# Investment, voluntary disclosure, and managerial incentives

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# Acknowledgements

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# Chapter 1

# Introduction

## 1.1 Introduction

### 1.1.1 Main research topic

This thesis is concerned with managerial investment incentives and voluntary disclosure, and how they work together. I study a setting where the manager makes three decisions; operating, investment and reporting decisions. The reporting decision is in this thesis represented by a voluntary disclosure decision; the manager can decide whether or not to disclose information about the investment decision he has already taken. How will the manager's reporting decision influence his incentives to invest? I look at the usefulness of the stock price in inducing investment when the manager controls the information that the stock market receives, and I relate this to accruals and how accruals can create investment incentives. I also study how the manager's control over the disclosure decision influences the owners' payoff and the contract that they will offer the manager. I develop an agency model to analyze these questions.

### 1.1.2 Developments in accounting theory

Today the informational approach to financial reporting and financial accounting research is well established. The central theme in the informational approach is that financial accounting data should provide information that is useful to financial statement users. The importance of the information approach is emphasized in the FASB's Statement of Financial Accounting

Concepts No. 1 (1978), paragraph 37, which states that:

"Financial reporting should provide information that is useful to present and potential investors and creditors and other users in assessing the amounts, timing, and uncertainty of prospective cash receipts."

The informational approach has not always been prevalent in accounting. Prior to the 1960s, the focus in accounting was on measurement; the measurement of the different parts of the financial statement such as earnings, asset and liabilites, and their specific elements (Beaver (2000)). To illustrate; in 1941 the Committee on Terminology of the American Institute of Certified Public Accountants (AICPA) defined accounting in terms of "recording, classifying and summarizing in a significant manner and in terms of money, transactions and events, which are in part, at least of financial character, and interpreting the results thereof". This was a transaction-based focus, with an emphasis on historical cost measurement.

Beaver (1998) called the transition to the informational approach in the 1960s an accounting revolution. At this time, not only the focus, but also the methods and tools in accounting research changed. In the 1960s, accounting researchers started to use information economics in their research. Information economics introduced analytical models that could be used to address accounting issues and also emphasized the informational approach[1]. Early contributions include Feltham (1968) and Demski and Feltham (1970).

There are still measurement issues in the informational approach, though. One example is fair value measurement. Fair value is said to contain more relevant information, since it reflects, or should reflect, current market values. But fair value is also a measurement issue; it is one of several alterantive ways to measure the value of an asset in the financial statement.

### 1.1.3 Agency theory in accounting

Agency theory is part of information economics and has become widely used in accounting research. Lambert (2001) gives an extensive overview of agency theory in accounting (mostly management accounting), and he states that "The primary feature of agency theory that has made it attractive to accounting researchers is that it allows us to explicitly incorporate conflicts

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[1] Following Ball and Brown's (1968) empirical study of the association between accounting numbers and changes in share price, also a new stream of empirical research emerged (Nichols and Wahlen (2004)) at around this time.

of interest, incentive problems, and mechanisms for controlling incentive problems into our models. This is important because much of the motivation for accounting and auditing has to do with the control of incentive problems".

Principal features of agency models are conflicts of interest, asymmetric information and uncertainty. Jensen and Meckling (1976) see the company as a nexus of contracts and show that agency theory can be used to study the conflicts that can arise between different parties (for instance beteween equity holders and debt holders, and between managers and owners). In my model, I use a principal-agent setting where the manager is the agent, and owners are principals, and I study the conflict of interest between these two parties.

Asymmetric information describes a situation where one of two (or more) parties has information that the other party does not have. For instance, the manager can possess information that owners do not have, about the company or about his own actions. Asymmetric information can take two forms; hidden action or hidden information. Hidden action (or moral hazard) occurs when the agent takes an action that the principal does not observe, while hidden information describes a situation where the agent has private information, either before or after the contract between them is signed. I will mainly focus on hidden action in my model.

Figure 1.1 is from Lambert (2001) and describes a typical time-line for a principal-agent model. First the parties agree on a contract $s$, then the agent chooses an action $a$ that creates an uncertain outcome $x$. After this, a performance measure $y$ is observed. The agent is compensated based on the performance measure according to the contract, and finally, the principal keeps the net outcome.



Contract s(x,y)  Agent selects action (**a**)  Performance measure (x,**y**, etc) observed  Agent is paid s(x,**y**) Principal keeps x-s(x,**y**)
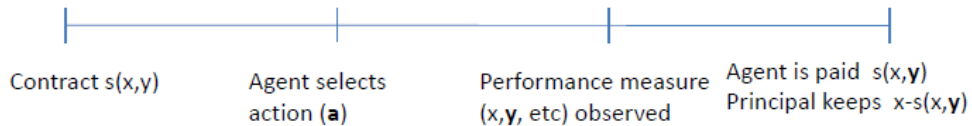
Figure 1.1. The timeline in a principal-agent model (Lambert (2001)).

According to Lambert (2001), there are two basic questions in accounting that are addressed using agency theory: "(i) How do features of information, accounting and compensation systems affect (reduce or make worse) incentive problems, and (ii) how does the existence of incentive

problems affect the design and structure of information, accounting, and compensation systems?".

Holmström (1979) develops an agency model that analyzes the  by now well-known risk-incentive trade-off in optimal incentive contracting. The basic principal-agent model has been extended in numerous directions that are relevant to accounting. Some of these include: multiple periods (Rogerson (1985), Christensen and Feltham  (2005) Chapters 25-28, Dutta and Reichelstein (2002, 2003, 2005 a,b), multiple actions (Holmström and Milgrom (1991), Baker (1992), Feltham and Xie (1994)), misreporting (manipulation) by the agent (Fischer and Verrecchia (2004), Goldman and Slezak (2006)), and the efficiency of different performance measures such as accounting numbers and stock price (Kim and Suh (1993), Paul (1992), Bushman and Indjejikian (1993)).

## 1.2   Accrual accounting

### 1.2.1   Basic concepts in accrual accounting

The purpose of the rest of this and the next section is to give an overview of the role of accrual accounting in financial reporting. Accrual accounting is a method that measures the performance of a company by recognizing events, such as transactions, when these events occur, regardless of when cash flows occur (FASB 1985, SFAC No 6, paragraphs 139, 145). Accrual accounting alters the timing of cash flow recognition in order to mitigate timing and matching problems (Dechow (1994)). Earnings is the typical performance measure in accrual accounting. Earnings is a summary measure, and with accrual accounting there is a certain level of aggregation involved.

As mentioned earlier, the objective of financial reporting is to provide information about a company's performance (FASB 1978, SFAC No 1, paragraph 42). This objective can be divided into two different sub-objectives:

1) to facilitate decision making. For instance, investors need financial information to valuate the company in order to make optimal investment decisions in a portfolio context.

2) to facilitate stewardship. The company enters into contracts  where the terms of the contracts depend on accounting numbers. For instance, the manager's incentive compensation

may depend on accounting earnings.

I will also refer to these objectives as valuation and contracting, respectively.

There are potentially several alternatives to using accrual accounting. One is cash reporting[2]. In cash accounting, a company's operations are recorded in the accounting system when cash is paid to or from the company. The time of recognition is when cash changes hands. Though simple, cash accounting has some disadvantages. Cash accounting results in matching problems, since it measures cash flows and not activities/events. Accrual accounting differs from cash accounting because it focuses on matching. Matching is the process where costs are aligned with the revenue they are related to[3]. Matching requires cash outlays (costs) to be expensed in the period that the associated revenue is recognized (Dechow (1994), see also Christensen and Demski (2003) pp.307-309). Paton and Littleton (1940) state in their book "An introduction to corporate accounting standards" that "The ideal is to match costs incurred with the effects attributable to or significantly related to such costs" and that "The revenue of a particular period should be charged with the costs which are reasonably associated with the product represented by such revenues". Matching is an essential part of accrual accounting.

Another alternative to accrual accounting could be for the management of the company to reveal all their available information, disaggregated. This could be both financial and non-financial information. Then every user would have to find what information is relevant for their use and structure this information for their own purposes. However, if it is costly to disclose information, then disclosing all information could be very costly. Using summary measures would then be a preferable alternative. If users of financial information have information processing costs, that would also make aggregation efficient. Beaver (1998) suggests that accrual accounting is a cost effective compromise between cash flow reporting and this extensive full reporting. FASB states in their Conceptual Framework that accrual accounting provides better information than cash flows about the firm's cash flow-generating ability (FASB (1978)).

According to Paton and Littleton (1940) matching of cost and revenues should occur in the period when revenue is recognized. Revenue recognition then leads the matching process.

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[2]The term cash accounting can be used both about accounting where only net cash flow is reported, and about an accounting system where all gross cash flows are reported. I will later discuss how incentives can differ in these two settings.

[3]Matching can also be achieved the other way around, by aligning revenues to the costs that they are related to, in the period that the costs occur. I will discuss this in a later section.

Recognition is defined as the process of formally recording or incorporating an item into the financial statement (SFAC No 5, paragraph 6). SFAS No 6 describes revenue recognition as the "essence of using accruals to measure performance of entities". According to Paton and Littleton (1940) matching can only occur after revenue has been recognized in a particular period. Generally, revenue should be recognized when it is earned, or realized or realizable, according to SFAC No 5, paragraph 83. The time when revenue is recognized is important because it determines when new information is recorded (Marton and Wagenhofer (2010)). Early recognition allows "softer" information which is more manipulable, and later recognition often implies "harder" information which is less manipulable (Glover et al. (2005)). Antle and Demski (1989) analyze early versus late revenue recognition and find that a revenue recognition rule that is optimal for stewardship is generally not optimal for consumption smoothing purposes. Asset valuation will have important implications for revenue recognition. Consider historical cost and fair value[4] as valuation rules for a capital asset (see Christensen and Demski (2003), p. 308, and Dutta and Zhang (2002)). With historical cost valuation, the sales revenue from the asset is recorded when goods are sold, and the asset's investment cost is spread over the asset's operating lifetime. With fair value, however, the market price of the asset is the basis for valuation, and market price will ideally reflect expected future cash flows (revenue from the investment). In this case, the change in market value in one period is recognized as income in this period, and an increase in expected future cash flows will be recognized as revenue in the current period. Income will typically be recognized earlier with fair value than with historical cost. An accrual accounting system based on historical cost will therefore lead to different timing of accruals[5] than fair value. Dutta and Zhang (2002) argue that for incentive purposes fair value will not be optimal because it is based on the manager's expected actions in the future, and rewarding future actions in the current period is not optimal.

Accrual accounting means that this period's cash flows are divided between those that affect this period's earnings and those that are moved to future periods through the balance sheet. The cash outflows, for instance, are separated in two; costs that are subtracted from current

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[4]I will discuss fair value more in Section 1.2.3.

[5]To be more precise, this regards both accruals and deferrals. Accruals are concerned with recognizing for instance a revenue (cost) item today when the related cash flow comes (is paid out) in the future. Deferrals are concerned with current cash flows that are recognized as revenue (costs) in later periods. To keep notation simple, I will use the term accruals for both of these procedures.

revenue, and costs that are moved to future periods via the balance sheet. An investment acquisition is recorded partly as current period's depreciation on the income statement, and the rest as an asset on the balance sheet. Production costs are allocated between expenses that are associated with this period's revenue on the income statement, and those that are related to future revenue on the balance sheet as inventory. Paton and Littleton (1940) state that an important task of the accounting process is this separation between current and future periods: "The fundamental problem of accounting, therefore, is the division of the stream of costs incurred between the present and the future in the process of measuring periodic income" (p. 67). Paton and Littleton see assets as future expenses. The balance sheet is the tool to move costs to future periods, and these costs will reduce income in future periods instead of the current period.

