labor market form a more accurate perception about managerial ability. The mandated high information quality leads to a higher career risk for the manager. To mitigate the manager's career risk, the shareholders consequently decrease the innovative investment.

4.4. Conclusions

This study examines shareholders joint decisions on the information quality and innovative investment in the presence of managers' career concerns. Innovation initiatives are instructed by shareholders with the objective to transform the firm and increase its competitiveness. However, this kind of investments expose the manager's ability conspicuously to the labor market. This exposure increases the manager's career risk, which must be compensated through an explicit contract. In other words, innovation generates managerial career risk, which is a cost to shareholders.

I identify two methods by which shareholders can mitigate managerial career risk: lowering reporting information quality and reducing innovative investment. Nevertheless, lowering information quality makes motivating managerial operating effort more difficult. Therefore, shareholders face a tradeoff between mitigating the manager career-risk and motivating the managerial effort. The relative value of innovation and the managerial effort for shareholders is mainly contingent on the level of

innovation urgency. I find that the impact of the manager's degree of career concerns on shareholders decisions on innovative investment, information quality and explicit incentives is non-monotonically contingent on the level of innovation urgency.

When the level of innovation urgency is high, shareholders focus more on innovation and reduce information quality to mitigate the manager's career risk. As a result, the information quality declines dramatically when the manager degree of career concerns increases. A lower information quality protects the manager in the labor market, and induces shareholders to increase innovative investment. Therefore, the shareholders increase innovative investment as the degree of career concern increases.

When the level of innovation urgency is low, as the manager's degree of career concern increases, shareholders rely on reducing innovative investment to mitigate the manager's career risk. As the innovative investment declines, the firm outcome becomes less volatile, and that allows shareholders to choose a higher explicit incentive to motivate the manager's operating effort.

For intermediate levels of innovation urgency, shareholders have to reduce both information quality and innovative investment in response to an increase in the manager's career concerns, which leads to both lower innovation profit and lower productive effort. Therefore, firms with intermediate levels of innovation urgency favor experienced managers (i.e. managers with lower career concerns) most.

This study contributes to the extant literature that examines the interaction between managers' career concerns and shareholders' investment decisions regarding innovation. My results indicate that the relationship between managers' career concerns and firms' investment and compensation decisions depend non-monotonically on the level of innovation urgency. When we examine the impact of career concerns on firms' decisions on investment, managerial incentives and manager selection, we need to consider the firms' innovation urgency. Because the level of innovation urgency may also varies among industries, my results shed light on cross-industry studies on the impact of career concerns on firms' aforementioned decisions.

A. Appendix

A.1. Appendix to Chapter 2

Appendix A.1.1: Bertrand Competition model

We now study a Bertrand competition market in which the firm's successful exploration reduces its production cost. The payoff functions of firms A and B are, respectively:

$$\begin{aligned}\Pi_A &= [p_A - (c - a_A)](1 - p_A + p_B) - k_1^A - k_2^A t_A, \\ \Pi_B &= [p_B - (c - a_B)](1 - p_B + p_A) - k_1^B t_B,\end{aligned}$$

where a_i is firm i 's production-cost reduction obtained through successful exploration; p_i is firm i 's price decision; c is the initial production cost for both firms without any successful explorations; and $1 - p_i + p_j$ represents firm i 's market demand for $i \in \{A, B\}$.

Taking the first-order condition of Π_i with respect to p_i , we can solve the Bertrand model and obtain firm i 's optimal price $p_i^* = c + 1 - \frac{2a_i}{3} - \frac{a_j}{3}$, and gross payoff without considering the investment/exploration cost,

$$W_i(a_i, a_j) = [p_i^* - (c - a_i)](1 - p_i^* + p_j^*) = \frac{(3+a_i-a_j)^2}{9}.$$

As in the main setting, we make some assumptions about several parameters to exclude uninteresting cases. We assume that A's exploration cost cannot be extremely large, such that when the successful-efforts regime is enforced, firm A as a large firm invests in at least one area. We assume that B's exploration cost is not very large as well, such that when A uses the full-cost method and invests in two areas, B will invest. To be more specific, we assume $k_1^A < \bar{K}_A$ and $k_1^B < \bar{K}_B$, where $\bar{K}_A = \frac{1}{9}ah\{(1-\gamma)^2 - h\} + 6(1+h-\gamma)\}$ and $\bar{K}_B = \frac{1}{9}ah(6+a-ah)$. We also assume that γ is not very small ($\gamma > \underline{\gamma}'$, where $\underline{\gamma}' = 2 - \frac{3-\sqrt{(3-2a)^2+(6-a)ah}}{a}$), such that firm B has an incentive to follow A's investment in the equilibrium.

With similar methodology as in the main setting, we can solve B's optimal investment decision upon A's report. The results are almost the same as in Lemmas 1 and 2, except for the close forms of regions that delimit B's strategies:

Region I is $k_1^B < \min\{\bar{K}_B, K_1'(\gamma)\}$ and $\gamma_1' < \gamma < 1$;

Region II is $k_1^B < \frac{(6-a)ah}{9}$ and $\underline{\gamma}' < \gamma < \gamma'_1$;

Region III is $Max\{\frac{(6-a)ah}{9}, K'_1(\gamma)\} < k_1^B < Min\{\bar{K}_B, K'_2(\gamma)\}$;

Region IV is $K'_2(\gamma) < k_1^B < \bar{K}$ and $\underline{\gamma}' < \gamma < 1$, with $K'_1(\gamma) = \frac{a\gamma[6-a(2-\gamma)]}{18}$, $\gamma'_1 = \frac{a-3+\sqrt{(3-a)^2+2ah(6-a)}}{a}$, and $K'_2(\gamma) = \frac{a[6-(4-\gamma)]}{9}$.

Firm B's optimal strategies when firm A reports using the successful-efforts method are summarized in the following table:

	$D = (1, 0)$ or $(2, 0)$	$D = (1, 1)$	$D = (2, 1)$	$D = (2, 2)$
Region I	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = s$	$I_B^*(D) = s$
Region II	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = d$	$I_B^*(D) = s$
Region III	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = 0$	$I_B^*(D) = s$
Region IV	$I_B^*(D) = d$	$I_B^*(D) = s$	$I_B^*(D) = 0$	$I_B^*(D) = 0$

Firm B optimally invests in a different area if A uses the full-cost method.

Given B's optimal investment strategy upon A's report, we could derive A's optimal accounting-reporting method choice and exploration investment. We obtain similar results as that in the main setting. Specifically, in the equilibrium,

(i) in Region I and Region II, firm A chooses to report under the full-cost method and firm B always explores a different area. Firm A explores one area if $k_1^A > K'_A(\gamma, k_1^B)$ and explores two areas if $k_1^A < K'_A(\gamma, k_1^B)$;

(ii) in Region III, firm A chooses to invest in one area using the full-cost method if $k_1^A > K'_A(\gamma, k_1^B)$, and invests in two areas using the successful-efforts method if $k_1^A < K'_A(\gamma, k_1^B)$. B invests in a different area if A reports no success or chooses the full-cost method, invests in a same area if A reports full success, and does not invest at all if A reports partial success;

(iii) in Region IV, firm A chooses to invest in one area using the full-cost method if $k_1^A > K'_A(\gamma, k_1^B)$, and invests in two areas using the successful-efforts method if $k_1^A < K'_A(\gamma, k_1^B)$. B invests in a different area if A reports no success or chooses the full-cost method, in a same area if A reports success in its only investment, and does not invest at all if A reports any success out of two investments.

$$K'_A(\gamma, k_1^B) = \begin{cases} ah(6+a)/9, & \text{Region I, II} \\ ah\{6+12h-6h(h+\gamma) \\ +a[1+h(2+h-\gamma(4-\gamma))]\}/9, & \text{Region III} \\ ah[6+6h(2-h)+a(1+h)^2]/9. & \text{Region IV} \end{cases}$$

Then we analyze A's optimal investment strategy when the successful-efforts method is enforced. In this case, A invests in two areas if $k_1^A < K_A^{SE'}(\gamma, k_1^B)$ and

invests in one area if $k_1^A > K_A^{SE'}(\gamma, k_1^B)$, where

$$K_A^{SE'}(\gamma, k_1^B) = \begin{cases} ah[6 + 6h(1 - h) + a(1 + h + h^2 - 2h\gamma)]/9, & \text{Region I} \\ ah\{6[1 + \gamma + h^2 - h(1 + \gamma)] \\ + a[1 + 3h^2 + \gamma(2 - \gamma) - h(1 + \gamma(4 - \gamma))]\}, & \text{Region II} \\ ah\{6[1 + (1 - h)(h + \gamma)] \\ + a[1 + h + h^2 + \gamma(2 - 4h) - \gamma^2(1 - h)]\}/9, & \text{Region III} \\ ah\{6(1 + h + \gamma - h^2) \\ + a[1 + h + h^2 + \gamma(2 - \gamma)]\}/9. & \text{Region IV} \end{cases}$$

We can prove that $K_A'(\gamma, k_1^B) < K_A^{SE'}(\gamma, k_1^B)$. Therefore, for firms with $K_A'(\gamma, k_1^B) < k_1^A < K_A^{SE'}(\gamma, k_1^B)$, enforcing the successful-efforts method induces them to increase exploration investment; for firms with $k_1^A < K_A'(\gamma, k_1^B)$ or $k_1^A > K_A^{SE'}(\gamma, k_1^B)$, their exploration investment does not change after the enforcement of the successful-efforts method.

When the full-cost method is enforced, firm A invests in two areas if $k_1^A < K_A^{FC'} = ah(6 + a)/9$, and in one area otherwise. We can prove that $K_A'(\gamma, k_1^B) \geq K_A^{FC'}$. Therefore, for firms with $K_A^{FC'} < k_1^A < K_A'(\gamma, k_1^B)$, enforcing the full-cost method induces them to decrease exploration investment; for firms with $k_1^A > K_A'(\gamma, k_1^B)$ or $k_1^A < K_A^{FC'}$, their exploration investment does not change after the enforcement of the full-cost method.

In summary, in the Bertrand competition model, the result is the same as that in the Cournot market.

Appendix A.1.2: Firm A Invests in up to One Area and Firm B Invests in up to Two Areas

In the main setting of our paper, we examine the innovator-imitator game assuming that A can invest in up to two areas while B can invest in up to one area. For completeness, we now consider the reverse case in which A is able to invest in up to one area and B can invest in up to two areas.¹ We assume A's cost of investing in one area is $k_1^A > 0$, and the cost of investing in a second area, k_2^A , is ∞ . We assume

¹In our paper, we are interested in cases of competition between firms with different sizes, as in reality the resistance to the proposal of eliminating the full-cost method is always from firms of smaller size.

Although settings in which firms are of similar sizes are not our focus, we examined the cases that both innovator and imitator are of the same size for completeness. In the setting in which both firms can only invest in up to one area, it is easy to verify that the firms' accounting-method choices depend on their investment costs and their decisions are determined by information spillover and preempting effects, which we have identified in the main setting. In the setting in which both firms can invest in many areas, we have countless cases and the analysis is hardly presentable. Nevertheless, the firms' accounting-method choices are still driven by the same two effects.

B's investment cost in the first area is $k_1^B > 0$, B's cost for the second investment is $k_2^B > 0$, and we assume $k_2^B < \bar{K}_2^B = \frac{4ah(1+a+ah)}{9}$ so that firm B will optimally invest in two areas when firm A reports under the full-cost method. Otherwise, if k_2^B is too high, A is able to preempt B simply by choosing the full-cost method and does not have any incentive to choose the successful-efforts method. In addition, as in the main setting, we assume $k_1^A, k_1^B < \bar{K}$.

The payoff functions of firms A and B in this alternative setup are, respectively:

$$\Pi_A = q_A(1 - q_A - q_B + a_A) - k_1^A \cdot t'_A, \quad (\text{A.1})$$

$$\Pi_B = q_B(1 - q_A - q_B + a_B) - k_1^B - k_2^B \cdot t'_B, \quad (\text{A.2})$$

where t'_A is an indicator variable that equals one if A explores one area and equals zero if A does not invest; t'_B is an indicator variable that is one if B invests in two areas and equals to zero if B invests in one area.

We first consider the case in which A uses the successful-efforts method in this alternative setup. We find that if A reports a success, B will imitate A's investment. In addition, when k_2^B is sufficiently low, B will also invest in an additional area. If A reports no success, B will invest in two different areas. The equilibrium in this alternative setup when A uses the successful-efforts is stated in Lemma 8.

Lemma 8. *In the alternative setup, when A uses the successful-efforts method,*

(i) *if firm A reports failure or does not invest at all, firm B will invest in two different areas;*

(ii) *if firm A reports a success, firm B invests in the same area, and invests in one more different area if $k_2^B < \frac{4ah(1+2a\gamma)}{9}$.*

We then consider the case in which A uses the full-cost method. We find that as B obtains no information from A's report, B will invest in two different areas. This result is formally stated in Lemma 9.

Lemma 9. *In the alternative setup, when A uses the full-cost method, firm B will invest in two different areas.*

Following a similar analysis to that in the main setup, we derive the equilibrium of A and B's optimal investment strategy and A's optimal reporting strategy. We formally present the results in Proposition 13.

Proposition 13. *For $\widehat{\gamma}_1 < \gamma \leq 1$, or $\underline{\gamma} < \gamma \leq \widehat{\gamma}_1$ and $k_2^B < \frac{4ah(1+2a\gamma)}{9}$, firm A invests in one area and chooses to use the full-cost method. Firm B invests in two different areas.*

For $\underline{\gamma} < \gamma \leq \widehat{\gamma}_1$ and $K_2^B > k_2^B > \frac{4ah(1+2a\gamma)}{9}$, firm A invests in one area and chooses to use the successful-effort method. Firm B invests in a same area if A reports success and invests in two different areas otherwise.

$$\widehat{\gamma}_1 = \frac{2a - \sqrt{1+2a[2+a(2-h)](1-h)} + 1}{a}.$$

The intuition here is similar to that in the main setting. The innovator's and imitator's strategies are decided by the interaction between the information-spillover effect and the preempting effect. When the information-spillover effect is strong, or firm B's investment cost is low, B has a stronger incentive to imitate A's successful investment. Therefore, A will choose the full-cost method to avoid B's imitation. When the information-spillover effect becomes weaker, A may have incentive to choose the successful-efforts method to preempt B's investment through disclosing its success. Specifically, as B's investment cost becomes higher, although it may still imitate A's successful investment, B will invest in only one area when A reports success; while if A chooses the full-cost method, B does not have any information about A's success and will invest in two different areas. For A, it is actually better to choose the successful-efforts since A's report of any success secures its preemptive advantage.

Appendix A.1.3: Proofs

We first list firm A and B's gross payoffs given different combinations of the two firms' exploration outcomes, W_A and W_B in Tab. A.1. W_A and W_B are useful in later proofs.

	$x_B = 0$	$x_B = 1$	$x_B = \gamma$
$x_A = 0$	$\frac{1}{9}, \frac{1}{9}$	$\frac{(1-a)^2}{9}, \frac{(1+2a)^2}{9}$	—
$x_A = 1$	$\frac{(1+2a)^2}{9}, \frac{(1-a)^2}{9}$	$\frac{(1+a)^2}{9}, \frac{(1+a)^2}{9}$	$\frac{(1+2a-\gamma a)^2}{9}, \frac{(1-a+2\gamma a)^2}{9}$
$x_A = 2$	$\frac{(1+4a)^2}{9}, \frac{(1-2a)^2}{9}$	$\frac{(1+3a)^2}{9}, \frac{1}{9}$	$\frac{(1+4a-\gamma a)^2}{9}, \frac{(1-2a+2\gamma a)^2}{9}$

Table A.1.: Firms A and B's profits, W_A, W_B given the outcomes of explorations.

For example, in the case that A and B both obtain a successful exploration in the same area, firm A's contribution margin per unit is increased by a , and firm B's contribution margin per unit is increased by γa . Firm A then chooses its production quantity q_A to maximize its profit $q_A(1 - q_B - q_A + a)$, and firm B chooses production quantity q_B to maximize its profit $q_B(1 - q_A - q_B + \gamma a)$. In the equilibrium, $q_A^* = \frac{1+(2-\gamma)a}{3}$ and $q_B^* = \frac{1+(2\gamma-1)a}{3}$. Firm A and firm B's gross payoffs without considering the exploration cost are $W_A(a, \gamma a) = \frac{(1+2a-\gamma a)^2}{9}$ and $W_B(\gamma a, a) = \frac{(1-a+2\gamma a)^2}{9}$, respectively.

Second, we present the close-form expressions of firm B's expected payoffs based on A's reports, $E[\Pi_B | I_B, D(I_A, \hat{x}_A)]$, which will be used in later proofs.

When A reports under the successful-efforts method, given A's report $D = (I_A, \hat{x}_A)$ and B's investment decision I_B , firm B's expected payoffs are:

$$\begin{aligned}
E[\Pi_B|0, D(1, 0)] &= E[\Pi_B|0, D(2, 0)] = W_B(0, 0) = \frac{1}{9}, \\
E[\Pi_B|s, D(1, 0)] &= E[\Pi_B|s, D(2, 0)] = W_B(0, 0) - k_1^B = \frac{1}{9} - k_1^B, \\
E[\Pi_B|d, D(1, 0)] &= E[\Pi_B|d, D(2, 0)] = hW_B(a, 0) + (1-h)W_B(0, 0) - k_1^B \\
&= \frac{1 + 4ah(1+a)}{9} - k_1^B, \\
E[\Pi_B|0, D(1, 1)] &= W_B(0, a) = \frac{(1-a)^2}{9}, \\
E[\Pi_B|s, D(1, 1)] &= W_B(\gamma a, a) - k_1^B = \frac{(1-a+2a\gamma)^2}{9} - k_1^B, \\
E[\Pi_B|d, D(1, 1)] &= hW_B(a, a) + (1-h)W_B(0, a) - k_1^B = \frac{(1-a)^2 + 4ah}{9} - k_1^B, \\
E[\Pi_B|0, D(2, 1)] &= W_B(0, a) = \frac{(1-a)^2}{9}, \\
E[\Pi_B|s, D(2, 1)] &= \frac{1}{2}W_B(\gamma a, a) + \frac{1}{2}W_B(0, a) - k_1^B \\
&= \frac{1 - 2a(1-\gamma) + a^2[1 - 2(1-\gamma)\gamma]}{9} - k_1^B, \\
E[\Pi_B|d, D(2, 1)] &= hW_B(a, a) + (1-h)W_B(0, a) - k_1^B = \frac{(1-a)^2 + 4ah}{9} - k_1^B, \\
E[\Pi_B|0, D(2, 2)] &= W_B(0, 2a) = \frac{(1-2a)^2}{9}, \\
E[\Pi_B|s, D(2, 2)] &= W_B(\gamma a, 2a) - k_1^B = \frac{(1-2a+2a\gamma)^2}{9} - k_1^B, \\
E[\Pi_B|d, D(2, 2)] &= hW_B(a, 2a) + (1-h)W_B(0, 2a) - k_1^B \\
&= \frac{1 + 4a(a+h-ah-1)}{9} - k_1^B.
\end{aligned}$$

When A reports under the full-cost method, given A's report $D = (I_A, \emptyset)$ and B's investment decision I_B , firm B's expected payoffs are:

$$\begin{aligned}
E[\Pi_B|0, D(1, \emptyset)] &= hW_B(0, a) + (1-h)W_B(0, 0) = \frac{1 - (2-a)ah}{9}, \\
E[\Pi_B|s, D(1, \emptyset)] &= hW_B(\gamma a, a) + (1-h)W_B(0, 0) - k_1^B = \frac{1 - h - h(1-a+2a\gamma)^2}{9} - k_1^B, \\
E[\Pi_B|d, D(1, \emptyset)] &= (1-h)E[\Pi_B|d, D(1, 0)] + hE[\Pi_B|d, D(1, 1)] \\
&= \frac{1 + 2ah + a^2h(5-4h)}{9} - k_1^B, \\
E[\Pi_B|0, D(2, \emptyset)] &= h^2W_B(0, 2a) + (1-h)^2W_B(0, 0) + 2h(1-h)W_B(0, a) \\
&= \frac{1 + 2ah[2 + a - (4-a)h]}{9}, \\
E[\Pi_B|s, D(2, \emptyset)] &= h^2E[\Pi_B|s, D(2, 2)] + (1-h)^2E[\Pi_B|s, D(2, 0)] + 2h(1-h)E[\Pi_B|s, D(2, 1)] \\
&= \frac{1 + 2ah[2(\gamma-1)(1+a\gamma) + a(1+h-2h\gamma)]}{9} - k_1^B, \\
E[\Pi_B|d, D(2, \emptyset)] &= h^2E[\Pi_B|d, D(2, 2)] + (1-h)^2E[\Pi_B|d, D(2, 0)] + 2h(1-h)E[\Pi_B|d, D(2, 1)] \\
&= \frac{1 + 6a^2(1-h)h}{9} - k_1^B,
\end{aligned}$$

Proof of Lemma 1

Proof. 1. When firm A reports full failure in its exploration, because

$$\begin{aligned}
E[\Pi_B|s, D(I_A, 0)] - E[\Pi_B|d, D(I_A, 0)] &= \frac{-4a(1+a)h}{9} < 0, \\
\text{and } E[\Pi_B|0, D(I_A, 0)] - E[\Pi_B|d, D(I_A, 0)] &= k_1^B - \frac{4a(1+a)h}{9} < 0 \text{ for } k_1^B < \bar{K},
\end{aligned}$$

firm B's optimal decision is d , namely $I_B^*(D) = d$ for $D = (I_A, 0)$.

2. When firm A reports at least one successful exploration, we first compare firm B's expected payoff with strategy s and that with strategy d , and obtain the following results:

$$\begin{aligned}
E[\Pi_B|s, D(2, 1)] - E[\Pi_B|d, D(2, 1)] &= \frac{2a\{[1 - (1-\gamma)a]\gamma - 2h\}}{9}, \\
E[\Pi_B|s, D(2, 2)] - E[\Pi_B|d, D(2, 2)] &= \frac{4a[\gamma - (1-a)h - (2-\gamma)a\gamma]}{9}, \\
E[\Pi_B|s, D(1, 1)] - E[\Pi_B|d, D(1, 1)] &= \frac{4a\{[1 - (1-\gamma)a]\gamma - h\}}{9}.
\end{aligned}$$

We can prove that

$$\begin{aligned} E[\Pi_B|s, D(2, 1)] - E[\Pi_B|d, D(2, 1)] &> 0 \text{ iff } \gamma > \frac{a + \sqrt{(a-1)^2 + 8ah} - 1}{2a}, \\ E[\Pi_B|s, D(2, 2)] - E[\Pi_B|d, D(2, 2)] &> 0 \text{ iff } \gamma > \frac{\sqrt{1 + 4a(a-1)(1-h)} - 1}{2a} + 1, \\ E[\Pi_B|s, D(1, 1)] - E[\Pi_B|d, D(1, 1)] &> 0 \text{ iff } \gamma > \frac{a + \sqrt{(a-1)^2 + 4ah} - 1}{2a}. \end{aligned}$$

We set $\gamma_1 = \frac{a + \sqrt{(a-1)^2 + 8ah} - 1}{2a}$, $\gamma_2 = \frac{\sqrt{1 + 4a(a-1)(1-h)} - 1}{2a} + 1$, $\gamma_3 = \frac{a + \sqrt{(a-1)^2 + 4ah} - 1}{2a}$, and we can prove that $\gamma_3 < \gamma_2 < \gamma_1$.

In the next step, we solve B's optimal investment strategy based on γ .