While cash accounting provides information about cash that has been paid in to and out of the company, accruals reflect management's expectations about the company's future cash flows (Beaver, 1998). For instance, the value of receivables in the financial statement contains management's expectations about uncollectables. The accounting value of inventory reflects management's information about what is the lowest of cost and market (LCM) value when the LCM principle is used for inventory valuation. Assets and liabilites such as these on the balance sheet tell us something about the expected future cash flows that these assets and liabilites will create. Managers have more information about the company's state than the outside world, and accruals is one way that managers can disclose this information[6]. Moving from cash accounting to accrual accounting makes accounting data more forward-looking (Glover, Ijiri, Levine, Liang (2005)).

### 1.2.2 Managerial discretion

The manager often has some discretion in estimating and reporting accruals. There are two opposing views on the manager's discretion; the signalling (or informational) view and the opportunism view (see for instance Beaver (1998), p. 84 for a discussion of this, or Louis and

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[6]The information content in accruals and earnings is shown to be significant. For instance, earnings and accruals are significant in predicting future cash flows and stock returns (Dechow (1994), Barth et al. (2001), Subramanyam (1996)), and Dechow et al. (1998) find that earnings and accruals are better predictors of future cash flows than current cash flows.

Robinson (2005) and Badertscher, Collins and Lys (2010) for empirical analyses).

## Signalling

When the manager uses his reporting discretion to convey his private information, this is often referred to as signalling. According to the signalling view, discretion can be used to increase the informational content of the report when the report reflects the manager's private information. This will increase the informational content of earnings. Christensen and Demski (2003) study extensively how the manager can use accruals to convey information.

## Opportunism

In the opportunistic view, accruals can be used in a manipulative way, to manage earnings in a way that maximizes the manager's own interests, or the company's interests. This is earnings management. A caution should be noted here regarding the use of the term earnings management. Some authors use this term very broadly, to cover many or all types of managerial discretion in reporting, such as signalling, opportunism and the manager's withholding of information (voluntary disclosure). Others use it more narrowly, to describe the opportunism side of managerial discretion. As a consequence, a broader use of the term makes it easier to include the potential positive and useful aspects of earnings management. The model that I will present in later chapters, deals with voluntary disclosures, and I will mostly refer to this as managerial reporting discretion, rather than earnings management, though from a broad perspective this could also be seen as a form of earnings management.

Reasons for such opportunism could be that the manager wants to smooth earnings over time, boost short-term earnings to meet expectations or analysts' targets, to increase the price of equity before IPOs, or that the manager wants to manage earnings to maximize his compensation (see for instance Watts and Zimmerman (1986) or Healy and Wahlen (1999)). Since cash flows are uncertain and it is difficult for outsiders to know exactly on what information the manager bases his estimates, the manager has some flexibility in his reporting without risking being punished ex post. Earnings management is about selecting the timing of accruals to mislead stakeholders or influence contractual outcomes (see for instance Healy and Wahlen (1999)).

There is a large empirical literature on earnings management, among others Healy (1985), Healy and Wahlen (1999), and Aboody and Kaznik (2009). The problem with finding out whether earnings have been managed, is that unmanaged earnings are not observable, and the ability of existing models to find a proxy for unmanaged earnings is far from perfect (Dechow, Hutton, Kim, and Sloan (2011)). Dechow, Ge, and Scrand (2010) discuss the different measures of earnings management that have been used in empirical studies. There is however, much evidence that some firms manage earnings (Healy and Wahlen (1999)).

Though earnings management is often viewed as a negative thing, it may still be efficient to allow earnings management. Allowing earnings management may reduce the cost of incentives and may actually increase the information in earnings (Sankar and Subramanyam (2001)), for instance when earnings management is informative about the manager's productive efforts (Demski (1998), Demski and Christensen (2003), Arya, Glover, Sunder (2003)) or when the manager wants to smooth consumption and earnings. It may also reduce costly real earnings management (defined as taking suboptimal real decisions to increase current earnings) when the manager can use both accounting earnings management and real earnings management to manage earnings (Ewert and Wagenhofer, 2005). Demski and Frimor (1999) study a two-period model with renegotiation and find that no communication (which they term performance measure garbling, manipulation or earnings management) is optimal. The reason in their model is that disclosure may negatively affect the agent at the renegotiation stage, and the agent will by disclosing give away some of his bargaining advantage at the renegotiation stage. Since the principal must cover the agency costs ex ante, it is optimal to limit communication. See also Christensen, Frimor and Sabac (2011) for a model with renegotiation where earnings management may be efficient.

Dechow and Skinner (2000) state that "No earnings management is clearly not an optimal solution. Some earnings management is expected and should exist in capital markets. This is necessary because of the fundamental need for judgement and estimates to implement accrual accounting - the first-order effect of allowing these judgements and estimates is to produce an earnings number that provides a "better" measure of economic performance than cash flows. Eliminating all flexibility would in turn eliminate the usefulness of earnings as a measure of economic performance". It follows that full elimination of discretion and earnings management

is not desirable.

Information that is to be recognized in the income statement or on the balance sheet should be relevant and reliable (SFAC No.5, Paragraph 65). Using estimates and managerial discretion in producing the accounting report calls for regulation on how the manager calculates earnings, in order for earnings to be informative and reliable. With no restrictions or costs regarding earnings management, the manager will use his discretion to a maximum and produce a uninformative report (Watts and Zimmerman, 1986). In the financial statement, the income statement is accompanied by information in footnotes. One argument for using notes to disclose information is that this is a way to disclose information that can be characterized as relevant, but that does not reach the required reliability requirements that are used in the income statement. Schipper (2007) discusses this distinction between disclosure in the financial statement as opposed to in notes.

### 1.2.3   Fair value

Historical cost is one way of measuring the value of an asset in the financial report. Historical cost is based on the original cost when the company bought the asset. Fair value is another measure. Fair value of an asset is defined by FASB as the price that would be received to sell an asset in an orderly transaction between market participants, while IASB uses the definition "Fair value is the amount for which an asset could be exchanged by knowledgeable, willing parties in an arm's length transaction" (FASB (2006), IASB (2009)). Usually, fair value will be equal to historical cost at the time of aquisition, but later these values will generally differ.

Fair vale is a market-based measure. If there exists a complete and perfect market for the asset, then fair value is the market price of the asset. For instance, tradable securities such as liquid stocks that are traded on a stock exchange, have a stock price that is easily observable and can be used as a fair value measure.

For many assets, however, a perfect and complete market does not exist, and for these assets a fair value is not easily observable. For instance, for a firm-specific machine there is often no immediate market and market price to use as a measure. Then estimates have to be used, and estimates are subject to uncertainty, subjectivity, manipulation and estimation errors. Estimation errors can be both intentional (from earnings management) and unintentional (from

uncertainty) and reduce the quality of earnings as a performance measure (Dechow and Dichev (2002)).

Both relevance and reliability are desirable characteristics of financial information. Fair value accounting can have implications for both these aspects. Proponents of fair value accounting claim that fair value gives relevant and timely information that is useful to decision makers. Barth (2006) states that fair values are relevant because "they reflect present economic conditions, i.e. the condition under which the users will make their decisions". Landsman (2007) provides empirical evidence that fair value information is relevant to investors. Fair value is seen as timely since it reflects current market conditions. On the other hand, using fair value estimates can make verification more difficult and lead to more subjective measures. Accruals based on fair value stand in contrast to the accruals that Paton and Littleton (1940) describe, which are based on transactions, objectivity, and historical cost value. Using estimates based on the manager's unverifiable information can lead to more manipulation (Watts (2003)). Christensen (2010) comments on the increasing use of fair value that "Fair value accounting relies even more on the private information of management, and enhances the possibilities for earnings management and leaves auditing less efficient". The reliability of the information could be reduced.

Laux and Leuz (2009) and Emerson et al. (2010) provide overviews of the fair value debate, and Barth and Landsman (1995) discuss measurement issues.

## 1.3   Modelling of accruals

### 1.3.1   Modelling accruals analytically

Typical examples of accruals are depreciation and change in inventory. In this section I will discuss these. Consider a company that generates operating cash flow of $(a_t + \varepsilon_t)$ in each period; think of this as short-term effort and uncertainty regarding the cash flow from effort. The company considers buying a machine (a capital investment) that will cost $-b$ in the first

period but will generate cash flow $x_t$ from period 2 to period $n$. The net cash flows $c$ will be

$$c_1 = -b + (a_1 + \varepsilon_1)$$
$$c_t = (a_t + \varepsilon_t) + x_t \ \text{ for } 2 \leq t \leq n.$$

Assume that the investment is profitable, implying $\left(-b + \sum\limits_{t=2}^{n} x_t\right) > 0$, with no discounting. If the company makes this investment, then the cash flow in period 1 will be very low (probably negative) because of the investment cost. A net income report based on cash accounting will show low performance in period 1, while the net income for later periods will be high because they carry none of the investment cost. The low net income occurs in period 1 despite the fact that the company has made a profitable investment and has produced operating income. With cash accounting, the net income measure is not very informative about the performance (achievements) in this example with a capital investment. An investor who only observes the aggregate cash flows in period 1 (net income, with cash accounting) will get a negative view of the company's performance, even though the company has taken actions that will increase the cash flow generating ability of the company. The investor cannot distinguish between a low net income that comes from the company making the investment (which would be good news) or from low effort or bad luck (bad news).

How would performance be measured with accrual accounting? Using the concept of assigning costs to revenues (from Paton and Littleton), the company will now distribute the investment cost over the periods in which the investment creates revenue (periods 2 to $n$), through depreciation (which is an accrual). There are several ways to do this, through various forms of increasing, decreasing or straight-line depreciation methods. The point is that through deprecation the investment cost is matched to the revenue it generates, in the periods when the revenue occurs. Period 1 net income will now be equal to $(a_1 + \varepsilon_1)$ while net income $I_t$ for periods 2 to $n$ will be: $I_t = c_t - depreciation_t = a_t + \varepsilon_t + x_t - depreciation_t$. The accrual process separates the effort and investment activities in the first period. A low net income in period 1 now must come from low cash flows from operating effort.

In order to do the accrual process in this example, the accounting system must be able to distinguish between cash flows from operations and from investment. If investment cost is

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going to be distributed to future periods, the accountant must know the size of the investment $b$. If for instance only aggregate cash flow $c_t$ is observable, then this is not possible (I will later discuss different alternatives in this scenario). When the accounting system can classify cash flows as coming from either effort or investment, then the investment can be capitalized and depreciated.

With accrual accounting, net income will be higher in period 1 and lower in later periods, compared to cash accounting. In this example, it is hard to argue against the claim that accrual accounting provides a better measure of company performance than cash accounting.

Another example is inventory recognition. Consider a company that produces goods for sale each period. A higher number of goods produced increases the production cost. With cash accounting, the production cost includes all cash ouflows that have paid for the manufacturing of goods, no matter what has happened to the goods after production (sold or stored as inventory). With accrual accounting, the value of goods produced but not yet sold are assigned to the balance sheet as inventory. Assume that the company expects higher demand next period and increases production in the current period to meet this demand (good news). A cash accounting report would only show increased production costs this period (ambiguous news). Accrual accounting would not charge this period's income with the cost of goods produced but not yet sold, and would not punish this period's income for higher expected demand next period. Accrual accounting would give a more accurate picture of activities in each of the two periods.

### 1.3.2   Existing models of accruals and performance evaluation

Recall the earlier discussion about the two uses of accounting information; valuation and contracting. Information may be used differently in valuation and contracting. Gjesdal (1981) shows that the ranking between different information systems is different for valuation than for contracting purposes. Paul (1992) shows that the weights on information are different in valuation and in contracting.

This thesis is mainly concerned with contracting rather than valuation, so I will mostly focus on the use of accounting information in a contracting setting[7]. According to the stewardship

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[7]Later I will introduce a model where stock price is part of the incentive contract, and then valuation uses of

view, accruals (and accrual accounting) are used to create performance measures that induce the manager to make decisions that are value-maximizing for the owner.