(i) When $\gamma_1 < \gamma \leq 1$:

From the above results, we have $E[\Pi_B|s, D] > E[\Pi_B|d, D]$ for $D = (1, 1), (2, 1)$, or $(2, 2)$. Therefore, s is a dominating strategy to d for firm B. We then compare firm B's expected payoff by strategy s with that by strategy 0, and obtain the following results:

$$\begin{aligned} E[\Pi_B|s, D(2, 1)] - E[\Pi_B|0, D(2, 1)] &= \frac{2a\gamma[1 - (1 - \gamma)a]}{9} - k_1^B > 0 \text{ iff } k_1^B < \frac{2a\gamma[1 - (1 - \gamma)a]}{9}, \\ E[\Pi_B|s, D(2, 2)] - E[\Pi_B|0, D(2, 2)] &= \frac{4a\gamma\{1 - (2 - \gamma)a\}}{9} - k_1^B > 0 \text{ for any } k_1^B < \bar{K}, \\ E[\Pi_B|s, D(1, 1)] - E[\Pi_B|0, D(1, 1)] &= \frac{4a\gamma\{1 - (1 - \gamma)a\}}{9} - k_1^B > 0 \text{ for any } k_1^B < \bar{K}. \end{aligned}$$

We set $K_1(\gamma) = \frac{2a\gamma[1 - (1 - \gamma)a]}{9}$. From the above results we obtain that $I_B^*(D) = s$ for $D = (1, 1)$ or $(2, 2)$; $I_B^*(D) = s$ for $D = (2, 1)$ if $k_1^B < \min\{\bar{K}, K_1(\gamma)\}$ which is Region I, and $I_B^*(D) = 0$ for $D = (2, 1)$ if $K_1(\gamma) < k_1^B < \bar{K}$, which is part of Region III.

(ii) When $\gamma_2 < \gamma \leq \gamma_1$:

we can prove that

$$\begin{aligned} E[\Pi_B|d, D(2, 1)] &> E[\Pi_B|s, D(2, 1)] \text{ and } E[\Pi_B|d, D(2, 1)] > E[\Pi_B|0, D(2, 1)] \text{ iff } k_1^B < \frac{4ah}{9}; \\ E[\Pi_B|s, D(2, 2)] &> E[\Pi_B|d, D(2, 2)], \text{ and } E[\Pi_B|s, D(2, 2)] > E[\Pi_B|0, D(2, 2)] \text{ iff } k_1^B < \frac{4a\gamma[1 - (2 - \gamma)a]}{9}; \\ E[\Pi_B|s, D(1, 1)] &> E[\Pi_B|d, D(1, 1)], \text{ and } E[\Pi_B|s, D(1, 1)] > E[\Pi_B|0, D(1, 1)] \text{ iff } k_1^B < \frac{4a\gamma[1 - (1 - \gamma)a]}{9}. \end{aligned}$$

We can prove that $\frac{4ah}{9} < \frac{4a\gamma[1 - (2 - \gamma)a]}{9} < \frac{4a\gamma[1 - (1 - \gamma)a]}{9}$ if $\gamma > \frac{2a + \sqrt{1 + 4a(a+h-1)} - 1}{2a}$, and $\frac{4a\gamma[1 - (2 - \gamma)a]}{9} < \frac{4ah}{9} < \frac{4a\gamma[1 - (1 - \gamma)a]}{9}$ if $\gamma < \frac{2a + \sqrt{1 + 4a(a+h-1)} - 1}{2a}$.

We set $K_2(\gamma) = \frac{4a\gamma[1-(2-\gamma)a]}{9}$ and $\underline{\gamma} = \frac{2a+\sqrt{1+4a(a+h-1)}-1}{2a}$, then we can obtain the following results:

if $k_1^B < \frac{4ah}{9}$, which is Region II, $I_B^*(D) = s$ for $D = (1, 1)$ or $(2, 2)$, and $I_B^*(D) = d$ for $D = (2, 1)$;

if $\frac{4ah}{9} < k_1^B < \min\{K_2(\gamma), \bar{K}\}$, which is part of Region III, $I_B^*(D) = s$ for $D = (1, 1)$ or $(2, 2)$, and $I_B^*(D) = 0$ for $D = (2, 1)$;

if $K_2(\gamma) < k_1^B < \bar{K}$, which is Region IV, $I_B^*(D) = s$ for $D = (1, 1)$; $I_B^*(D) = 0$ for $D = (2, 2)$ or $D = (2, 1)$. \square

Although we are not interested in the case that $\gamma < \underline{\gamma}$ in the paper, we still provide firm B's optimal strategy in this case below for completeness.

Firm B's optimal investment strategy when $\gamma < \underline{\gamma}$:

1. When $\gamma_2 < \gamma < \underline{\gamma}$,

if $k_1^B < K_2(\gamma)$, $I_B^*(D) = s$ for $D = (1, 1)$ or $(2, 2)$, and $I_B^*(D) = d$ for $D = (2, 1)$;

if $K_2(\gamma) < k_1^B < \frac{4ah}{9}$, $I_B^*(D) = s$ for $D = (1, 1)$, $I_B^*(D) = d$ for $D = (2, 1)$, and $I_B^*(D) = 0$ for $D = (2, 2)$;

if $\frac{4ah}{9} < k_1^B < \min\{\frac{4a\gamma[1-(1-\gamma)a]}{9}, \bar{K}\}$, $I_B^*(D) = s$ for $D = (1, 1)$, and $I_B^*(D) = 0$ for $D = (2, 1)$ or $D = (2, 2)$.

2. When $\gamma_3 < \gamma \leq \gamma_2$, we can prove that

$E[\Pi_B|d, D(2, 1)] > E[\Pi_B|s, D(2, 1)]$, and $E[\Pi_B|d, D(2, 1)] > E[\Pi_B|0, D(2, 1)]$ iff $k_1^B < \frac{4ah}{9}$;

$E[\Pi_B|d, D(2, 2)] > E[\Pi_B|s, D(2, 2)]$, and $E[\Pi_B|d, D(2, 2)] > E[\Pi_B|0, D(2, 2)]$ iff $k_1^B < \frac{4ah(1-a)}{9}$;

$E[\Pi_B|s, D(1, 1)] > E[\Pi_B|d, D(1, 1)]$, and $E[\Pi_B|s, D(1, 1)] > E[\Pi_B|0, D(1, 1)]$ iff $k_1^B < \frac{4a\gamma[1-(1-\gamma)a]}{9}$.

Therefore, we have the following results:

if $k_1^B < \frac{4ah(1-a)}{9}$, $I_B^*(D) = s$ for $D = (1, 1)$; $I_B^*(D) = d$ for $D = (2, 1)$ or $D = (2, 2)$;

if $\frac{4ah(1-a)}{9} < k_1^B < \frac{4ah}{9}$, $I_B^*(D) = s$ for $D = (1, 1)$, $I_B^*(D) = d$ for $D = (2, 1)$, and $I_B^*(D) = 0$ for $D = (2, 2)$;

if $\frac{4ah}{9} < k_1^B < \frac{4a\gamma[1-(1-\gamma)a]}{9}$, $I_B^*(D) = s$ for $D = (1, 1)$, and $I_B^*(D) = 0$ for $D = (2, 1)$ or $D = (2, 2)$;

if $\frac{4a\gamma[1-(1-\gamma)a]}{9} < k_1^B < \bar{K}$, $I_B^*(D) = 0$ for $D = (1, 1)$, $D = (2, 1)$ or $D = (2, 2)$.

3. When $0 < \gamma \leq \gamma_3$, we can prove that

$E[\Pi_B|d, D(I_A, 1)] > E[\Pi_B|s, D(I_A, 1)]$, and $E[\Pi_B|d, D(I_A, 1)] > E[\Pi_B|0, D(I_A, 1)]$ iff $k_1^B < \frac{4ah}{9}$;

$E[\Pi_B|d, D(2, 2)] > E[\Pi_B|s, D(2, 2)]$, and $E[\Pi_B|d, D(2, 2)] > E[\Pi_B|0, D(2, 2)]$ iff $k_1^B < \frac{4ah(1-a)}{9}$.

Therefore, we have the following results:

if $k_1^B < \frac{4ah(1-a)}{9}$, $I_B^*(D) = d$ for $D = (1, 1)$, $D = (2, 1)$ or $D = (2, 2)$;

if $\frac{4ah(1-a)}{9} < k_1^B < \frac{4ah}{9}$, $I_B^*(D) = d$ for $D = (1, 1)$, $D = (2, 1)$, and $I_B^*(D) = 0$ for $D = (2, 2)$.

if $\frac{4ah}{9} < k_1^B < \bar{K}$, $I_B^*(D) = 0$ for $D = (1, 1)$, $D = (2, 1)$ or $D = (2, 2)$.

In the case $\gamma \leq \underline{\gamma}$, from the above results we can see that when firm A invests in two areas and reports under the successful-efforts method, s is a dominated strategy for firm B. When firm A invests in one area and reports success, s might be firm B's optimal strategy; however firm A will prefer the full-cost method by then to avoid firm B's imitating. Therefore in the equilibrium, firm B will not follow firm A's investment because γ is low and the spillover effect is very weak. We do not include the detailed analysis of this case in our main text because we focus on the imitating behavior of firm B.

Proof of Lemma 2

Proof. When firm A reports using the full-cost method and invests in one area, namely $D = (1, \emptyset)$, because

$$E[\Pi_B|d, D(1, \emptyset)] - E[\Pi_B|s, D(1, \emptyset)] = \frac{4ah\{1 - \gamma + a[1 - h + (1 - \gamma)\gamma]\}}{9} > 0,$$

$$\text{and } E[\Pi_B|d, D(1, \emptyset)] - E[\Pi_B|0, D(1, \emptyset)] = \frac{4ah(1 + a - ah)}{9} - k_1^B > 0 \text{ for } k_1^B < \bar{K},$$

firm B's optimal investment decision is d .

When firm A reports using the full-cost method and invests in two areas, namely $D = (2, \emptyset)$, because

$$E[\Pi_B|d, D(2, \emptyset)] - E[\Pi_B|s, D(2, \emptyset)] = \frac{4ah\{1 - \gamma + a[1 - h(2 - \gamma) + \gamma - \gamma^2]\}}{9} > 0,$$

$$\text{and } E[\Pi_B|d, D(2, \emptyset)] - E[\Pi_B|0, D(2, \emptyset)] = \frac{4ah(1 + a - 2ah)}{9} - k_1^B > 0 \text{ for } k_1^B < \bar{K},$$

firm B's optimal investment decision is d .

Therefore, $I_B^*(D) = d$ is firm B's optimal investment decision when firm A uses the full-cost method. \square

Proof of Lemma 3

Proof. We have proved that when $I_A = 1$, the full-cost method is always the optimal reporting method for firm A. Now we solve firm A's optimal reporting method when $I_A = 2$.

When A uses the full-cost method, according to Lemma 2, $I_B^*(D) = d$ for $D = (I_A, \emptyset)$. We have

$$E[\Pi_A|2, FC] = hE[\Pi_A|I_A = 2, a_B = a] + (1-h)E[\Pi_A|I_A = 2, a_B = 0] = \frac{1}{9} + \frac{2ah}{3} + a^2h - k_1^A - k_2^A.$$

When A uses the successful-efforts method, because B's optimal strategy depends on γ and k_1^B , we need to consider different regions of γ and k_1^B :

(i) In Region I, according to Lemma 1, $I_B^*(D) = s$ for $D = (2, 1)$ or $(2, 2)$, and $I_B^*(D) = d$ for $D = (2, 0)$. We have

$$\begin{aligned} E[\Pi_A|2, SE] &= h^2W_A(2a, \gamma a) + (1-h)^2[hW_A(0, a) + (1-h)W_A(0, 0)] \\ &\quad + h(1-h)(W_A(a, \gamma a) + W_A(a, 0)) - k_1^A - k_2^A \\ &= \frac{1 + ah\{2[3 + (2-h)h - \gamma] + a[(3 + h^2) - 4(1+h)\gamma + \gamma^2]\}}{9} - k_1^A - k_2^A. \end{aligned}$$

It can be proved that $E[\Pi_A|2, SE] < E[\Pi_A|2, FC]$ in Region I.

(ii) In Region II, according to Lemma 1, $I_B^*(D) = s$ for $D = (2, 2)$, $I_B^*(D) = d$ for $D = (2, 1)$, and $I_B^*(D) = d$ for $D = (2, 0)$. We have

$$\begin{aligned} E[\Pi_A|2, SE] &= h^2W_A(2a, \gamma a) + (1-h)^2[hW_A(0, a) + (1-h)W_A(0, 0)] \\ &\quad + 2h(1-h)(hW_A(a, a) + (1-h)W_A(a, 0)) - k_1^A - k_2^A \\ &= \frac{1 + ah\{2(3 + h^2 - h\gamma) + a[9 + 7h^2 - h(8 - \gamma)\gamma]\}}{9} - k_1^A - k_2^A. \end{aligned}$$

It can be proved that $E[\Pi_A|2, SE] < E[\Pi_A|2, FC]$ in Region II.

(iii) In Region III, according to Lemma 1, $I_B^*(D) = s$ for $D = (2, 2)$, $I_B^*(D) = 0$ for $D = (2, 1)$, and $I_B^*(D) = d$ for $D = (2, 0)$. We have

$$\begin{aligned} E[\Pi_A|2, SE] &= h^2W_A(2a, \gamma a) + (1-h)^2[hW_A(0, a) + (1-h)W_A(0, 0)] \\ &\quad + 2h(1-h)W_A(a, 0) - k_1^A - k_2^A \\ &= \frac{1 + ah\{6 + 4h - 2h(h + \gamma) + a[9 + h(6 + h - (8 - \gamma)\gamma)]\}}{9} - k_1^A - k_2^A. \end{aligned}$$

It can be proved that $E[\Pi_A|2, SE] > E[\Pi_A|2, FC]$ in Region III.

(iv) In Region IV, according to Lemma 1, $I_B^*(D) = 0$ for $D = (2, 2)$ or $(2, 1)$, and $I_B^*(D) = d$ for $D = (2, 0)$. We have

$$\begin{aligned} E[\Pi_A|2, SE] &= h^2 W_A(2a, 0) + (1-h)^2 [h W_A(0, a) + (1-h) W_A(0, 0)] \\ &\quad + 2h(1-h) W_A(a, 0) - k_1^A - k_2^A \\ &= \frac{1 + ah[2(3-h)(1+h) + a(3+h)^2]}{9} - k_1^A - k_2^A. \end{aligned}$$

It can be proved that $E[\Pi_A|2, SE] > E[\Pi_A|2, FC]$ in Region IV.

We define Region FC as the union of Regions I and II, and Region SE as the union of Regions III and IV. \square

Proof of Proposition 1

Proof. We derive firm A's optimal investing and reporting strategy as well as B's optimal investing strategy in this proof.

We first prove that A will always invest under the assumption $k_1^A < \bar{K}$. In other words, not to invest is not A's optimal strategy.

According to Lemma 1, if A does not invest at all ($I_A = x_A = 0$), $I_B^* = d$. Therefore,

$$E[\Pi_A|I_A = 0] = h W_A(0, a) + (1-h) W_A(0, 0) = \frac{1 - (2-a)ah}{9}.$$

We have $E[\Pi_A|1, FC] = \frac{1 - [2 + a(5-4h)]ah}{9} - k_1^A$. We can prove that $E[\Pi_A|0, D] < E[\Pi_A|1, FC]$ when $k_1^A < \bar{K}$. Thus, for firm A, not investing is dominated by the strategy of investing in one area and using the full-cost method.

We now derive firm A's optimal investment strategy given its optimal reporting choice obtained in Lemma 3.

In Region FC, according to Lemma 3, A's optimal reporting method $R^* = FC$, and according to Lemma 2, B's optimal investing strategy $I_B^* = d$. We then compare $E[\Pi_A|1, FC]$ with $E[\Pi_A|2, FC]$, and find that $I_A^* = 1$ if $k_2^A > \frac{4ah(1+a+ah)}{9}$, and $I_A^* = 2$ if $k_2^A < \frac{4ah(1+a+ah)}{9}$.

In Region $SE \cap III$, according to Lemma 3, A prefers the full-cost method if it invests in one area, and prefers the successful-efforts method if it invests in two areas. We then compare $E[\Pi_A|1, FC]$ with $E[\Pi_A|2, SE]$, and find that $(R^*, I_A^*) = (FC, 1)$ if $k_2^A > \frac{ah\{4(1+h)-2h(h+\gamma)+a[4+h(10+h+(\gamma-8)\gamma)]\}}{9}$, and $(R^*, I_A^*) = (SE, 2)$ if $k_2^A < \frac{ah\{4(1+h)-2h(h+\gamma)+a[4+h(10+h+(\gamma-8)\gamma)]\}}{9}$. According to Lemma 1 and Lemma 2, we obtain $I_B^*(D) = s$ for $D = (2, 2)$, $I_B^*(D) = 0$ for $D = (2, 1)$, and $I_B^*(D) = d$ for $D = (2, 0)$ or $(1, \emptyset)$.

In Region $SE \cap IV$, according to Lemma 3, A prefers the full-cost method if it invests in one area, and prefers the successful-efforts method if it invests in two areas.

We then compare $E[\Pi_A|1, FC]$ with $E[\Pi_A|2, SE]$, and find that $(R^*, I_A^*) = (FC, 1)$ if $k_2^A > \frac{ah\{4+2(2-h)h+a[4+h(10+h)]\}}{9}$, and $(R^*, I_A^*) = (SE, 2)$ if $k_2^A < \frac{ah\{4+2(2-h)h+a[4+h(10+h)]\}}{9}$. According to Lemma 1 and Lemma 2, we obtain $I_B^*(D) = 0$ for $D = (2, 2)$ or $(2, 1)$, and $I_B^*(D) = d$ for $D = (2, 0)$ or $(1, \emptyset)$.

We summarize all the thresholds for firm A's cost in A's investment decision by defining $K_A(\gamma, k_1^B)$ as

$$K_A(\gamma, k_1^B) = \begin{cases} \frac{4ah(1+a+ah)}{9}, & \text{for Region FC,} \\ \frac{ah[4(1+h)-2h(h+\gamma)+4a+ah(10+h+(\gamma-8)\gamma)]}{9}, & \text{for Region SE} \cap \text{III,} \\ \frac{ah\{4+2(2-h)h+a[4+h(10+h)]\}}{9}, & \text{for Region SE} \cap \text{IV.} \end{cases} \quad \square$$

Proof of Lemma 4

Proof. When the successful-efforts method is enforced, we compare A's expected payoffs with no investment $E[\Pi_A|0, D]$, one investment $E[\Pi_A|1, SE]$, and two investments $E[\Pi_A|2, SE]$, and then find A's optimal investing strategy.

As derived in the proof of Proposition 1, $E[\Pi_A|0, D] = \frac{1-(2-a)ah}{9}$.

We have

$$E[\Pi_A|1, SE] = \frac{1 + \{2(1+h-\gamma) + a[5-h-(4-\gamma)\gamma]\}ah}{9} - k_1^A.$$

As derived in the proof of Lemma 3,

$$E[\Pi_A|2, SE] = \begin{cases} \frac{1+ah\{2[3+(2-h)h-\gamma]+a[(3+h)^2-4(1+h)\gamma+\gamma^2]\}}{9} - k_1^A - k_2^A. & \text{for Region I,} \\ \frac{1+ah\{2(3+h^2-h\gamma)+a[9+7h^2-h(8-\gamma)\gamma]\}}{9} - k_1^A - k_2^A & \text{for Region II,} \\ \frac{1+ah\{6+4h-2h(h+\gamma)+a[9+h(6+h-(8-\gamma)\gamma)]\}}{9} - k_1^A - k_2^A & \text{for Region III,} \\ \frac{1+ah[2(3-h)(1+h)+a(3+h)^2]}{9} - k_1^A - k_2^A. & \text{for Region IV.} \end{cases}$$

It can be easily proved that $E[\Pi_A|1, SE] > E[\Pi_A|0, D]$ iff $k_1^A < \frac{ah\{2(2+h-\gamma)-a[h-(2-\gamma)^2]\}}{9}$. Setting $K_1^A = \frac{ah\{2(2+h-\gamma)-a[h-(2-\gamma)^2]\}}{9}$, we can prove that $K_1^A < \bar{K}$.

If $k_1^A < K_1^A$, as derived above, investing in one area is a better strategy than no investment. Then we compare $E[\Pi_A|2, SE]$ with $E[\Pi_A|1, SE]$, and find there is a threshold $K_A^{SE}(\gamma, k_1^A, k_1^B)$, that A prefers to invest in one area if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, and prefers to invest in two areas if $k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$.

If $k_1^A > K_1^A$, no investment is a better strategy than investing in one area. Then we compare $E[\Pi_A|2, SE]$ with $E[\Pi_A|0]$, and find there is a threshold $K_A^{SE}(\gamma, k_1^A, k_1^B)$, that A prefers not to invest if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, and prefers to invest in two areas if $k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$.

The closed-form expression of $K_A^{SE}(\gamma, k_1^A, k_1^B)$ is:

$$K_A^{SE}(\gamma, k_1^A, k_1^B) = \begin{cases} \frac{2(2-h)(1+h)+a[4+h(7+h-4\gamma)]}{9/(ah)} & \text{for } Region I \text{ and } k_1^A < K_A, \\ \frac{a[4+h+7h^2+(4-8h)\gamma-(1-h)\gamma^2]+2[2+h^2+\gamma-h(1+\gamma)]}{9/(ah)} & \text{for } Region II \text{ and } k_1^A < K_A, \\ \frac{2(1-h)(h+\gamma)+4+a[4+h^2+h(7-\gamma)(1-\gamma)+(4-\gamma)\gamma]}{9/(ah)} & \text{for } Region III \text{ and } k_1^A < K_A, \\ \frac{2(2+h-h^2+\gamma)+a[4+h(7+h)+(4-\gamma)\gamma]}{9/(ah)} & \text{for } Region IV \text{ and } k_1^A < K_A, \\ \frac{ah\{2[4+(2-h)h+\gamma]+a[8+6h+h^2-4(1+h)\gamma+\gamma^2]\}}{9/(ah)} - k_1^A & \text{for } Region I \text{ and } k_1^A > K_A, \\ \frac{ah\{2(h^2-h\gamma+4)+a[8+7h^2-h(8-\gamma)\gamma]\}}{9} - k_1^A & \text{for } Region II \text{ and } k_1^A > K_A, \\ \frac{ah\{4(2+h)-2h(h+\gamma)+a[8+h(6+h-(8-\gamma)\gamma)]\}}{9} - k_1^A & \text{for } Region III \text{ and } k_1^A > K_A, \\ \frac{ah[8+2(2-h)h+a(2+h)(4+h)]}{9} - k_1^A & \text{for } Region IV \text{ and } k_1^A > K_A. \end{cases}$$

□

Proof of Proposition 2

Proof. When the successful-efforts method is enforced, we have derived A's optimal investing strategy in Lemma 4.

For $k_1^A < K_1^A$, we can prove $K_A^{SE}(\gamma, k_1^A, k_1^B) > K_A(\gamma, k_1^B)$. Therefore, firm A's number of investment increases from one area to two areas if $K_A(\gamma, k_1^B) < k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$ after the enforcement of the successful-efforts method, and does not change otherwise.