The discussion and previous example regarding depreciation show that accruals play an important part in measuring performance. Cash flows and earnings based on accrual accounting can give very different pictures about the company's periodic profitability. When there is a conflict of interest between owners and the manager, it is important (for stewardship purposes) that the performance measure not only reflects the company's profitability during the period, but also that it gives the manager incentives to make optimal decisions. When accounting income is used in the manager's incentive compensation, accruals become the basis for managerial incentives.

Considerable research has been done on the use of performance measures based on accrual accounting versus performance measures based on cash flows. The central theme in much of this literature is how to create optimal investment incentives with accruals. Both accruals and investments are multi-period by nature, and it is therefore natural to analyze investments when studying accruals. In contrast to the simple model of investment and depreciation above, these models present principal-agent conflicts where the agent (typically the manager) has private information, and there is a conflict of interest between the principal (the owners) and the agent. The models therefore become more complex than accrual models with no managerial incentive issues.

The models are multi-period, with an initial investment cost, and cash inflows from investment that occur over many periods. One strand of this literature considers a setting where the manager has a shorter time horizon or has a different (higher) discount rate than the owner. He may therefore be reluctant to invest, because the benefits of the investment come far in the future, or he may choose an investment with cash flows that arrive soon rather than another investment with higher NPV that has cash flows in later periods. Waiting to compensate the manager until cash flows are realized may not solve the incentive problem when the manager has a different discount rate than the owner or has private information, and it may not even be feasible if the manager leaves the company before all cash flows are realized. Another line of models describe a setting where the manager makes both effort and investment decisions, and

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information will also be relevant.

the cash flow from the manager's effort and investment decisions cannot be separated. When only aggregate cash flows are available for contracting, effort and investment problems become intertwined. This creates problems of giving the manager incentives to make both optimal effort and investment decisions.

In general, the models describe how (some form of) accruals do better than cash flows in incentive contracting when there is an investment problem.

I will divide my discussion of this literature into two parts; the first is where the agent has private information about the productivity of the investment, and the second where the agent has private information about the amount he invests.

## Private information about productivity

Rogerson (1997), Reichelstein (1997, 2000) and Dutta and Reichelstein (DR) (2002, 2005a) present models where the manager has private information about the investment's productivity. However, invested amount is observable. Since the principal does not know the investment's productivity, she does not know what the optimal invested amount is and delegates this decision to the manager. In addition, the manager can have a different discount rate than the principal, and his discount rate may be his private information. This makes his investment preferences different from the owners', and if cash flow is used as a performance measure the manager will make investment decisions that are sub-optimal for owners.

Most of these models focus on the concept of goal congruence. By finding a goal congruent performance measure, the owners ensure that the manager makes investment decisions that maximize net present value (though not taking into account the manager's compensation), irrespective of the manager's discount rate.

The observable investment cost is allocated over the operating life of the investment through depreciation. By distributing the investment cost over the periods when income from investment occurs, matching is achieved. How this allocation over periods should occur, is not obvious, however.

Rogerson (1997) analyzes how accruals can be used to give the manager optimal investment incentives. In his model, the manager makes a one-shot decision about how much to invest in a project. The manager has private information about the productivity of the investment,

but the company (or its accountant) has information about the time pattern of the cash flows that the investment creates. Rogerson shows that when the manager's compensation is weakly increasing in income, and the investment cost is allocated to period-t income according to the Relative marginal benefits allocation rule, the manager will choose an efficient investment level. The relative marginal benefits allocation rule determines a charge $a_t$ in period t according to the following function:

$$a_t = \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^i}}$$

where $\rho_t$ represents the cash flows from the project in period $t$, relative to other periods (the cash flow profile). Cash flow from investment is $x_t = \rho_t \cdot \lambda$ where $\lambda$ is a constant scale factor and $\rho_t$ varies between periods. The parameter $T$ is the projects life, and $r$ is the principal's interest rate.

This charge can be implemented through an appropriate depreciation charge (the relative benefits depreciation), and an interest charge on the book value of the investment[8]. Residual income (RI) is income less an interest charge on capital, and the optimal performance measure in Rogerson (1997) is a special case of residual income, where the relative benefits depreciation schedule is used to calculate depreciation and the resulting income. The depreciation will contain project-specific information about the time pattern of cash flow from investment. Rogerson shows that the manager will make optimal investment decisions with a performance measure based on this depreciation rule regardless of his discount rate. This is beneficial to the principal because she does not know the agent's discount rate. The principal can use this allocation rule to ensure that the agent makes investment decisions that are optimal for her (the principal).

Reichelstein (1997) generalizes the result in Rogerson (1997) to a setting where there is a sequence of overlapping investment decisions. The purpose of using depreciation and allocation is to match the investment cost (incurred at time 0) with the revenue it generates in the periods that constitute the investment's useful life. Reichelstein (2000) and DR (2002) extend the models to explicitly include moral hazard problems (effort) and demonstrate how RI and relative marginal depreciation is cost-effective relative to cash-based performance measures

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[8]The depreciation will be $d_t = \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^i}} - r \cdot \left[1 - \sum_{j=1}^{t-1} d_j\right]$ and the capital charge will be $r \cdot \left[1 - \sum_{j=1}^{t-1} d_j\right]$.

(Reichelstein 2000) and derive the optimal incentive contract with both moral hazard and asymmetric information (DR, 2002).

## Private information about how much the manager invests

The second case is where the investment cost is not (perfectly) observable, but there is no asymmetric information regarding investment productivity. Dutta and Reichelstein (2003, 2005b) study this issue. The agent makes both effort and investment decisions, and only the aggregate cash flows from these decisions are observable. When investment cost is not observable, it is not possible to use an allocation or depreciation rule based on investment cost, and it becomes difficult to give optimal incentives to both effort and investment decisions at the same time.

In these models there is a forward-looking signal about investment payoff that is used either directly (DR, 2003) or through a stock price (DR, 2005b). The signal and the stock price are used to separate the investment problem from the effort problem. In DR (2003) the signal equals the expected future cash flow from investment, plus noise. The signal is valuable to contracting if the effort problem is not stationary, and if there is not full commitment. If the effort problem is non-stationary, the optimal incentive weight on cash flows from effort incentive purposes will be different each period, and this causes the manager to invest to much or too little relative to first best. The forward-looking signal is then useful in giving investment incentives. If the effort problem is stationary, it is optimal to set the same cash bonus each period, and the agent will in this case invest the optimal amount. There is therefore no need for the forward-looking signal to create investment incentives.

In DR (2005b) the signal contains all information about future cash flows from the investment; this includes the uncertain part of these cash flows. The stock market observes this signal and includes it in the stock price. The signal is always valuable for contracting through the stock price. First, stock price gives the manager investment incentives, as stock price depends on the invested amount. When the manager is rewarded based on stock price, a higher investment increases his expected stock-based compensation. Second, using stock price in incentives, even when cash flows can be used in contracts, is valuable since it protects the manager from some of the investment risk. Both cash flows and stock price contain investment risk. Including stock price as well as cash flows in the contract, makes it possible to filter away some of this

investment risk from the manager's compensation and reduce the manager's total risk (in a similar way that is done in relative performance evaluation).

Though these models do not model accruals explicitly, they are closely related to the accruals litterature in the sense that the forward-looking signal and the stock price can be used as an accrual that matches the revenue from the investment, to the investment cost (see DR 2005b, ft. 8). The future income from the investment is moved forward in time in order to create optimal investment incentives, by using forward-looking information in the incentive contract.

Accruals can here be seen as a forecast about the future. By including the stock price (or signal) in the compensation, the principal includes a forecast about future payoffs. The stock price (or signal) plays the role of an accrual in this setting. They reflect the forward-looking information (about future cash flows) in the same way as an accrual. Recall the discussion about fair value accounting above. The stock price in DR (2005b) reflects the market price of the claim to the investment cash flows and satisfies the definition of a fair value measure. Consequently, the stock price reflects the fair value of the investment.

Wagenhofer (2003) reaches a similar conclusion as Dutta and Reichelstein about the use of matching for managerial incentives. He studies a model where unobservable investment is personally costly to the manager, and where only short-term contracts are available. In his model, he finds an optimal depreciation rate and finds that accruals with this deprecation rate is more efficient than cash flows for incentive purposes. So in contrast to DR (2003) and DR (2005b) investment cost is moved to future periods through depreciation. This is possible because the principal observes imperfect information ex post about the manager's investment decision, and he uses this information to depreciate the investment cost. The model is similar to DR (2003) and DR (2005b) in that investment cost is not perfectly observable, but it is also similar to Rogerson (1997) and Reichelstein (1997) in that this model uses depreciation (a deferral) instead of moving revenue forward (an accrual).

The models in this literature show the usefulness of using accruals for incentive reasons, by distributing investment cost to the periods the revenue occurs, or by moving revenue to the period the investment occurs. Both types of accrual can do better than cash flows in creating investment incentives.

## 1.4 Investment incentives and voluntary disclosure

In this section I will give a very short description of the model I will study in Chapters 2 and 3, and I will discuss how accruals are related to this model. First, however, I will discuss disclosure, since this is a central aspect of my model and makes my model different from the accruals models presented earlier.

I separate between mandatory and voluntary disclosure. Mandatory disclosure refers to a setting where information must be disclosed, by law or other type of regulation. Voluntary disclosure describes a setting where a company has private information and where the company (or its manager) decides whether to disclose this information. Whether or not certain types of disclosures should be voluntary or mandatory is a topic of debate in the literature. Arguments for more regulation and mandatory disclosure are that this will increase information to the stock market and reduce the companies' cost of capital (Leuz and Verrecchia (2000), Verrecchia (2001)), that one firm's disclosure may have positive externalities on other firms (Dye (1990)), and that there are economies of scale in information production, and more mandatory discloures may reduce investors' costly information production (Beyer et al. (2010)). On the other hand, there are arguments for letting the companies and their managers decide themselves whether to disclose information. First, disclosure cay be costly (Verrecchia (1983)), and mandatory disclosure will therefore impose costs on the companies. Second, making some disclosures mandatory may alter the effect of other types of disclosed information, and may actually reduce the informativeness of the stock price about the manager's action, thereby making the stock price less useful for stewardship purposes (Dye (1985), Dye (2001)). In addition, using regulation to make disclosures mandatory may fit some but not all companies since companies are different, and it reduces the companies' ability to assess the benefits and costs of disclosure and make qualified disclosure decisions themselves.

Regulation does not only cover mandatory vs voluntary disclosure, but also to whom information is given, when it is disclosed. Disclosures may be selective, in the sense that only certain participants in the stock market are given information. In the US, the Securities and Exchange Commission (SEC) does, among its other tasks, oversee this aspect of the capital markets. The mandate for the SEC is to create a level playing field for all investors in the market. This means that everybody should have equal access to information and that the information that

is disclosed is reliable. For instance, the SEC adopted "Regulation Fair Disclosure" in 2000. The intention of this policy was to stop selective disclosure to a select group of analysts, and this is one way to achieve equal access to information[9]. As a result, the manager's discretion in disclosing information to stock market participants is reduced.

In my model, the mananger's voluntary disclosure decision is related to the earnings management literature, which I discussed earlier. Managers can use accruals to manage earnings. But they can also use voluntary disclosures to control the information that the market receives. In the traditional earnings management literature, there is mandatory disclosure and possible manipulation of the disclosed information. I look at a setting where there is voluntary disclosure, but the report, if disclosed, has to be truthful. Both are examples of how the manager can use discretion to influence the information in the stock market.

### 1.4.1 Voluntary disclosure

The unraveling result (Grossman and Hart (1980), Grossman (1981), Milgrom (1981)) states that if the seller of a good can costlessly disclose the quality of the good, then he will always do so if such disclosure is costless[10]. The reason is that the buyer of the good will downwardly revise his estimate of the quality of the good, down to the lowest possible level of quality if the information is not disclosed. This means that a company that is publicly traded will always disclose its information to the stock market.