For $K_1^A < k_1^A < \bar{K}$, if γ, k_1^B are in Regions I and II (which is Region FC), we can prove $K_A^{SE}(\gamma, k_1^A, k_1^B) < K_1^A$. Because we assume that A has a convex investment-cost function, namely $k_2^A > k_1^A$, we have $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$. Therefore, firm A doesn't invest at all when the successful-efforts reporting method is enforced. If γ, k_1^B are in Regions III and IV (which is Region FC/SE), we can prove $K_A^{SE}(\gamma, k_1^A, k_1^B) > K_A(\gamma, k_1^B)$. Therefore, after the enforcement of the successful-efforts reporting method, firm A's number of investment increases from one to two if $K_A(\gamma, k_1^B) < k_2^A < K_A^{SE}(\gamma, k_1^A, k_1^B)$, decreases from one to zero if $k_2^A > K_A^{SE}(\gamma, k_1^A, k_1^B)$, and does not change otherwise. □

Proof of Proposition 3

Proof. When the full-cost reporting method is enforced, as shown in the proof of Proposition 1, $E[\Pi_A|0, D] < E[\Pi_A|1, FC]$, firm A will invest in at least one area.

We have already derived $E[\Pi_A|1, FC]$ and $E[\Pi_A|2, FC]$'s value in the proof of Proposition 1 and Lemma 3. Comparing $E[\Pi_A|1, FC]$ with $E[\Pi_A|2, FC]$, we find that $E[\Pi_A|1, FC] < E[\Pi_A|2, FC]$ if $k_2^A > \frac{4ah(1+a+ah)}{9}$, and $E[\Pi_A|1, FC] < E[\Pi_A|2, FC]$ if $k_2^A < \frac{4ah(1+a+ah)}{9}$.

Setting $K_A^{FC} = \frac{4ah(1+a+ah)}{9}$, we can prove that $K_A(\gamma, k_1^B) = K_A^{FC}$ in Region FC; $K_A(\gamma, k_1^B) > K_A^{FC}$ in Region FC/SE.

Therefore, in Region FC, enforcing the full-cost method does not affect firm A's investment; in Region FC/SE, A's number of investments reduces from two to one

after enforcing the full-cost method if $K_A^{FC} < k_2^A < K_A(\gamma, k_1^B)$, and does not change otherwise. \square

Proof of Lemma 8

Proof. In the alternative setup, $I_A \in \{0, 1\}$, $\hat{x}_A \in \{0, 1, \emptyset\}$ and $I_B^*(D) \in \{s, d, sd, dd\}$, where sd means firm B invests in both A's area and an additional area, dd means firm B invests in two areas different from A's investment, and s and d are the same as those in the main setup.

When A reports under the successful-efforts method, we compare firm B's expected payoffs of all four possible investment strategies, $I_B \in \{s, d, sd, dd\}$, based on firm A's report $D(I_A, \hat{x}_A)$, and then we solve for firm B's optimal strategy $I_B^*(D)$.

1. If firm A reports failure ($D = (1, 0)$), or does not invest at all, it's easy to prove $I_B^*(D) = dd$ under assumption $k_2^B < \bar{K}_2^B$.
2. If firm A reports success ($D = (1, 1)$), firm B's expected payoffs by different investment strategies are

$$\begin{aligned}
E[\Pi_B|s, D(1, 1)] &= W_B(\gamma a, a) = \frac{(1 - a + 2a\gamma)^2}{9} - k_1^B; \\
E[\Pi_B|d, D(1, 1)] &= hW_B(a, a) + (1 - h)W_B(0, a) = \frac{(1 - a)^2 + 4ah}{9} - k_1^B; \\
E[\Pi_B|sd, D(1, 1)] &= hW_B(\gamma a + a, a) + (1 - h)W_B(\gamma a, a) - k_1^B - k_2^B \\
&= \frac{1 + a\{-2 + 4h + 4\gamma + a[1 + 4\gamma(2h + \gamma - 1)]\}}{9} - k_1^B - k_2^B; \\
E[\Pi_B|dd, D(1, 1)] &= h^2W_B(2a, a) + (1 - h)^2W_B(0, a) + 2h(1 - h)W_B(a, a) - k_1^B - k_2^B \\
&= \frac{1 + a(a + 8h + 8ah^2 - 1)}{9} - k_1^B - k_2^B.
\end{aligned}$$

As in the main setup, we only consider the case $\underline{\gamma} < \gamma < 1$, and obtain that $E[\Pi_B|s, D(1, 1)] > E[\Pi_B|d, D(1, 1)] > 0$ and $E[\Pi_B|sd, D(1, 1)] > E[\Pi_B|dd, D(1, 1)]$.

Because $E[\Pi_B|sd, D(1, 1)] - E[\Pi_B|s, D(1, 1)] = \frac{4ah(1+2a\gamma)}{9} - k_2^B$, we derive that for $D = (1, 1)$, $I_B^*(D) = sd$ if $k_2^B < \text{Min}\{\frac{4ah(1+2a\gamma)}{9}, \bar{K}_2^B\}$, namely $k_2^B < \frac{4ah(1+2a\gamma)}{9}$ or $\frac{1+h}{2} < \gamma < 1$; and $I_B^*(D) = s$ if $\bar{K}_2^B > k_2^B > \frac{4ah(1+2a\gamma)}{9}$ and $\underline{\gamma} < \gamma < \frac{1+h}{2}$. \square

Proof of Lemma 9

Proof. When A reports under the full-cost method, we compare firm B's expected payoffs of all four possible investment strategies, $I_B \in \{s, d, sd, dd\}$, given firm A's

report $D(1, \emptyset)$, in order to find firm B's optimal strategy $I_B^*(D)$. We have

$$\begin{aligned}
E[\Pi_B|s, D(1, \emptyset)] &= hW_B(\gamma a, a) + (1-h)W_B(0, 0) - k_1^B \\
&= \frac{1-h-h(1-a+2a\gamma)^2}{9} - k_1^B; \\
E[\Pi_B|d, D(1, \emptyset)] &= h^2W_B(a, a) + (1-h)^2W_B(0, 0) \\
&\quad + h(1-h)[W_B(0, a) + W_B(a, 0)] - k_1^B; \\
&= \frac{1+a[2+a(5-4h)]h}{9} - k_1^B; \\
E[\Pi_B|sd, D(1, \emptyset)] &= h(hW_B(a+\gamma a, a) + (1-h)W_B(a, 0)) \\
&\quad + (1-h)E[\Pi_B|s, D(1, \emptyset)] - k_1^B - k_2^B \\
&= \frac{1+ah\{2+4\gamma+a[5-4(1-\gamma)\gamma-h(4-8\gamma)]\}}{9} - k_1^B - k_2^B; \\
E[\Pi_B|dd, D(1, \emptyset)] &= h^2(hW_B(2a, a) + (1-h)W_B(2a, 0)) \\
&\quad + (1-h)^2(hW_B(0, a) + (1-h)W_B(0, 0)) \\
&\quad + 2h(1-h)(hW_B(a, a) + (1-h)W_B(a, 0)) - k_1^B - k_2^B \\
&= \frac{1}{9} + \frac{2ah}{3} + a^2h - k_1^B - k_2^B.
\end{aligned}$$

We can prove that $E[\Pi_B|d, D(1, \emptyset)] > E[\Pi_B|s, D(1, \emptyset)] > 0$ and $E[\Pi_B|dd, D(1, \emptyset)] > E[\Pi_B|sd, D(1, \emptyset)]$.

Because $E[\Pi_B|dd, D(1, \emptyset)] - E[\Pi_B|d, D(1, \emptyset)] = \frac{4ah(1+a+ah)}{9} - k_2^B$, under the assumption $k_2^B < \bar{K}_2^B$, firm B's optimal strategy when A reports under the full-cost regime is to invest in two areas different from A, namely $I_B^*(D) = dd$ for $D = (1, \emptyset)$. \square

Proof of Proposition 13

Proof. We now derive firm A's optimal investing and reporting strategy as well as B's optimal investing strategy.

Firstly we calculate firm A's expected payoffs of different investing and reporting strategies given $I_B^*(D)$ derived in Lemma 8 and Lemma 9.

If A does not invest, we have

$$E[\Pi_A|0] = h^2W_A(0, 2a) + (1-h)^2W(0, 0) + 2h(1-h)W_A(0, a) = \frac{1+2ah(a+ah-2)}{9}.$$

If A invests and reports under the full-cost regime, we have

$$\begin{aligned}
E[\Pi_A|1, FC] &= h(h^2W_A(a, 2a) + (1-h)^2W(a, 0) + 2h(1-h)W_A(a, a)) \\
&\quad + (1-h)E[\Pi_A|0] - k_1^A \\
&= \frac{1+6a^2h(1-h)}{9} - k_1^A.
\end{aligned}$$

If A invests and reports under the successful-efforts regime,

(i) when $k_2^B < \frac{4ah(1+2a\gamma)}{9}$, we have

$$\begin{aligned} E[\Pi_A|1, SE] &= h(hW_A(a, a + \gamma a) + (1 - h)W_A(a, \gamma a)) + (1 - h)E[\Pi_A|0] - k_1^A \\ &= \frac{1 + ah\{2(h - \gamma) + a[6 - 2h^2 - (4 - \gamma)\gamma - h(3 - 2\gamma)]\}}{9} - k_1^A. \end{aligned}$$

(ii) when $k_2^B > \frac{4ah(1+2a\gamma)}{9}$, we have

$$\begin{aligned} E[\Pi_A|1, SE] &= hW_A(a, \gamma a) + (1 - h)E[\Pi_A|0] - k_1^A \\ &= \frac{1 + ah\{4h - 2\gamma + a[6 - 2h^2 - (4 - \gamma)\gamma]\}}{9} - k_1^A. \end{aligned}$$

Secondly, we compare firm A's expected payoffs with different investing and reporting strategies to derive firm A's optimal strategy.

It can be proved that $E[\Pi_A|1, FC] > E[\Pi_A|0]$. Therefore, no investment is a dominated strategy for A.

When $k_2^B < \frac{4ah(1+2a\gamma)}{9}$, we can prove that $E[\Pi_A|1, FC] > E[\Pi_A|1, SE]$. Thus, firm A optimally invests in one area and chooses the full-cost method, namely $(R^*, I_A^*) = (FC, 1)$.

When $k_2^B > \frac{4ah(1+2a\gamma)}{9}$, we can prove that

$$\begin{aligned} E[\Pi_A|1, FC] &> E[\Pi_A|1, SE] \text{ if } \gamma > \frac{2a - \sqrt{1 + 2a(2 + a(2 - h))(1 - h)} + 1}{a}, \text{ and} \\ E[\Pi_A|1, FC] &< E[\Pi_A|1, SE] \text{ if } \gamma < \frac{2a - \sqrt{1 + 2a(2 + a(2 - h))(1 - h)} + 1}{a}. \end{aligned}$$

Set $\widehat{\gamma}_1 = \frac{2a - \sqrt{1 + 2a(2 + a(2 - h))(1 - h)} + 1}{a}$, and we can conclude the above results in Proposition 13. \square

A.2. Appendix to Chapter 3

Proof of Proposition 4

Proof. The following conditions are equivalent given the raider's belief in Eq 3.5:

$$\begin{aligned} h(G, \hat{e}) \leq \bar{h} &\Leftrightarrow \hat{e} \leq \frac{1 - d}{1 - d + db}, \\ h(B, \hat{e}) \leq \bar{h} &\Leftrightarrow \hat{e} \leq \frac{d}{b + d - db}, \\ \text{where } \frac{1 - d}{1 - d + db} &< \frac{d}{b + d - db}. \end{aligned} \tag{A.3}$$

- When the raider's belief satisfies $\hat{e} > \frac{d}{b+d-db}$ such that she always offers a high price, $\alpha = \beta = 1$, the manager will receive no private benefit regardless of his effort as the takeover always succeeds. Her best response is to make no effort, $e^* = 0$. Hence this cannot be an equilibrium.

- When the raider's belief satisfies

$$\frac{1-d}{1-d+db} < \hat{e} < \frac{d}{b+d-db} \quad (\text{A.4})$$

such that she offers a separating bidding strategy, i.e., $\alpha = 1$ and $\beta = 0$, the manager's expected payoff is:

$$\Pi_m(e) = e(1-d)m - \frac{e^2}{2}$$

Thus the manager chooses the optimal effort of $e^* = (1-d)m$, which cannot satisfy the raider's belief constraint in (A.4), given that $0 < m < 1$.