In practice, however, not all information is disclosed. Verrecchia (1983) studies one such case. In his model, the manager (or the company) observes a signal about the value of the company, and he can choose whether or not to disclose the signal he observes. The result is a partial disclosure equilibrium, where the manager discloses if the the signal is above a treshold. The reason that not all information is disclosed in equilibrium is that disclosure in his model is costly. If there is no disclosure, the stock market does not know whether this is because performance is very low, or if performance is just low enough so that having to bear the disclosure cost is not justified. The stock price with no disclosure will be strictly higher than

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[9]For discussions about the Regulation Fair Disclosure, see for instance Arya, Glover and Mittendorf (2005), Gomes, Gorton and Madureira (2007), and Gadarowski and Sinha (2010).

[10]There are also other reasons, beside a disclosure cost, why a seller or acompany may not always fully disclose its information. An overview is given in Beyer, Cohen, Lys and Walther (2010), section 3.

what the stock price would be with the lowest possible performance revealed. The disclosure cost creates a credible reason for the company not to disclose. The result is that the manager discloses good news and withholds bad news. See also Dye (1986) and Verrecchia (1990) for related models, and Verrecchia (2001) and Dye (2001) for overviews of the disclosure literature.

There are two aspects of the existing literature on voluntary disclosure that I will discuss in relation to my model; agency conflicts between the manager and the owners, and real effects of voluntary disclosure. These themes are closely related.

Most existing models of voluntary disclosure look only at the manager's disclosure incentives and not at the effort and investment incentives. As both Beyer et al (2010) and Berger (2011) note, an incentive system is designed not only to motivate the manager to disclose information, but also to induce efficient effort and investment decisions by the manager. Therefore, looking at all these issues together could be very useful. In my model, the manager makes both effort and investment decisions, and a disclosure decision. I analyze how these decisions will influence each other.

In addition, most existing models study pure exchange economies. This means that the models analyze how and when information about performance is disclosed (or not disclosed), but they do not analyze how the performance was created. Disclosure or no disclosure then has no impact on production decisions (such as effort and investment) because production is not modelled (exceptions are Kanodia (2006) and Beyer and Guttman (2011) who discuss real effects of disclosure). Berger (2011) claims that models of voluntary disclosure would benefit from incorporating these incentive issues and real effects: "Instead, the literature seems to have reached a point where incorporating real effects on production and investment choices needs to occur to provide substantial new insights into the causes and consequences of managers' disclosure choices" (Berger (2011), p. 206). My model is concerned with both disclosure and production and focuses on the interaction between these decisions.

### 1.4.2 A short description of my model

My model is based on a simplified version of DR (2005b). There are two important differences, though. One is that in my model there are only two periods, and the manager works in the company only in the first period. The second is that in my model, the manager can decide

whether or not to disclose the signal he receives. Voluntary disclosure and its implications on incentives are the focus of my analysis.

The manager makes one investment decision and one effort decision (so there is no effort in period 2), both at the beginning of the first period. Aggregate cash flow from both effort and investment is available for contracting. The investment cost alone is not contractible. Depreciation based on investment cost is therefore not feasible. Matching of the investment cost to revenue through depreciations, as in Paton and Littleton (1940), is not an option. This assumption of no disaggregation may seem an extreme assumption. For instance, much of the discussion in Paton and Littleton (1949) uses disaggregation to implement accrual accounting. However, for certain costs, aggregation may be a realistic assumption. R&D is one example. Investments in human resouces could be another example where investment costs are difficult to separate from cash flows from operations.

Cash flows from investment occur in period 2, after the manager has left the company, so the manager can not be compensated based on realized investment cash flow. If the manager is compensated based only on cash flows in period 1, he will reduce his compensation for every dollar he invests. Since the incoming cash flow from the investment does not occur until period 2, he will not receive any of the rewards. He will therefore not invest at all. The principal must match (some of) the future revenue from the investment to the investment cost in period 1 in the manager's compensation, if she is going to give the manager any incentive to invest.

At the end of the first period, the manager privately observes a perfect signal about the future cash flows from the investment. He decides whether to disclose this or not. The disclosure decision is assumed not to be contractible. A stock price is formed in the stock market based on all available information, and the manager is compensated based on cash flow and this stock price. If the signal is disclosed, then, the stock price at time 1 will contain information about future cash flows at time 2. I look at how the manager's control of information influences his effort and investment decisions.

### 1.4.3 Accruals and my model

If the manager in my model discloses his signal, the signal and disclosure can be used for matching purposes. The manager will then (through his stock-based compensation) be compensated

for the perod-2 cash flows even though they have not yet materialized. The future income from the investment is matched to the investment cost, and this creates investment incentives for the manager.

In this case, revenue and costs are matched in the period when the costs occur. Normally, revenue takes the lead. Inventory, for instance, is expensed in the period the goods are sold. Paton and Littleton (1940) argue that costs should be charged to the period when the associated revenue occurs. This is also in line with the depreciation schedules suggested in Rogerson (1997) and Reichelstein (1997), where investment costs are allocated to the periods when the benefits from the investment occur (through the Relative benefits allocation rule). In my case, that would mean charging the whole investment cost in period 2, because all the revenue is realized in period 2. This is infeasible because the investment cost is not observable (only aggregately with cash flows from operations). In my model, revenues are matched to the period the cost occurs instead.

In the model, the manager controls the disclosure decision, while the stock market forms a stock price in an automatic way. The manager knows, when making the disclosure decision, what the resulting stock price will be. Interpreting the stock price as an accrual, the manager controls the accrual and makes the accrual decision that maximizes his utility. This is in line with the opportunistic view on earnings manipulation and accruals discussed earlier. When disclosing, however, the manager increases the information to the market. The accrual both adds information and is under the manager's discretion.

In my model, the manager can hide bad information, but if he discloses, he can not misreport, and the disclosure will always be truthful. This is in line with most of the literature on voluntary disclosure[11]. This means that the only way of managing earnings in my setting, is to decide whether to hide information. If the manager could costlessly and limitlessly manage earnings by misreporting, he would do so as much as he could to maximize his period-1 compensation. This would make the information he discloses uninformative.

To sum up, in my model the manager controls information that eventually will be the basis for his compensation in a way similar to a manager who is compensated based on accounting

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[11]The models in Kwon, Newman, and Zang (2009) and Einhorn and Ziv (2011) are exceptions, with both voluntary disclosure and costly misreporting.

earnings and has some discretion in setting the accruals that will be part of earnings. In both settings the manager, by his reporting choice, influences his own performance measure. I study how the effectiveness of the performance measure is influenced by the manager's reporting discretion.

### 1.4.4  Outline of the rest of the thesis

The rest of the thesis is outlined as follows. In Chapter 2 I develop the model that I briefly described in Section 1.4.2. I show that when the manager controls the disclosure decision, this influences the power of the stock bonus in inducing investment. In the model in Chapter 2, a higher stock bonus is needed to induce a given investment level with voluntary disclosure than with full disclosure. In this model, the risk is independent of the amount the manager invests. In Chapter 3, I relax this assumption, and analyze a model where the total investment risk is increasing in the invested amount. In this chapter, I show (numerically) that the stock bonus may be more effective in inducing investment with voluntary disclosure than with full disclosure. Chapter 4 contains a discussion and conclusion.

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# Chapter 2

# Investment, disclosure, and managerial incentives

## 2.1   Introduction

In this chapter I study how a manager's decision to voluntary disclose information affects his effort and investment incentives. The manager can choose to inform the market about the future payoffs from the investment he has made. The prospect of later controlling information about investment outcome affects his initital investment decision. In general, the manager is less responsive to stock-based incentives than he would be in a world of full discosure in this model.

A company gives its manager stock-based compensation to reduce a moral hazard problem of investment. The manager privately learns about investment outcome, and can choose either to disclose or withhold this information. I show that the manager will be less responsive to stock-based incentives in this case of voluntary disclosure than when the information is always revealed (full disclosure). The reason is that the manager can hide bad outcomes, and the prospect of hiding information weakens his incentives to invest. With voluntary disclosure, a given stock-based bonus will to a lesser degree solve incentive problems because the manager also controls the information on which he is evaluated. For given bonus parameters, the manager will invest less with voluntary disclosure than with full disclosure. On the other hand, voluntary disclosure also reduces the manager's risk and the company's expected disclosure costs.

I use an agency model where the contract includes both stock price and cash flows as performance measures, using a simplified version of Dutta and Reichelstein (2005) as a benchmark. The manager makes effort and investment decisions, which jointly determine future cash flows. Effort is personally costly to the manager, but investment is not, as the investment cost is paid with company cash flows. The cash flow from effort and the cost of investing are aggregately observable, but the company's reporting system is unable to distinguish beween the two. The principal introduces a cash-based bonus to overcome the manager's moral hazard problem for effort. This bonus will also give the manager an incentive to underinvest in the project, since investment costs will reduce company cash flows and the manager's compensation in the first period. Using stock price as an additional performance measure is a way to mitigate this underinvestment problem.

The manager privately learns the true value of future payoffs from investment. He can choose whether to disclose this information to the stock market. I assume that the future realized payoffs from the investment are not available for contracting. However, if the manager chooses to reveal his private information, future investment payoffs will be perfectly incorporated into the current stock price. This forward-looking quality of stock price makes it useful in inducing investment. Assuming disclosure is costly to the company, the disclosure equilibrium that results is similar to the one in Verrecchia (1983), and only good news will be revealed. If payoffs are bad, information about them will not be disclosed by the manager. The stock price will not perfectly reveal the true value of these low payoffs, but the non-disclosure in itself will signal bad news, and the stock price will be set correspondingly low by the market. In this way, the manager reaps the full value of the benefits of high payoffs, but is protected from very bad outcomes through his own voluntary disclosure decision. With voluntary disclosure, the manager can avoid being punished when these bad outcomes occur. The manager's risk is reduced, but so are his incentives to invest.

Several earlier studies have analyzed the use of stock price as a managerial performance measure[1]. However, in these models the information the manager releases to the stock market may be noisy, but he will always disclose the information with certainty. In the model I present

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[1]See for instance Paul (1992), Bushman and Indjejikian (1993a, 1993b), Feltham and Wu (2000), and Dutta and Reichelstein (2005).

in this chapter, on the other hand, the manager can choose whether to disclose information to the stock market, and I show how this decision changes the informativeness of the stock price and consequently the initial incentive problem.

There is also an extensive literature on company disclosures[2] (see for instance Verrecchia (2001), Dye (2001) and Beyer, Cohen, Lys, and Walther (2010) for overviews). In my model, there is a cost of disclosure, and the manager reveals good news but withholds bad news[3]. However, the disclosure literature typically assumes there is no conflict of interest between the manager hired to run the company, and the company's owners. In my model I seek to study the possible interaction between this conflict of interest and the disclosure decision that is taken by the manager. The model shows how the incentive problems inside the company change when the disclosure decision itself is part of the agency problem.

Nagar (1999) studies a manager's voluntary disclosure decision in a career concerns model, and finds that a risk averse manager only discloses his signal if it is above a treshold value[4]. Other studies have examined situations where the manager always discloses his signal, but he can misreport[5]. An exception is Einhorn and Ziv (2011) who study voluntary disclosure with possible misreporting, but their model do not have production decisions or a conflict of interest between the manager and owners. In my model the manager can choose whether to disclose, but his report is always truthful.

The main contribution of the model in this chapter is to show how the manager's control over a disclosure decision will reduce the strength of his incentives, and how it changes incentive problems inside the company. I introduce moral hazard into a firm's voluntary disclosure framework, or put differently, I introduce voluntary disclosure into a setting with managerial moral hazard and performance-based incentives. I show how disclosure and investment incentives

---

[2]The most relevant strand of this literature in relation to the current paper discusses the emergence of a partial disclosure equilibrium (see Verrecchia (1983), Dye (1986), Jung and Kwon (1988), Suijs (2007), and Eithorn (2007)). The reasons why full disclosure does not occur in these models are the existence of disclosure costs, uncertainty about whether the manager actually possesses private information, uncertaity about investor response, and private information about the manager's reporting objective.