- When the raider's belief is $\hat{e} = \frac{d}{b+d-db}$, the raider offers a high price when observing the good signal, $\alpha = 1$. When observing the bad signal, the raider is indifferent between two prices and she follows a mixed-bidding-strategy:

$$p(B) = \begin{cases} v_0 & \text{with prob } 1 - \beta \\ 1 + v_0 & \text{with prob } \beta \end{cases}$$

Then the manager's expected payoff is:

$$\Pi_m(e) = e(1-d)(1-\beta)m - \frac{e^2}{2}$$

The manager's optimal effort in this case is $e^* = (1-d)(1-\beta)m$. If $\hat{e} = e^*$, we get $\beta^* = 1 - \frac{d}{m(1-d)(b+d-db)}$. It can be shown that $\beta^* < 0$ given our assumptions about b , d , and m . Thus the mixed-bidding-strategy under the belief $\hat{e} = \frac{d}{b+d-db}$ cannot be an equilibrium strategy.

- When the raider's belief satisfies $\hat{e} < \frac{1-d}{1-d+db}$ such that she always offers a low price, i.e., $\alpha = \beta = 0$, the manager's expected payoff is:

$$\Pi_m(e) = e \cdot m - \frac{1}{2}e^2. \quad (\text{A.5})$$

By taking the first order condition of $\Pi_m(e)$ with respect to e , we obtain the manager's optimal effort of $e^* = m$. To satisfy the raider's belief constraint, $e^* = m = \hat{e} < \frac{1-d}{1-d+db}$ must hold, i.e., $d < \frac{1-m}{1-(1-b)m}$. Given our assumption about d , $\frac{1}{2} \leq d \leq 1$, we have $d < \frac{1-m}{1-(1-b)m}$ holds if and only if $C1$ holds, where $C1$ is $m < \frac{1}{1+b}$ and $\frac{1}{2} \leq d < \frac{1-m}{1-(1-b)m}$.

- When the raider's belief is $\hat{e} = \frac{1-d}{1-d+db}$, the raider offers a low price when observing the bad signal, $\beta = 0$. When observing the good signal, the raider is indifferent between two prices and she follows a mixed-bidding-strategy:

$$p(G) = \begin{cases} p_l & \text{with probability } 1 - \alpha \\ p_h & \text{with probability } \alpha \end{cases}$$

Then the manager's expected payoff is:

$$\Pi_m(e) = [1 - d + d(1 - \alpha)] \cdot e \cdot m - \frac{1}{2}e^2. \quad (\text{A.6})$$

By taking the first order condition of $\Pi_m(e)$ with respect to e , we obtain the manager's optimal effort of $e^* = m(1 - d\alpha)$. To satisfy the raider's belief $e^* = \hat{e}$, $m(1 - d\alpha) = \frac{1-d}{1-d+db}$ must hold, i.e., $\alpha^* = \frac{1}{d} \frac{bdm - (1-d)(1-m)}{(1-d)m + bdm}$. It can be shown that $0 < \alpha^* < 1$ if and only if condition C2 holds, where C2 is $m > \frac{1}{1+b}$, or $m < \frac{1}{1+b}$ and $\frac{1-m}{1-(1-b)m} \leq d < 1$.

□

Proof of Corollary 1

Proof. In the mixed-price-bidding equilibrium, the manager's optimal effort $e^* = \frac{1-d}{1-d+db}$. The raider always offers a low price v_0 upon a bad signal, and offers a high price $1 + v_0$ with probability α^* and a low price v_0 with probability $1 - \alpha^*$ upon a good signal, where $\alpha^* = \frac{1}{d} \frac{bdm - (1-d)(1-m)}{(1-d)m + bdm}$.

Given our assumption about b , d , and m , we have

$$\frac{\partial e^*}{\partial d} = -\frac{b}{(1-d+db)^2} < 0,$$

$$\text{and } \frac{\partial \alpha^*}{\partial d} = \frac{1-m-(1-b)d\{2-d-m[2-(1-b)d]\}}{m(d-d^2+bd^2)^2} > 0. \quad \square$$

Proof of Proposition 5

Proof. Given Equations (3.6) and (3.7), according to Proposition 4, the expected payoff for the current shareholder is

$$\Pi_s = \begin{cases} e^* + (1 - e^*)v_0, & \text{given C1,} \\ e^* + [1 - e^* + e^*d\alpha^*]v_0 + [(1 - e^*)(1 - d)\alpha^*], & \text{given C2.} \end{cases}$$

The expected firm value is

$$\Pi_v = \begin{cases} e^* + (1 - e^*)v_0, & \text{given C1,} \\ e^* + [1 - e^* + e^*d\alpha^*]v_0 & \text{given C2.} \end{cases}$$

$$\text{C1: } m \leq \frac{1}{1+b} \text{ and } d < \frac{1-m}{1-(1-b)m};$$

C2: $m > \frac{1}{1+b}$, or $m \leq \frac{1}{1+b}$ and $d \geq \frac{1-m}{1-(1-b)m}$.

In the low-price-bidding equilibrium (*C1* holds), $e^* = m$. In the mixed-price-bidding equilibrium (*C2* holds), $e^* = \frac{1-d}{1-d+db}$ and $\alpha^* = \frac{1}{d} \frac{b d m - (1-d)(1-m)}{(1-d)m + b d m}$.

Substituting e^* and α^* into Π_s and Π_v , we have

$$\Pi_s = \begin{cases} m + (1-m)v_0, & \text{given } C1 \\ \frac{b^2 d m [1-d(1-v_0)] + (1-d)^2 [m - (1-m)v_0] + b(1-d)(d+m+2d m v_0 - 1)}{[1-(1-b)d]^2 m}, & \text{given } C2 \end{cases}, \quad (\text{A.7})$$

and

$$\Pi_v = \begin{cases} m + (1-m)v_0, & \text{given } C1 \\ \frac{-(1-d)^2 v_0 + [1-(1-b)d]m\{1+v_0-d[1+(1-b)v_0]\}}{[1-(1-b)d]^2 m}, & \text{given } C2 \end{cases}. \quad (\text{A.8})$$

It's easy to prove that Π_s and Π_v are continuous under our assumptions about b , d , m , and v_0 . We will prove the following two cases separately: (1) when $m \leq \frac{1}{1+b}$, and (2) when $m > \frac{1}{1+b}$.

1. When $m \leq \frac{1}{1+b}$, both low-price-bidding equilibrium and mixed-price bidding-equilibrium are possible depending on the information quality d .
 - When $\frac{1}{2} < d \leq \frac{1-m}{1-(1-b)m}$, the equilibrium is the low-price-bidding equilibrium. Choosing any information quality within this range yields the same payoff for both the current shareholders and the expected firm value, $\Pi_s = \Pi_v = m + (1-m)v_0$.
 - When $\frac{1-m}{1-(1-b)m} \leq d \leq 1$, the equilibrium is the mixed-price-bidding equilibrium.

Taking the partial derivative of Π_s with respect to d , we have

$$\frac{\partial \Pi_s}{\partial d} = \frac{-b[b^2 d m - b(2-2d-m) + (1-d)(m-2v_0)]}{(1-d+bd)^3 m}.$$

Solving the first order condition $\frac{\partial \Pi_s}{\partial d} = 0$, we have $d_s = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$.

The second order condition holds, i.e., $\frac{\partial^2 \Pi_s}{\partial d^2} |_{d_s} = \frac{-[m-(2+bm)b-2v_0]^4}{8b^2 m(b+v_0)^3} < 0$.

Similarly, taking the partial derivative of Π_v with respect to d , we have

$$\frac{\partial \Pi_v}{\partial d} = \frac{-b[bm(1-d+bd) - 2(1-d)v_0]}{(1-d+bd)^3 m}.$$

Solving the first order condition $\frac{\partial \Pi_v}{\partial d} = 0$, we have $d_v = \frac{2v_0-m}{2v_0+bm-m}$. In addition, the second order condition holds, i.e., $\frac{\partial^2 \Pi_v}{\partial d^2} |_{d_v} = \frac{-[(b-1)m+2v_0]^4}{8b^2 m v_0^3} < 0$.

Next, we need to check whether the maximum points d_s and d_v are within the feasible range of d , $d \in [\frac{1-m}{1-(1-b)m}, 1]$.

- If $\frac{1-m}{1-(1-b)m} < d_s < 1$, i.e., $\frac{1-b}{2} < v_0 < 1$, the optimal information quality that maximizes the current shareholders' expected payoff is $d_s^* = d_s = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$.
- If $d_s \notin (\frac{1-m}{1-(1-b)m}, 1)$, i.e., $0 < v_0 < \frac{1-b}{2}$, we need to compare Π_s at $\frac{1-m}{1-(1-b)m}$ and 1. Since $\Pi_s(d = \frac{1-m}{1-(1-b)m}) = m + (1-m)v_0 > \Pi_s(d = 1) = v_0$, the optimal information quality is $\frac{1}{2} \leq d_s^* < \frac{1-m}{1-(1-b)m}$, with $\Pi_s(d_s^*) = m + (1-m)v_0$. The proof is the same for d_v^* .

In sum, the optimal information quality that maximizes the current shareholders' expected payoff when $m \leq \frac{1}{1+b}$ is

$$d_s^* = \begin{cases} [\frac{1}{2}, \frac{1-m}{1-(1-b)m}], & \text{if } 0 < v_0 \leq \frac{1-b}{2} \\ \frac{2v_0-m+b(2-m)}{2v_0-m+b(2+bm)}, & \text{if } \frac{1-b}{2} < v_0 < 1 \end{cases} \quad (\text{A.9})$$

Similarly, we can get the optimal information quality that maximizes the expected firm value when $m \leq \frac{1}{1+b}$ as below:

$$d_v^* = \begin{cases} [\frac{1}{2}, \frac{1-m}{1-(1-b)m}], & \text{if } 0 < v_0 \leq \frac{1}{2} \\ \frac{2v_0-m}{2v_0-m+bm}, & \text{if } \frac{1}{2} < v_0 < 1 \end{cases} \quad (\text{A.10})$$

2. When $m > \frac{1}{1+b}$, only the mixed-price-bidding equilibrium is possible. In this case we need to check whether the maximum points d_s and d_v are within the feasible range of d , $[\frac{1}{2}, 1]$.

- If $d_s = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m} \in (\frac{1}{2}, 1)$, i.e., $\frac{m(1+b)^2}{2} - b < v_0 < 1$, $d_s^* = d_s$. If $\frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m} \notin (\frac{1}{2}, 1)$, i.e., $0 < v_0 < \frac{m(1+b)^2}{2} - b$, then $d_s^* = \frac{1}{2}$ because $\Pi_s(d = \frac{1}{2}) > \Pi_s(d = 1)$.
- If $d_v = \frac{2v_0-m}{2v_0+bm-m} \in (\frac{1}{2}, 1)$, i.e., $\frac{m(1+b)}{2} < v_0 < 1$, $d_v^* = d_v$. If $\frac{2v_0-m}{2v_0+bm-m} \notin (\frac{1}{2}, 1)$, i.e., $v_0 < \frac{m(1+b)}{2}$, then $d_v^* = \frac{1}{2}$ because $\Pi_v(d = \frac{1}{2}) > \Pi_v(d = 1)$.

Thus when $m > \frac{1}{1+b}$, we have the following optimal information quality that maximizes the current shareholders' expected payoff and the expected firm value, respectively,

$$d_s^* = \begin{cases} \frac{1}{2}, & \text{if } 0 < v_0 \leq \frac{(1+b)^2 m}{2} - b, \\ \frac{2v_0-m+b(2-m)}{2v_0-m+b(2+bm)}, & \text{if } \frac{(1+b)^2 m}{2} - b < v_0 < 1, \end{cases} \quad (\text{A.11})$$

$$d_v^* = \begin{cases} \frac{1}{2}, & \text{if } 0 < v_0 \leq \frac{(1+b)m}{2}, \\ \frac{2v_0-m}{2v_0-m+bm}, & \text{if } \frac{(1+b)m}{2} < v_0 < 1. \end{cases} \quad (\text{A.12})$$

Combining (A.9)-(A.12), we get Proposition 5. □

Proof of Corollary 2

Proof. Let us consider the case in which $0 < m < \frac{1}{1+b}$ and the case in which $\frac{1}{1+b} \leq m < 1$.

When $0 < m < \frac{1}{1+b}$:

- for $0 < v_0 \leq \frac{1-b}{2}$, d_s^* and d_v^* can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b)m}]$;
- for $\frac{1-b}{2} < v_0 \leq \frac{1}{2}$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$, and d_v^* can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b)m}]$. Since it can be proved $\frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m} > \frac{1-m}{1-(1-b)m}$, we have $d_s^* > d_v^*$;
- for $\frac{1}{2} < v_0 \leq 1$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$, and $d_v^* = \frac{2v_0-m}{2v_0+bm-m}$, and $d_s^* > d_v^*$ holds.

When $\frac{1}{1+b} \leq m < 1$:

- for $0 < v_0 \leq \frac{m(1+b)^2}{2} - b$, $d_s^* = d_v^* = \frac{1}{2}$;
- for $\frac{m(1+b)^2}{2} - b < v_0 \leq \frac{m(1+b)}{2}$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m} > d_v^* = \frac{1}{2}$;
- for $\frac{m(1+b)}{2} < v_0 \leq 1$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$ and $d_v^* = \frac{2v_0-m}{2v_0+bm-m}$, $d_s^* > d_v^*$ holds.

Combining all cases, we conclude that $d_s^* \geq d_v^*$. □

Proof of Proposition 6

Proof. We only show the proof for the change of the optimal information quality, d_s^* , that maximizes the current shareholders' payoff. Similar proof follows for the optimal information quality, d_v^* , that maximizes the expected firm value.

Suppose the raider's private benefit b decreases to b' after antitakeover laws, where $0 < b' < b < 1$. The optimal information quality levels for the current shareholders are d_s^* and d_s^{**} before and after the antitakeover laws, respectively.

1. When $0 < m < \frac{1}{1+b}$:

- For $0 < v_0 \leq \frac{1-b}{2}$, according to Proposition 5, d_s^* can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b)m}]$; d_s^{**} can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b')m}]$. Since $b' < b$, we can show that $\frac{1-m}{1-(1-b)m} < \frac{1-m}{1-(1-b')m}$. d_s^{**} varies in a larger range than d_s^* .
- For $\frac{1-b}{2} < v_0 \leq \frac{1-b'}{2}$, according to Proposition 5, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$; d_s^{**} can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b')m}]$. It can be shown that $\frac{1-m}{1-(1-b')m} > \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$. Therefore d_s^{**} could be higher than d_s^* .

- For $\frac{1-b'}{2} < v_0 \leq 1$, according to Proposition 5, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$ and $d_s^{**} = \frac{b'(2-m)-m+2v_0}{b'(2+bm)+2v_0-m}$. It can be shown that $d_s^{**} > d_s^*$.

Notice that as $b \rightarrow 0$, for $0 < v_0 \leq \frac{1}{2}$, d_s^* and d_s^{**} can be any value in the range $[\frac{1}{2}, 1]$; for $v_0 > \frac{1}{2}$, $d_s^* \rightarrow 1$ and $d_s^{**} \rightarrow 1$.

2. When $\frac{1}{1+b} \leq m < \frac{1}{1+b'}$, we need to consider two cases: (i) $b > \frac{1+\sqrt{1-(1+b')m}}{m} - 1$, and (ii) $b \leq \frac{1+\sqrt{1-(1+b')m}}{m} - 1$.

- If $b > \frac{1+\sqrt{1-(1+b')m}}{m} - 1$, it can be proved $\frac{1-b'}{2} < \frac{m(1+b)^2}{2} - b$.
 - For $0 < v_0 \leq \frac{1-b'}{2}$, according to Proposition 5, $d_s^* = \frac{1}{2}$ and d_s^{**} can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b')m}]$. Therefore $d_s^{**} \geq d_s^*$.
 - For $\frac{1-b'}{2} < v_0 \leq \frac{m(1+b)^2}{2} - b$, according to Proposition 5, $d_s^* = \frac{1}{2}$ and $d_s^{**} = \frac{b'(2-m)-m+2v_0}{b'(2+bm)+2v_0-m}$. Therefore $d_s^{**} > d_s^*$.
 - For $\frac{m(1+b)^2}{2} - b < v_0 \leq 1$, according to Proposition 5, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$ and $d_s^{**} = \frac{b'(2-m)-m+2v_0}{b'(2+bm)+2v_0-m}$. It can be shown that $d_s^{**} > d_s^*$.
- If $b \leq \frac{1+\sqrt{1-(1+b')m}}{m} - 1$, it can be proved $\frac{1-b'}{2} \geq \frac{m(1+b)^2}{2} - b$.
 - For $0 < v_0 \leq \frac{m(1+b)^2}{2} - b$, according to Proposition 5, $d_s^* = \frac{1}{2}$; d_s^{**} can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b')m}]$. Therefore $d_s^{**} \geq d_s^*$.
 - For $\frac{m(1+b)^2}{2} - b < v_0 \leq \frac{1-b'}{2}$, according to Proposition 5, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$; d_s^{**} can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b')m}]$. It can be shown that $\frac{1-m}{1-(1-b')m} > \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$, thus d_s^{**} could be higher than d_s^* .
 - For $\frac{1-b'}{2} < v_0 \leq 1$, according to Proposition 5, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$ and $d_s^{**} = \frac{b'(2-m)-m+2v_0}{b'(2+bm)+2v_0-m}$. It can be shown that $d_s^{**} > d_s^*$.

3. When $\frac{1}{1+b'} \leq m < 1$:

- For $0 < v_0 \leq \frac{m(1+b')^2}{2} - b'$, according to Proposition 5, $d_s^* = d_s^{**} = \frac{1}{2}$.
- For $\frac{m(1+b')^2}{2} - b' < v_0 \leq \frac{m(1+b)^2}{2} - b$, according to Proposition 5, $d_s^* = \frac{1}{2}$ and $d_s^{**} = \frac{b'(2-m)-m+2v_0}{b'(2+bm)+2v_0-m}$. It can be shown $d_s^{**} > d_s^*$.
- For $\frac{m(1+b)^2}{2} - b < v_0 \leq 1$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$, and $d_s^{**} = \frac{b'(2-m)-m+2v_0}{b'(2+bm)+2v_0-m}$. It can be shown $d_s^{**} > d_s^*$.

Combining all above cases, we get $d_s^{**} \geq d_s^*$ for any $b' < b$.

□

Proof of Proposition 7

Proof. The shareholder's expected payoff Π_s and the expected firm's value Π_v in equilibrium are given by Eq (A.7) and Eq (A.8), respectively. Given the optimal information quality d_s^* derived in Proposition 5, we have the following analysis.

1. When $0 < m < \frac{1}{1+b}$:

- For $0 < v_0 \leq \frac{1-b}{2}$, d_s^* can be any value in the range $[\frac{1}{2}, \frac{1-m}{1-(1-b)m}]$.

$\Pi_v(d_s^*) = \Pi_s(d_s^*) = m + v_0 - mv_0$. Decreasing b does not affect neither Π_v or Π_s .

- For $\frac{1-b}{2} < v_0 \leq 1$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$.

We have $\Pi_v(d_s^*) = \frac{b^2[m(2-v_0)+4v_0]+(2b+v_0)(m+4v_0^2)}{4(b+v_0)^2}$, and $\Pi_s(d_s^*) = v_0 + \frac{(1+b)^2 m}{4(b+v_0)}$.

Taking the partial derivative of $\Pi_v(d_s^*)$ and $\Pi_s(d_s^*)$ with respect to b , we have $\frac{\partial \Pi_v(d_s^*)}{\partial b} = \frac{-bm(1-v_0)^2}{2(b+v_0)^3} < 0$, and $\frac{\partial \Pi_s(d_s^*)}{\partial b} = \frac{(1+b)m(b+2v_0-1)}{4(b+v_0)^2} > 0$. Therefore, as b decreases, $\Pi_v(d_s^*)$ increases and $\Pi_s(d_s^*)$ decreases.

2. When $\frac{1}{1+b} \leq m < 1$:

- For $0 < v_0 \leq \frac{1-b}{2}$, $d_s^* = \frac{1}{2}$.

We have $\Pi_v(d_s^*) = \frac{(1+b)m(1+v_0+bv_0)-v_0}{m(1+b)^2}$ and $\Pi_s(d_s^*) = \frac{m+b(-1+(2+b)m)-v_0+(1+b)^2 mv_0}{m(1+b)^2}$.

Taking the partial derivative of $\Pi_v(d_s^*)$ and $\Pi_s(d_s^*)$ with respect to b , we have $\frac{\partial \Pi_v(d_s^*)}{\partial b} = \frac{2v_0-(1+b)m}{m(1+b)^3} < 0$; $\frac{\partial \Pi_s(d_s^*)}{\partial b} = \frac{2v_0-1+b}{m(1+b)^3} < 0$. Therefore, as b decreases, $\Pi_v(d_s^*)$ increases, and $\Pi_s(d_s^*)$ increases.

- For $\frac{1-b}{2} < v_0 \leq \frac{m(1+b)^2}{2} - b$, $d_s^* = \frac{1}{2}$.

We have $\Pi_v(d_s^*) = \frac{(1+b)m(1+v_0+bv_0)-v_0}{m(1+b)^2}$ and $\Pi_s(d_s^*) = \frac{m+b(-1+(2+b)m)-v_0+(1+b)^2 mv_0}{m(1+b)^2}$.

Taking the partial derivative of $\Pi_v(d_s^*)$ and $\Pi_s(d_s^*)$ with respect to b , we have $\frac{\partial \Pi_v(d_s^*)}{\partial b} = \frac{2v_0-(1+b)m}{m(1+b)^3} < 0$; $\frac{\partial \Pi_s(d_s^*)}{\partial b} = \frac{2v_0-1+b}{m(1+b)^3} > 0$. Therefore, as b decreases, $\Pi_v(d_s^*)$ increases, and $\Pi_s(d_s^*)$ decreases.

- For $\frac{m(1+b)^2}{2} - b < v_0 \leq 1$, $d_s^* = \frac{b(2-m)-m+2v_0}{b(2+bm)+2v_0-m}$.

We have $\Pi_v(d_s^*) = \frac{b^2[m(2-v_0)+4v_0]+(2b+v_0)(m+4v_0^2)}{4(b+v_0)^2}$, and $\Pi_s(d_s^*) = v_0 + \frac{(1+b)^2 m}{4(b+v_0)}$.

Taking the partial derivative of $\Pi_v(d_s^*)$ and $\Pi_s(d_s^*)$ with respect to b , we have $\frac{\partial \Pi_v(d_s^*)}{\partial b} = \frac{-bm(1-v_0)^2}{2(b+v_0)^3} < 0$, and $\frac{\partial \Pi_s(d_s^*)}{\partial b} = \frac{(1+b)m(b+2v_0-1)}{4(b+v_0)^2} > 0$. Therefore, as b decreases, $\Pi_v(d_s^*)$ increases and $\Pi_s(d_s^*)$ decreases.

Combining all the cases, we get Proposition 7.

□

A.3. Appendix to Chapter 4

Proof of Lemma 6:

Proof. The deduction of $w_2(y)$ follows standard procedures. We have:

$y = i \cdot (m + a) + e + \epsilon$, where $a \sim N[0, 1/h_a]$, and $\epsilon \sim N[0, 1/h]$.

Therefore, after observing y , the labor market's updated belief about a , $w_2(y)$, is:

$$w_2(y) = E[a|y] = \frac{Cov(a, y)}{Var[y]} \cdot (y - E[y]).$$

Since $Cov(a, y) = i/h_a$ and $E[y] = i \cdot m + \hat{e}$, the above equation yields $w_2(y) = k_2(y - i \cdot m - \hat{e})$, where $k_2 = \frac{i/h_a}{var_y}$ and $var_y \equiv Var[y] = i^2/h_a + 1/h$.