[3]A disclosure equilibrium where only good news is revealed is supported by empirical work by Berger and Hann (2007) and Kothari, Shu and Wysocki (2009).

[4]Nagar, Nanda and Wysocki (2003) study the link between managerial disclosures and stock-based incentives empirically, and find a positive relationship between stock-based compensation and disclosures. They conclude that stock-based compensation mitigates a risk averse manager's unwillingness to disclose information.

[5]Examples of this line of work are Dye (1983, 1985), Christensen and Feltham (2000), Bar-Gill and Bebchuk (2003), Natarajan (2004), Goldman and Slezak (2006), and Crocker and Slemrod (2007).

interact in a manager's decision problem.

The chapter proceeds as follows. In Section 2.2 I present the basic elements of the model. In Section 2.3 I describe the disclosure equilibrium and in Section 2.4 the manager's investment decision. I discuss the principal's problem in Sections 2.5 and 2.6. In Section 2.7 I present some comparative statics analysis, while Section 2.8 contains the Conclusion.

## 2.2   Model

In this section I will present the model. The timeline in  Figure 2.1 gives a description of what happens in the two periods.
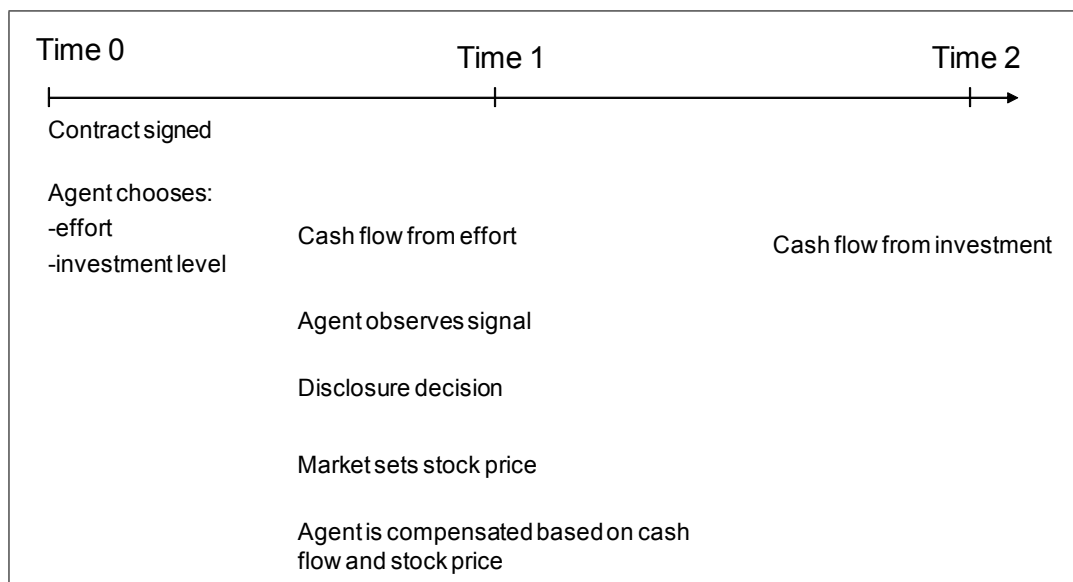


Figure 2.1. Timeline.

I use the basic setup of the model in Dutta and Reichelstein (2005), with effort, investment and stock price compensation. The agent is hired to run the company, and I assume he works there only one period. He makes decisions in the first period, and effects of these decisions occur in both period  1 and 2. I assume that the agent can only be compensated in period 1. One possible explanation is that cash flow effects of his decisions materialize a long time after the decisions are made, and the agent may no longer be working in the company at this future

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time. This means that the total value of the company, as measured by the cash flows in period 1 and 2, cannot be contracted on.

In period 1, the agent invests $b \in \left[\underline{b}, \overline{b}\right]$ and exerts effort $a \in [0, \bar{a}]$. Cash flow from investment does not occur until later (period 2). Effort produces cash flow in period 1. This cash flow is uncertain, and I call the noise parameter $\varepsilon$. The agent incurs a personal cost $e(a)$ from exerting effort, where $e(\cdot)$ is monotonically increasing, twice differentiable, and strictly convex, and $e(0) = 0$. In period 1, only the aggregate cash flows from effort and invested amount are observable to owners and the market.

After making the investment decision, but before any payments have occurred (I call this time $1^-$), the agent perfectly learns the value of investment payoffs and chooses whether to disclose this information. If he discloses the signal, the company will incur a cost $\kappa$ (this cost reduces cash flows in period 2). This could be a cost of verifying information or loss of competitive position (see Dye (1985,1986) for a discussion of different types of disclosure costs). Also, I assume that the agent must be truthful if he discloses (no lying, no misreporting), and that the disclosure decision itself is not contractible. I define the disclosure decision as $d \in \{0, 1\}$ where $d = 0$ denotes no disclosure, and $d = 1$ denotes disclosure. A superscript in variables will reflect $d$.

Investment $b$ yields expected income $m(b)$ in the second period. Uncertainty is reflected in the parameter $\mu$. The cash flow from investment is a positive function of the amount of capital invested, with decreasing marginal productivity: The function $m(b)$ is assumed to be non-negative in the relevant range, strictly concave and twice differentiable, and satisfies $m'(b) > 1$ when $b \to \underline{b}$ and $m'(b) \to 0$ when $b \to \overline{b}$. In addition to making the investment decision in period 1, the agent must also exert operating effort in period 1.

The observable aggregate cash flows in period 1 and 2, $c_1$ and $c_2$, are given by:

$$c_1 = a + \varepsilon - b \tag{2.1}$$

$$c_2 = m(b) + \mu - d \cdot \kappa \tag{2.2}$$

The noise term $\varepsilon$ is assumed to be normally distributed:

$$\varepsilon \sim N(0, \sigma^2) \tag{2.3}$$

I assume that uncertainty regarding investment payoff is independent of $\varepsilon$ and is uniformly distributed over the interval $[-\overline{\mu}, \overline{\mu}]$ :

$$\mu \sim U(-\overline{\mu}, \overline{\mu}) \tag{2.4}$$

The expected value of $\mu$ is zero and the variance $\sigma_\mu^2$ is equal to

$$var(\mu) \equiv \sigma_\mu^2 = \frac{1}{12}(2\overline{\mu})^2 = \frac{1}{3}\overline{\mu}^2 \tag{2.5}$$

I restrict attention to compensation schemes that are linear in the two performance measures, first-period cash flows and stock price. The contract $s$ assigns the weight $u$ to the stock price $P$ and $\beta$ to the cash flow $c_1$. Fixed compensation is given by $\alpha$.

$$s = \alpha + \beta c_1 + uP \tag{2.6}$$

$$= \alpha + \beta(a + \varepsilon - b) + uP$$

There is no discounting. The principal is assumed to be risk-neutral and to care only about total net cash flows in the two periods. Her expected utility at time 0 can then be expressed as

$$EU_0^P = E(c_1 - s + c_2) \tag{2.7}$$

I assume that the agent's preferences can be expressed in mean-variance terms. The agent's certainty equivalent CE at time 0 is given by:

$$CE_0 = E(s) - e(a) - \frac{1}{2}\rho \cdot var(s) \qquad (2.8)$$

where $\rho$ is a measure of risk aversion.

A subscript 0 on $CE$ refers to the fact that the expectations and variances are taken with respect to the information at time 0. I assume that the agent's outside option would give him a CE of zero at time 0.

I assume throughout that all parties have rational expectations; the agent, the principal and the stock market. For instance this means that the actions the principal and the market expect the manager to take are the same as the actions the manager actually takes, regarding both effort, investment and disclosure. It also means that the agent rationally anticipates this rationality from the principal and market, and he can correctly infer their conjectured values of the different choice variables.

## 2.3   Information, stock price and disclosure equilibrium

This section describes the agent's payoff if he does or does not release the signal about future payoff, and it caracterizes the disclosure equilibrium. The section ends with a presentation of a numerical example that I will use throughout the chapter.

To solve the dynamics of this model, I use backward induction.

### 2.3.1   Period 2

In period 2, cash flow is realized from the period-1 investment. Since there is no cash left after this (assuming net cash flows are paid out to owners at time 1 and 2), and stock price is calculated on an ex-dividend basis, the stock price at the end of period 2 is equal to zero.

### 2.3.2   Period 1: Time $1^{-}$

The agent receives the signal $f$ at the end of period 1. It is assumed to give a perfect prediction of future investment payoffs:

$$f = m(b) + \mu \tag{2.9}$$

Before observing $f$, but after choosing $b$, the agent knows that the distribution of $f$ is uniform with a mean equal to $m(b)$ and support $[m(b) - \overline{\mu}, m(b) + \overline{\mu}]$ :

$$f \sim U\left[m(b) - \overline{\mu}, m(b) + \overline{\mu}\right] \tag{2.10}$$

Since the principal and the stock market do not know the real value of $b$, they use the conjectured value in their distribution of $f$. The principal and the market believes the agent invested $\hat{b}$, and their distribution of $f$ is given by $\hat{f}$:

$$\hat{f} \sim U\left[m(\hat{b}) - \overline{\mu}, m(\hat{b}) + \overline{\mu}\right] \tag{2.11}$$

where $\hat{b}$ is their conjectured value of $b$.

The disclosure decision will influence the stock price, compensation and the agent's utility. To see whether the agent will choose to disclose his private information, I will calculate the agent's certainty equivalent at the time he makes the disclosure decision both with and without disclosure and compare them.

**The agent discloses the signal**

If the agent discloses the signal, the market will take the signal at face value and incorporate it into the stock price. The stock price at the end of period 1 is assumed to be the expected net value of future net cash flows[6]

$$P = E\left[c_2, d = 1\right] \tag{2.12}$$

---

[6]In the general setup of this model, it is possible that expected future cash flows are negative. To keep stock price a positive value, I assume that there exist assets in place (not modelled here) so that the value of the company is always positive. I thus disregard limited liability and bankruptcy issues.

which gives (superscript 1 on P reflects $d = 1$) :

$$P^1 = f - \kappa \tag{2.13}$$

The stock price reflects future investment cash flows perfectly, net of the disclosure cost. The agent's expected compensation is now:

$$
\begin{aligned}
& E_{1^-}\left[s \mid f, d = 1\right] \tag{2.14} \\
= \; & \alpha + \beta(a - b) + uP^1 \\
= \; & \alpha + \beta(a - b) + u\left(f - \kappa\right)
\end{aligned}
$$

The variance of compensation at time $1^-$ is given by

$$var_{1^-}(s) = \beta^2 \sigma^2 \tag{2.15}$$

Note that the uncertainty regarding investment payoff $(\mu)$ is now resolved, and only uncertainty about $\varepsilon$ remains. I can now find the agent's certainty equivalent at time $1^-$. Since the signal is disclosed, the company incurs the disclosure cost $\kappa$.

$$
\begin{aligned}
CE_{1^-}^1 \; = \; & E(s) - e(a) - \frac{1}{2}\rho \cdot var(s) \\
= \; & \alpha + \beta(a - b) + u(f - \kappa) \tag{2.16} \\
& -e(a) - \frac{1}{2}\rho\beta^2\sigma^2
\end{aligned}
$$

### The agent does not disclose the signal

I first find the value of the stock price. First, I assume that the agent only discloses the signal if it is above a threshold value, and I will subsequently prove that this will be the case in a sequentially rational equilibrium. In this case, the market adjusts its expectations about future cash flows downwards accordingly. The stock price will now reflect a distribution of $f$ that is truncated above from the threshold value of $f$. Call the actual cut-off value $f^{CO}$ and the market's conjecture of this value $\hat{f}^{CO}$. I have:

$$
\begin{aligned}
P^0 &= E_{1^-}\left[m(b) + \mu \mid d = 0\right] & (2.17)\\
&= E_{1^-}\left[m(b) + \mu \mid f < \hat{f}^{CO}\right] & (2.18)
\end{aligned}
$$

The market will use its conjectured value of $b$, $\hat{b}$, in forming the stock price. Since the distribution of $\mu$ is truncated, the support of $\hat{f}$ is no longer $\left[m(\hat{b}) - \overline{\mu}, m(\hat{b}) + \overline{\mu}\right]$, but $\left[m(\hat{b}) - \overline{\mu}, \hat{f}^{CO}\right]$ using the information available to the market. The mean of this truncated uniform variable is given by:

$$
E(\hat{f} \mid \hat{f} < \hat{f}^{CO}) = \frac{1}{2}(m(\hat{b}) - \overline{\mu} + \hat{f}^{CO}) \tag{2.19}
$$

and the variance is:

$$
var(\hat{f} \mid \hat{f} < \hat{f}^{CO}) = \frac{1}{12}\left[\hat{f}^{CO} - (m(\hat{b}) - \overline{\mu})\right]^2 \tag{2.20}
$$

The no-disclosure stock price is therefore:

$$
\begin{aligned}
P^0 &= E(\hat{f} \mid \hat{f} < \hat{f}^{CO}) & (2.21)\\
&= \frac{1}{2}(m(\hat{b}) - \overline{\mu} + \hat{f}^{CO})
\end{aligned}
$$

The agent's compensation is based on the stock price, and the expected value of his compensation is:

$$E_{1-}\left[s \mid f, d=0\right] \tag{2.22}$$

$$= \alpha + \beta(a-b) + uP^0 \tag{2.23}$$

$$= \alpha + \beta(a-b) + u\left(\frac{1}{2}(m(\hat{b}) - \overline{\mu} + \hat{f}^{CO})\right)$$

The variance can be calculated in the same way as in the disclosure case:

$$Var_{1-}(s) = \beta^2 \sigma^2 \tag{2.24}$$

For the agent, the uncertainty regarding $f$ and $P$ is resolved at this point in time, with or without disclosure. The agent's total certainty equivalent depends on the mean and variance of his compensation, in addition to his cost of effort:

$$CE^0_{1-} = E(s) - e(a) - \frac{1}{2}\rho \cdot var(s)$$

$$= \alpha + \beta(a-b) + u\frac{1}{2}(m(\hat{b}) - \overline{\mu} + \hat{f}^{CO}) - e(a) - \frac{1}{2}\rho\beta^2\sigma^2 \tag{2.25}$$

**The disclosure decision**

The disclosure equilibrium is illustrated in Figure 2.2. The agent will choose to disclose the signal if his certainty equivalent with disclosure is higher than without disclosure:

$$CE^1_{1-} \geq CE^0_{1-} \tag{2.26}$$

Comparing the certainty equivalents, this comes down to the following[7]: Disclose if the following condition holds:

$$f \geq \frac{1}{2}(m(\hat{b}) - \overline{\mu} + \hat{f}^{CO}) + \kappa \tag{2.27}$$
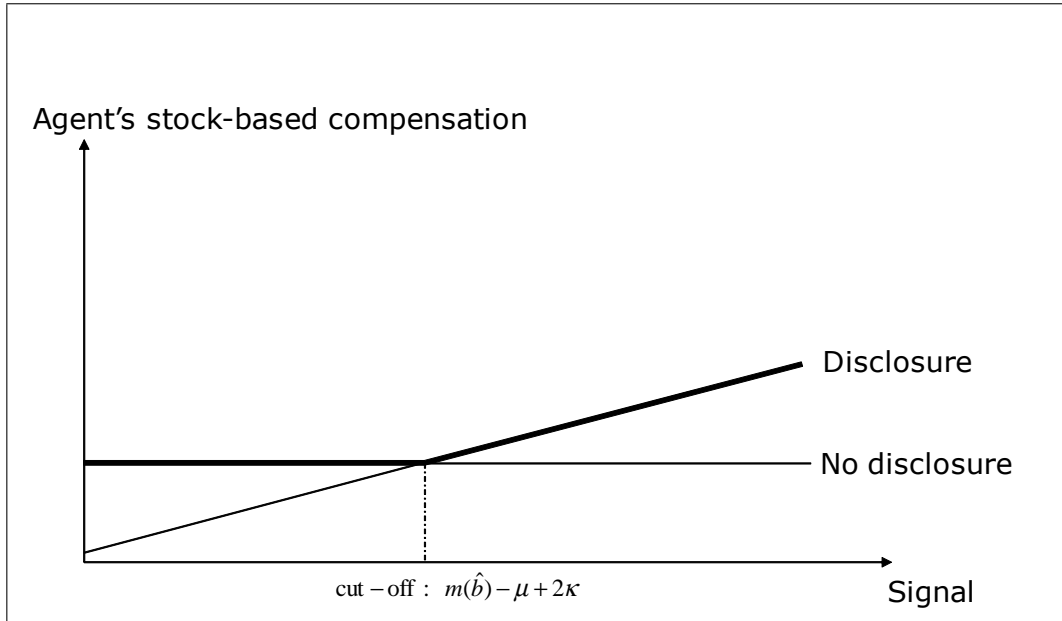


Figure 2.2. Disclosure equilibrium.

The right-hand side defines the agent's cut-off value $f^{CO}$. In a rational expectations equilibrium, the market's conjectures about the manager's cut-off will always be equal to the cut-off the manager chooses, meaning that these values will be equal:

$$\hat{f}^{CO} = f^{CO} \tag{2.28}$$

The cut-off value must then be given as

---

[7] An underlying condition for this to hold is that $u > 0$. For now, I assume that this holds, and optimality is shown later.

$$f^{CO} \equiv \frac{1}{2}(m(\hat{b}) - \bar{\mu} + \hat{f}^{CO}) + \kappa = \hat{f}^{CO} \tag{2.29}$$

giving

$$\hat{f}^{CO} = f^{CO} = m(\hat{b}) - \bar{\mu} + 2\kappa \tag{2.30}$$

See Verrecchia (1983, 1990) for related disclosure equilibria. Since I assume equality of $\hat{f}^{CO}$

and $f^{CO}$ from rational expectations, I will use the equality in (2.28) in the rest of the chapter, and will only use the notation $f^{CO}$ for this value. The no-disclosure stock price becomes:

$$\begin{aligned} P^0 &= \frac{1}{2}(m(\hat{b}) - \bar{\mu} + m(\hat{b}) - \bar{\mu} + 2\kappa) \\ &= m(\hat{b}) - \bar{\mu} + \kappa \end{aligned} \tag{2.31}$$

### 2.3.3 Example: Presentation

I will now present a numerical example. The example will be used to illustrate the main aspects of the model, throughout the paper.

I assume the production function takes the following form:

$$m(b) = 2b - \frac{1}{2}b^2 \tag{2.32}$$

The relevant investment range is given by $\underline{b} = 0$ and $\bar{b} = 2$.

Effort cost is assumed to be quadratic:

$$e(a) = \frac{2}{5}a^2 \tag{2.33}$$

The parameter $\rho$ which represents the agent's risk-aversion, is set to $\frac{1}{2}$. The risk parameters are $\bar{\mu} = \frac{12}{5}$ and $\sigma = \frac{6}{5}$, which makes the variances

$$var(\mu) = \sigma_\mu^2 = \frac{1}{3}\bar{\mu}^2 = \frac{144}{75} = 1.92 \tag{2.34}$$

$$\sigma^2 = \frac{36}{25} = 1.44 \tag{2.35}$$

The disclosure cost is set to $\frac{1}{4}$. I further assume that the agent's outside option can be represented by a certainty equivalent of zero.

### 2.3.4   Example: The disclosure decision:

The disclosure stock price equals the signal net of the disclosure cost.

$$P^1 = f - k = f - \frac{1}{4} \tag{2.36}$$

The no-disclosure stock price is the expected value of $f$, given that $f$ is below the (conjectured) cutoff $\hat{f}^{CO}$.

$$
\begin{aligned}
P^0 &= \frac{1}{2}(m(\hat{b}) - \overline{\mu} + \hat{f}^{CO}) \\
&= \frac{1}{2}\left(2\hat{b} - \frac{1}{2}\hat{b}^2 - \frac{12}{5} + \hat{f}^{CO}\right)
\end{aligned} \tag{2.37}
$$

The manager will disclose when the disclosure stock price is higher than the no-disclosure stock price.

$$
\begin{aligned}
P^1 &> P^0 \\
f - \frac{1}{4} &> \frac{1}{2}\left(2\hat{b} - \frac{1}{2}\hat{b}^2 - \frac{12}{5} + \hat{f}^{CO}\right)
\end{aligned} \tag{2.38}
$$

The cut-off is the value of $f$ where this is an equality:

$$f^{CO} \equiv \frac{1}{2}\left(2\hat{b} - \frac{1}{2}\hat{b}^2 - \frac{12}{5} + \hat{f}^{CO}\right) + \frac{1}{4} \tag{2.39}$$

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The equilibrium occurs when $f^{CO} = \hat{f}^{CO}$

$$f^{CO} = \frac{1}{2}\left(2\hat{b} - \frac{1}{2}\hat{b}^2 - \frac{12}{5} + f^{CO}\right) + \frac{1}{4} \tag{2.40}$$

$$f^{CO} = 2\hat{b} - \frac{1}{2}\hat{b}^2 - \frac{19}{10} \tag{2.41}$$

Figure 2.3 shows the equilibrium (using $\hat{b} = 0.84702$) .
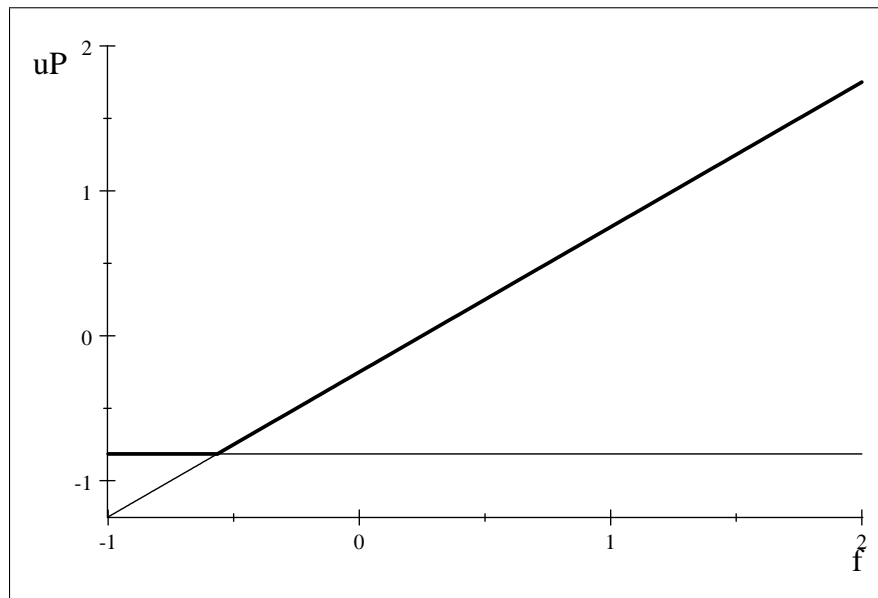


Figure 2.3. Stock-based compensation $uP$ as a function of the signal $f$.

The kinked line is the agent's effective compensation, with the optimal disclosure decision. Although the contract in itself is linear, the compensation with voluntary disclosure turns out to be piecewise linear and convex. This is the effect of the voluntary disclosure decision. In this model, the convexity is a result of the voluntary disclosure setting, not necessarily from optimal contracting. With voluntary disclosure and linear contracts, the resulting compensation is in some ways similar to option contracts, as seen in Figures 2.2 and 2.3; piecewise linear and convex. The setting is different from an option contract, but the effects and results are related to and in some ways similar to option compensation[8]. I restrict my attention to linear contracts,

---

[8]Hemmer, Kim and Verrecchia (2000), Feltham and Wu (2001), and Flor, Frimor and Munk (2011) study the optimality of convex contracts, but without the voluntary disclosure setting.

but an interesting extension of this model could be to consider how a setting with a (piece-wise linear) convex contract (and full disclosure) would be different from or similar to this one.