It can be proved that $\frac{\partial k_2}{\partial h} > 0$, and $\frac{\partial k_2}{\partial h_a} < 0$. □

Proof of Lemma 7:

Proof. From Eq 4.4, $C_R = \frac{\rho}{2h_a} \frac{i^2/h_a}{var_y}$. Substituting $var_y = i^2/h_a + 1/h$ into C_R , it can be derived that:

$$\frac{\partial C_R}{\partial h} = \frac{i^2 \rho}{2(h_a + h \cdot i^2)^2} > 0;$$

$$\frac{\partial C_R}{\partial i} = \frac{h \cdot i \cdot \rho}{(h_a + h \cdot i^2)^2} > 0. \quad \square$$

Proof of Proposition 8:

Proof. In the model, the shareholders make decisions on the i , h , and w_1 simultaneously. However, for the sake of illustration, I first calculate the shareholders' optimal linear contract taking information i and h as given. Then, I solve for the shareholders' optimal information quality given i and the shareholders' optimal linear contract. Finally, I solve for the shareholders optimal investment decision. According to the envelope theorem, the result I derive from solving the three choice variables sequentially will be the same as solving them simultaneously.

First, I solve for the shareholders optimal linear contract taking h and i as given: $w_1^*(i, h)$. Substituting the manager's optimal effort $e^* = k_1 + k_2$ into the manager's expected utility function Eq 4.2 yields:

$$U(w_1, w_2, e) = k_1(i \cdot m + k_1 + k_2) + c_1 - \frac{\rho}{2} k_1^2 var_y - \frac{1}{2} (k_1 + k_2)^2 - \frac{\rho}{2} k_2^2 var_y.$$

In the equilibrium, the manager's IR constraint should be binding, namely $U(w_1, w_2, e) = 0$. It can be easily verified that $var_y = \frac{i/h_a}{k_2}$. As a result, c_1 can be derived as:

$$c_1^*(k_1, i, h) = \frac{k_2^2 - k_1^2 + (k_2^2 + k_1^2)\rho \cdot var_y}{2} - k_1 \cdot i \cdot m.$$

Substituting $c_1 = c_1^*(k_1, i, h)$ into shareholder's objective function as shown in Eq 4.5, and from the first order condition w.r.t k_1 , it can be derived:

$$k_1^*(i, h) = \frac{1-k_2}{1+\rho var_y}.$$

Consequently, $c_1^*(i, h)$ can be calculated as:

$$c_1^*(i, h) = c_1^*(k_1^*(i, h), i, h) = \frac{k_2^2 - k_1^{*2} + (k_2^2 + k_1^{*2})\rho \cdot var_y}{2} - k_1^* \cdot i \cdot m.$$

The shareholders' optimal linear contract taking i and h as given is:

$$w_1^*(i, h) = k_1^*(i, h) \cdot y + c_1^*(i, h).$$

Next, I solve for the shareholders optimal information quality given $w_1^*(i, h)$ and i : $h^*(i)$. After substituting $e = k_1 + k_2$, $k_2 = \frac{i/h_a}{var_y}$ and $w_1^*(i, h)$ derived above into Eq 4.5, the shareholder objective function can be expressed as:

$$\pi_s(h, i) = i \cdot m + \frac{1 + \rho \cdot i/h_a \cdot (2 - \frac{i}{h_a}/var_y)}{2(1 + \rho \cdot var_y)} - \frac{\rho}{2h_a} \frac{i^2/h_a}{var_y} - \frac{c}{2}i^2. \quad (A.13)$$

In order to derive the optimal h for a given level of i , $h^*(i)$, it is instructive to solve for the optimal volatility of the signal, var_y , for the shareholders first. Because $var_y = i^2/h_a + 1/h$ and $h > 0$, var_y should be no less than i^2/h_a . I focus on the interior solution which is sustainable under Condition 1. From the first order condition of $\pi_s(h, i)$ w.r.t var_y , with Condition 1, it can be derived:

$$var_y^*(i) = \frac{i[\sqrt{2}h_a + (2+\sqrt{2})i\rho]}{h_a^2 + 2i\rho h_a - i^2\rho^2}.$$

The optimal information quality $h^*(i)$ can be calculated as:

$$h^*(i) = \frac{1}{var_y^*(i) - i^2/h_a}.$$

Substituting $var_y = var_y^*(i)$ into $k_1^*(i, h) = \frac{1-k_2}{1+\rho var_y}$ and $k_2 = \frac{i/h_a}{var_y}$, we can obtain $k_1^*(i) = 1 - \frac{\sqrt{2}}{2} - \frac{3\sqrt{2}-4}{2h_a}i\rho$ and $k_2^*(i) = \frac{\sqrt{2}}{2} - \frac{(2-\sqrt{2})}{2h_a}i\rho$.

Now, I calculate the shareholders optimal i in the equilibrium. Substituting $h = h^*(i)$ and $w_1 = w_1^*(i, h)$ into Eq 4.5, the shareholder's objective function can be expressed as

$$\pi_s(i) = i \cdot m + \frac{h_a^2 - 2(\sqrt{2} - 1)h_a i\rho + (3 - 2\sqrt{2})i^2\rho^2}{2h_a^2} - \frac{c}{2}i^2.$$

The first order condition w.r.t. i yields:

$$i^* = \frac{h_a^2 m - (\sqrt{2}-1)\rho h_a}{h_a^2 c - (3-2\sqrt{2})\rho^2}. \quad \square$$

Proof of Corollary 3:

Proof. It can be verified that under Condition 1,

$$\frac{\partial i^*}{\partial m} = \frac{1}{c - (3-2\sqrt{2})(\rho/h_a)^2} > 0 \text{ and } \frac{\partial h^*(i)}{\partial i} < 0.$$

Therefore, I can derive that $\frac{\partial h^*}{\partial m} = \frac{\partial h^*(i)}{\partial i^*} \cdot \frac{\partial i^*}{\partial m} < 0$. \square

Proof of Corollary 4:

Proof. It can be easily verified that $i^* = \frac{h_a^2 m - (\sqrt{2}-1)\rho h_a}{h_a^2 c - (3-2\sqrt{2})\rho} < i_0 = m/c$ for any $\rho/h_a > 0$. \square

Proof of Proposition 9:

$$Proof. \quad \frac{d i^*}{d \frac{\rho}{h_a}} = (5\sqrt{2} - 7) \cdot \frac{-(\rho/h_a)^2 + 2(1+\sqrt{2})m \cdot \rho/h_a - (3+2\sqrt{2})c}{[c - (3-2\sqrt{2})(\rho/h_a)^2]^2}$$

Therefore, it can be derived that:

$$\frac{d i^*}{d \frac{\rho}{h_a}} < 0 \text{ if } m < \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}, \text{ and } \frac{d i^*}{d \frac{\rho}{h_a}} > 0 \text{ if } m > \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}. \quad \square$$

Proof of Proposition 10:

Proof. Substituting $i^* = \frac{h_a^2 m - (\sqrt{2}-1)\rho h_a}{h_a^2 c - (3-2\sqrt{2})\rho}$ into k_1^* as shown in Eq 4.10, we can rewrite k_1^* as:

$$k_1^* = \frac{(2-\sqrt{2}) \cdot c - (3\sqrt{2}-4)m \cdot \rho/h_a}{2[c - (3-2\sqrt{2})(\rho/h_a)^2]}.$$

$$\text{As a result, we have } \frac{d k_1^*}{d \frac{\rho}{h_a}} = \frac{2(10-7\sqrt{2})c \cdot \rho/h_a - m[(17\sqrt{2}-24)(\rho/h_a)^2 + (3\sqrt{2}-4)c]}{2[c - (3-2\sqrt{2})(\rho/h_a)^2]^2}.$$

Therefore, we can derive:

$$\frac{d k_1^*}{d \frac{\rho}{h_a}} < 0 \text{ if } m > \frac{(6-4\sqrt{2})c\rho/h_a}{(5\sqrt{2}-7)(\rho/h_a)^2 + (\sqrt{2}-1)c}, \text{ and } \frac{d k_1^*}{d \frac{\rho}{h_a}} > 0 \text{ if } m < \frac{(6-4\sqrt{2})c\rho/h_a}{(5\sqrt{2}-7)(\rho/h_a)^2 + (\sqrt{2}-1)c}. \quad \square$$

Proof of Proposition 11:

Proof. Substituting $i^* = \frac{h_a^2 m - (\sqrt{2}-1)\rho h_a}{h_a^2 c - (3-2\sqrt{2})\rho}$, h^* and w_1^* derived in Proposition 8 into the shareholders' payoff function as shown in Eq 4.5, the shareholders' equilibrium expected payoff can be calculated as:

$$\pi_s^*(m, \frac{\rho}{h_a}) = \frac{c + m[m - 2(\sqrt{2}-1)\rho/h_a]}{2[c - (3-2\sqrt{2})(\rho/h_a)^2]}.$$

As a result, we have:

$$\frac{d^2 \pi_s^*(m, \frac{\rho}{h_a})}{dm d \frac{\rho}{h_a}} = \frac{-(5\sqrt{2}-7)(\rho/h_a)^2 + (6-4\sqrt{2})m \cdot \rho/h_a - (\sqrt{2}-1)c}{[c - (3-2\sqrt{2})(\rho/h_a)^2]^2}.$$

Therefore, we can derive:

$$\begin{aligned} -\frac{d^2 \pi_s^*(m, \frac{\rho}{h_a})}{dm d \frac{\rho}{h_a}} &> 0 \text{ if } m < \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}; \\ -\frac{d^2 \pi_s^*(m, \frac{\rho}{h_a})}{dm d \frac{\rho}{h_a}} &< 0 \text{ if } m > \frac{(\sqrt{2}-1)(\rho/h_a)^2 + (\sqrt{2}+1)c}{2\rho/h_a}. \end{aligned}$$

□

Proof of Proposition 12:

Proof. Taking the linear contract w_1 as the optimal contract given i and h , $w_1^*(h, i)$, we have the shareholders' expected payoff function as $\pi_s(k_1^*, c_1^*, h, i)$.

For a given level of h , the optimal investment for the shareholder, $i^*(h)$ should satisfy the first order condition that:

$$\frac{\partial \pi_s(k_1^*, c_1^*, h, i)}{\partial i} = 0 \text{ for } i = i^*(h).$$

The impact of h on the above first order condition is:

$$\frac{\partial \frac{\partial \pi_s(k_1^*, c_1^*, h, i)}{\partial i}}{\partial h} = \frac{\partial^2 \pi_s(k_1^*, c_1^*, h, i)}{\partial i \partial h}.$$

In the equilibrium, we have $i = i^*$ and $h = h^* = h^*(i^*)$. $h^*(i)$ is shown in Proposition 8.

As shown in the proof of Proposition 8, we have $\frac{\partial \pi_s(k_1^*, c_1^*, h, i)}{\partial h} = 0$ if $h = h^*(i)$ for any i . It can be verified that

$$\frac{\partial h^*(i)}{\partial i} = -\frac{\frac{\partial^2 \pi_s(k_1^*, c_1^*, h, i)}{\partial i \partial h}}{\frac{\partial^2 \pi_s(k_1^*, c_1^*, h, i)}{\partial h^2}}, \text{ where } h = h^*(i).$$

The denominator of the above equation, $\frac{\partial^2 \pi_s(k_1^*, c_1^*, h, i)}{\partial h^2}$ is negative for $h = h^*(i)$. Therefore, if $h = h^*(i)$, we have $\frac{\partial^2 \pi_s(k_1^*, c_1^*, h, i)}{\partial i \partial h} \propto \frac{\partial h^*(i)}{\partial i}$.

As derived in the proof of Corollary 3, $\frac{\partial h^*(i)}{\partial i} < 0$. As a result, $\frac{\partial^2 \pi_s(k_1^*, c_1^*, h, i)}{\partial i \partial h} < 0$ for $i = i^*$ and $h = h^*$. □

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