## 2.4   Time 0. The investment decision

In this section I will describe the manager's investment decision at time 0. Before I do so for the voluntary disclosure setting, I will describe the investment decision in some other cases. I start with the first best setting, and then move on to the full disclosure setting and the situation where there is no signal to disclose (the no signal case). I then present the investment decision with voluntary disclosure and illustrate this with the numerical example.

### 2.4.1   First best investment and effort levels (FB)

Initially, it may be instructive to describe the first best level of investment and effort, denoted $b^{FB}$ and $a^{FB}$. I find $b^{FB}$ by maximizing the net value of the investment, depending on $b$, and finding the first-order condition. To find first best, I maximize

$$a - e(a) - b + m(b) \tag{2.42}$$

The first order condition for investment is

$$-1 + m'(b^{FB}) = 0 \tag{2.43}$$

or

$$m'(b^{FB}) = 1 \tag{2.44}$$

Similarly for effort, the first order condition is:

$$1 - e'(a) = 0 \tag{2.45}$$

$$e'(a^{FB}) = 1 \tag{2.46}$$

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### 2.4.2 Full disclosure (F)

As a benchmark case, I look at the case where the agent always discloses the signal; either the disclosure decision is contractible or the principal controls the decision and always prefers to disclose.

The agent's certainty equivalent is

$$CE_0 = \alpha + \beta E\left(c_1\right) - e(a) + u\left[m(b) - \kappa\right] - \frac{1}{2}\rho(\beta^2\sigma^2 + u^2\sigma_\mu^2) \tag{2.47}$$

where the stock price variance is given by

$$var\, P^F = \sigma_\mu^2 = \frac{1}{3}\bar{\mu}^2 \tag{2.48}$$

The first-order condition for investment determines the chosen investment level:

$$\frac{\partial CE_0}{\partial b} = -\beta + um'(b) = 0 \tag{2.49}$$

I call the level of $b$ that satisfies this FOC $b^F$.

### 2.4.3 No signal and no possible disclosure (N)

I will here discuss the setting where there is no signal, and the signal $f$ in the model cannot be used. In this case there is no signal to disclose and no information will be revealed to the market at time $1^-$. This is different from the case where the manager voluntarily decides not to disclose in the sense that in this new case, the fact that the market does not receive a signal does not signal bad news. The stock price will be based on the market's conjectures only, and contains no new information. The stock price will be fixed at

$$P^N = m(\hat{b}) \tag{2.50}$$

The agent's certainty equivalent will be:

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$$CE_0 = \alpha + \beta(a - b) + uP^N - e(a) - \frac{1}{2}\rho\beta^2\sigma^2 \tag{2.51}$$

It is clear from differentiating this with respect to $b$, that the agent will not receive any of the benefits from the investment, but will have to bear part of the cost:

$$\frac{\partial CE_0}{\partial b} = -\beta \tag{2.52}$$

The investment decision is based on the agent's cash flow based compensation only. I call this level of investment $b^N$, and the agent will obviously invest as little as possible, as long as $\beta > 0$:

$$b^N = \underline{b} \tag{2.53}$$

On the other hand, as will be discussed later, in this case it is possible that it is optimal to set $\beta = 0$. Then the agent receives only fixed compensation, and no bonus of any kind, and he is indifferent to how much is invested. I assume that when indifferent, the agent chooses what is optimal for the principal (the most efficient level), and he invests the first best amount, $b^{FB}$. It is then no point in giving the manager any stock-based compensation. So when $\beta = 0$, it follows that $u = 0$.

The agent' s FOC for effort is:

$$\frac{\partial CE_0}{\partial a} = \beta - e'(a) = 0 \tag{2.54}$$

$$\beta = e'(a) \tag{2.55}$$

When $\beta > 0$, then $a > 0$. When $\beta = 0$, then $a = 0$, since the agent in this case has no incentives to spend any costly effort.

In sum, there are two cases to consider when there is no signal. I call these Case 1 and Case 2 in Table 2.1. The stock bonus will never be positive ($u = 0$) when there is no signal since the stock price has no information value. Which one of these two solutions will be preferred, depends on the relative benefits (and costs) of effort versus investment.

| | $\beta > 0$ | $\beta = 0$ |
|---|---|---|
| $u > 0$ | Interior solution $a > 0, b > \underline{b}$ | Never optimal |
| $u = 0$ | Case 1 $b = \underline{b}, a > 0$ | Case 2 $b = b^{FB}, a = 0$ |

Table 2.1. Possible solutions. The no signal cases are Case 1 and Case 2.

### 2.4.4   Voluntary disclosure (V)

In order to find the agent's preferred investment level with voluntary disclosure I first find the agent's certainty equivalent, which depends on the agent's expectations about what will happen at time $1^-$, 1 and 2. The agent knows that he will make an optimal disclosure decision at time $1^-$ . So I allow the investment decision to depend potentially on his expected future disclosure strategy, and then later find out if this is the case (it is).

**The probability of disclosure**

At time 0, the agent influences the probability that $f$ is above $f^{CO}$ when he chooses the investment level. Higher investment moves the distribution of $f$ upwards and increases the probability of disclosure at time $1^-$.

Recall that the distribution of $f$ is: $f \sim U[m(b) - \overline{\mu}, m(b) + \overline{\mu}]$. The probability that $f$

is below the cut-off value $f^{CO}$ is the cumulative probability $\Pi(f^{CO})$ from the lower bound of the distribution $[m(b) - \overline{\mu}]$ up to $f^{CO}$, see Figure 2.4.
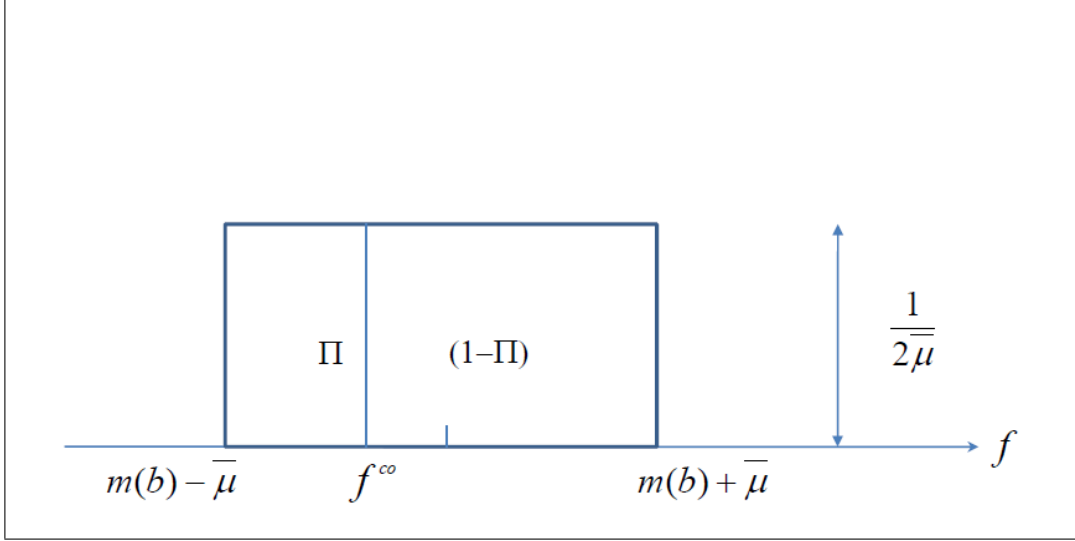
Figure 2.4. The distribution of $f$, and the probability of disclosure $(1 - \Pi)$.

I then have[9]:

$$
\begin{aligned}
\Pi(f^{CO}) &= \int\limits_{m(b)-\overline{\mu}}^{f^{CO}} \frac{1}{2\overline{\mu}} df \\
&= \frac{f^{CO} - (m(b) - \overline{\mu})}{2\overline{\mu}} \\
&= \frac{m(\hat{b}) - m(b)}{2\overline{\mu}} + \frac{\kappa}{\overline{\mu}}
\end{aligned}
\tag{2.56}
$$

The term $\Pi(f^{CO})$ is the probability of no disclosure, and $(1 - \Pi(f^{CO}))$ is the probability of disclosure.

**The agent's certainty equivalent and investment decision**

The agent's CE at time 0 is:

---

[9]If $\frac{f^{CO} - (m(b) - \overline{\mu})}{2\overline{\mu}} \leq 0$, then $\Pi(f^{CO}) = 0$. If $\frac{f^{CO} - (m(b) - \overline{\mu})}{2\overline{\mu}} \geq 1$, then $\Pi(f^{CO}) = 1$. If $\Pi(f^{CO}) = 0$ the agent always discloses the signal, and if $\Pi(f^{CO}) = 1$, the agent never discloses.

$$CE_0 = \alpha + \beta(a - b) - e(a) - \frac{1}{2}\rho\beta^2\sigma^2 \tag{2.57}$$

$$+u\left((1 - \Pi(f^{CO})) \cdot \frac{1}{2}\left(m(b) + m(\hat{b})\right) + \Pi(f^{CO}) \cdot \left(m(\hat{b}) + \kappa - \overline{\mu}\right)\right)$$

$$-\frac{1}{2}\rho u^2 \cdot \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2$$

For a full calculation of the expression for the agent's certainty equivalent and differentiation of this with respect to $b$, see Appendix 2.A.1. When the agent makes the investment decision, he takes the market's conjectures $\hat{b}$ as given, since he cannot influence this. This means that his optimal choice of investment is calculated keeping the market's expectations constant.

From the agent's first-order condition (in Appendix 2.A.2), I show that:

i) An increase in investment increases the probability of disclosure.

ii) An increase in investment also directly influences the disclosure stock price. The disclosure stock price increases because of higher future cash flows from the investment

iii) An increase in investment changes the variance of the agent's compensation

iv) Increased investment reduces first-period cash flow based bonus compensation

More specifically, I find that the agent's FOC for investment is given by[10]:

$$\frac{\partial CE_0}{\partial b} = -\beta + m'(b)uZ = 0 \tag{2.58}$$

where $Z = Z(b, \hat{b}, \kappa, \overline{\mu}, u, \rho)$ is defined as

---

[10] For the agent's FOC to give an optimum, it is required that the second derivative is negative in the relevant range. A discussion of conditions that have to be met to satisfy this requirement is presented in Appendix 2.A.5.

$$Z \quad \equiv \quad \left( \frac{m(b) - m(\hat{b}) - 2\kappa + 2\overline{\mu}}{2\overline{\mu}} \right) \tag{2.59}$$

$$-\frac{1}{2}\rho u \left\{ \begin{array}{l} \frac{1}{4\overline{\mu}} \left( \Pi(f^{CO}) - \frac{1}{3} \right) \cdot \left[ m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa \right]^2 \\ + \frac{1}{2} (1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot \left[ m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa \right] \end{array} \right\}$$

$Z$ reflects the net effect of stock price and disclosure on the agent's choice of investment. I call the level of investment that satisfies the agent's FOC $b^V$. Using the fact that $\hat{b} = b$ in a rational expectations equilibrium, I show in the appendix that $Z$ reduces to:

$$Z = (1 - \Pi) - \rho u \left(1 - \Pi\right)^2 \Pi\overline{\mu} \tag{2.60}$$

and $\Pi$ becomes

$$\Pi = \frac{\kappa}{\overline{\mu}}$$

Since $\Pi$ is a probability with a value between zero and one, it is clear that in equilibrium $Z < 1$. $Z$ measures, net of $u$ and $m'(b)$, the effect of increasing investment on the agent's utility from stock-based compensation. The first term $(1 - \Pi)$, shows the increase in expected compensation from increasing investment. The expected increase in cash flow is reflected in stock price only in case of disclosure, which occurs with probability $(1 - \Pi)$. The second term reflects the increase in risk imposed on the agent when he increases investment. Whenever $\Pi$ is different from one or zero (whenever there is uncertainty up front about the disclosure of the signal) an increase in investment increases the agent's risk. With higher risk aversion $\rho$, the lower is the value of $Z$, and the smaller is the agent's net increase in utility from increasing investment. A manager with a higher degree of risk aversion will invest less than a manager will lower risk aversion for a given contract.

The term $(uZ)$ in (2.58), which is what gives the manager incentives to invest, is concave

in $u$ (see Appendix 2.A.4 for details). This occurs when stock bonus $u$ is

$$u^{\max} = \frac{1}{2\rho(1 - \Pi)\Pi\overline{\mu}} \tag{2.61}$$

and $uZ$ reaches the value of $uZ = \frac{1}{4\rho\Pi\overline{\mu}}$. Setting a value of $u$ higher than this value will not increase the manager's incentives to invest. When $u$ is concave, the same incentive effect from $uZ$ can be reached by two different levels of $u$, but the principal will always choose the lower of these two values since the principal's cost in terms of risk premium increases in $u$. I note that a specific value of $u^{\max}$ only exists when $\rho > 0$. So if the agent were risk neutral, such a maximum would not exist.

### Investment incentives with voluntary and full disclosure

For a given stock bonus, investment is lower with voluntary disclosure than with full disclosure (see Appendix 2.A.6 for details). I compare the first order conditions in (2.49) for full disclosure with (2.58) and (2.60) for voluntary disclosure. I find that (2.49) is equivalent to (2.58) with $Z = 1$. Combined with the above discussion, I have that

$$Z(b, \hat{b}, \kappa, \overline{\mu}, u, \rho)) < 1 \quad and \quad b^V < b^F \tag{2.62}$$

When incentives are held fixed, there are two reasons why the agent will choose a lower investment with voluntary disclosure than with full disclosure (two reasons why Z in (2.60) is different from 1). The first is that with full disclosure the agent's compensation increases with the fraction (bonus) $u$ for every increase in investment payoffs, while the same number with voluntary disclosure is $(1 - \Pi(f^{CO}))\cdot u \leq u$. The term $(1 - \Pi(f^{CO}))$ is the probability of disclosure, and this is lower than 1. If the manager does not disclose the signal, he will not get any rewards from investing, and the prospect of this reduces his incentives to invest. I will discuss this further in Section 2.6.3.

The second reason is that the agent's marginal change in risk is different in the two cases. The risk premiums are

$$RP^F = (\beta^2 \sigma^2 + u^2 \sigma_\mu^2) \qquad (2.63)$$

$$RP^V = u^2 \cdot \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2 \qquad (2.64)$$

The derivatives with respect to $b$ are:

$$\frac{\partial RP^F}{\partial b} = 0 \qquad (2.65)$$

In equilibrium (when $\hat{b} = b$) :

$$\frac{\partial RPV}{\partial b} = \rho u^2 (1 - \Pi)^2 \Pi \overline{\mu} m'(b) \geq 0 \qquad (2.66)$$

With full disclosure, the risk the manager has to bear does not depend on the amount invested, (2.63) is constant in $b$. On the other hand, when there is voluntary disclosure, the manager's risk premium depends on $b$, because both $\Pi$ and $m(b)$ in (2.64) depend on $b$. With voluntary disclosure the manager increases his risk when increasing investment. From (2.60), it is clear that the risk term decreases $Z$ . While stock price risk with voluntary disclosure is never higher than stock price risk in the full disclosure setting, it is the marginal increase in risk that determines the manager's incentives, and this is higher with voluntary disclosure than with full disclosure. With voluntary disclosure, increasing investment increases the manager's probability of ending up in the risky part of the effective compensation in Figure 2.2, where compensation depends on the risky investment. This also decreases the manager's incentives to invest below the full disclosure level.

To summarize: Investment will be lower with voluntary disclosure compared to full disclosure, given the same contract. This means that if there is underinvestment with full disclosure, this problem will be even more severe with voluntary disclosure. Disclosure and investment decisions are not independent in the agent's optimization problem, and must be considered together. The fact that the manager in many cases controls the information flow to the market,

while being compensated based on the stock price which incorporates this information, compli-
cates incentive issues. Later, in Section 2.6, I will discuss the principal's optimization problem,
and I will then use some of the results from this section.

### 2.4.5   Example: The agent's first order conditions:

For a given investment level $b$, the distribution of the signal $f$ is uniformly distributed:

$$f \sim U \left[ 2b - \frac{1}{2}b^2 - \frac{12}{5}, 2b - \frac{1}{2}b^2 + \frac{12}{5} \right]$$

The probability of non-disclosure $\Pi$ is

$$
\begin{aligned}
\Pi(f^{CO}) &= \frac{m(\hat{b}) - m(b)}{2\bar{\mu}} + \frac{\kappa}{\bar{\mu}} \\
&= \frac{2\hat{b} - \frac{1}{2}\hat{b}^2 - \left(2b - \frac{1}{2}b^2\right)}{2 \cdot \frac{12}{5}} + \frac{\frac{1}{4}}{\frac{12}{5}} \\
&= \frac{2\hat{b} - \frac{1}{2}\hat{b}^2 - \left(2b - \frac{1}{2}b^2\right)}{\frac{24}{5}} + \frac{5}{48}
\end{aligned}
\tag{2.67}
$$

The agent's $CE$ is:

$$
\begin{aligned}
CE_0 &= \alpha + \beta(a - b) - \frac{2}{5}a^2 - \frac{1}{2} \cdot \frac{1}{2}\beta^2 \cdot \frac{36}{25} \\
&\quad + u \left( \begin{array}{c} (1 - \Pi(f^{CO})) \cdot \frac{1}{2} \left( 2b - \frac{1}{2}b^2 + 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) \\[2mm] + \Pi(f^{CO}) \cdot \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 + \frac{1}{4} - \frac{12}{5} \right) \end{array} \right) \\
&\quad - \frac{1}{2}\frac{1}{2}u^2 \cdot \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \\
&\quad \cdot \left( 2b - \frac{1}{2}b^2 - \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) + 2 \cdot \frac{12}{5} - 2 \cdot \frac{1}{4} \right)^2
\end{aligned}
\tag{2.68}
$$

where $\Pi(f^{CO})$ is given by (2.67).

I differentiate wrt $b$ :

$$\frac{\partial CE_0}{\partial b}$$

$$= -\beta + u \begin{pmatrix} -\frac{\partial \Pi}{\partial b} \cdot \frac{1}{2} \left( 2b - \frac{1}{2}b^2 + 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) \\ +(1 - \Pi(f^{CO})) \cdot \frac{1}{2}(2 - b) + \frac{\partial \Pi}{\partial b} \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 + \frac{1}{4} - \frac{12}{5} \right) \end{pmatrix}$$

$$-\frac{1}{16}u^2 \begin{pmatrix} \left( -\frac{\partial \Pi}{\partial b} \cdot (\frac{1}{3} + \Pi(f^{CO}) + (1 - \Pi(f^{CO})) \cdot \frac{\partial \Pi}{\partial b}) \right) \\ \cdot \left( 2b - \frac{1}{2}b^2 - \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) + 2 \cdot \frac{12}{5} - 2 \cdot \frac{1}{4} \right)^2 \\ +(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \\ \\ \cdot 2 \left( 2b - \frac{1}{2}b^2 - \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) + 2 \cdot \frac{12}{5} - 2 \cdot \frac{1}{4} \right) \cdot (b - 2) \end{pmatrix} \quad (2.69)$$

where

$$\frac{\partial \Pi}{\partial b} = -\frac{(2 - b)}{\frac{24}{5}} \quad (2.70)$$

I rewrite and get:

$$\frac{\partial CE_0}{\partial b}$$

$$= -\beta + u(2 - b)\frac{1}{\frac{24}{5}} \left( \left( 2b - \frac{1}{2}b^2 - \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) + \frac{43}{10} \right) \right)$$

$$-\frac{1}{4}u^2 \begin{pmatrix} \left( \left( \frac{1}{\frac{48}{5}} \right) \cdot ((\Pi(f^{CO}) - \frac{1}{3})) \right) \\ \cdot \left( 2b - \frac{1}{2}b^2 - \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) + \frac{43}{10} \right)^2 \\ +\frac{1}{2}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \\ \\ \cdot \left( 2b - \frac{1}{2}b^2 - \left( 2\hat{b} - \frac{1}{2}\hat{b}^2 \right) + \frac{43}{10} \right) \end{pmatrix} \cdot (2 - b) \quad (2.71)$$

I find the agent's first order condition in equilibrium, where $\hat{b} = b$:

$$\frac{\partial CE_0}{\partial b} \tag{2.72}$$

$$= -\beta + u\,(2 - b)\,\frac{1}{\frac{24}{5}}\left(\frac{43}{10}\right)$$

$$-\frac{1}{4}u^2 \left( \begin{array}{c} \left(\left(\frac{1}{\frac{48}{5}}\right)\cdot(\Pi - \frac{1}{3})\right)\cdot\left(\frac{43}{10}\right)^2 \\ +\frac{1}{2}(1-\Pi)(\frac{1}{3}+\Pi)\cdot\left(\frac{43}{10}\right) \end{array} \right)\cdot(2 - b) = 0$$

and from (2.67) and $\hat{b} = b$, I find that:

$$\Pi(f^{CO}) = \frac{5}{48} \tag{2.73}$$

I rearrange the first order condition and get:

$$-\beta + u\,(2 - b)\,\frac{43}{48} - u^2\cdot(2 - b)\,\frac{1849}{18\,432} = 0 \tag{2.74}$$

I will later analyze this first order condition in more detail.

## 2.5 The principal's problem: No signal solutions, corner solutions, and the full disclosure case

The previous comparison of investment with voluntary and full disclosure is contingent on all other things being equal. More specifically, the contract was held constant, with the same bonus coefficients $\beta$ and $u$ in both cases. In this and the following section I will study the optimal contract. In this section I present the principal's problem in the no signal case and full disclosure case. I also find the first best solution in the numerical example, and use the example to solve the principal's problem in the full disclosure case. Finally I present the possible corner solutions in the numerical example.

### 2.5.1 The no signal case and corner solutions

Recall the two possible cases from Table 2.1 (Case 1 and Case 2). These are the two cases to consider when there is no signal. When there is no signal, the principal will choose either Case 1 or Case 2, and she will choose the one wich gives her the highest expected payoff.

But even if this signal exists, and the stock price incorporates its value into the stock price, the principal can choose not to use the stock price in the incentive contract. She will choose to do so (only) if the interior solution with $u > 0$ gives lower expected payoff than the highest of Case 1 and Case 2.

I will here describe the characteristics for Case 1 and Case 2 and find conditions for when the principal will choose one over the other.

### Case 1

In Case 1, $u = 0$, and investment is at the lowest possible value $\underline{b}$ and $\beta$ and effort are positive. I call the investment level with no signal $b^N$, so $b^N = \underline{b}$ in this case.

The principal maximizes

$$W^N \equiv a - b + m(b) - e(a) - \rho \frac{1}{2} \beta^2 \sigma^2 \tag{2.75}$$

subject to

$$\beta = e'(a) \tag{2.76}$$

The bonus parameter $u$ has no incentive effects and will only contribute to the fixed compensation. The sum of $u$ and $\alpha$ will be set so that the agent's participation constraint is satisfied.

I substitute for $\beta$ in the maximand, then differentiate w.r.t. $a$ :

$$\frac{\partial W^N}{\partial a} = 1 - e'(a) - \rho e'(a) e''(a) \sigma^2 = 0 \tag{2.77}$$

Defining $a_1^N$ as the optimal effort level the principal wants to induce here, Case 1 effort is given by:

$$e'(a_1^N) = \frac{1}{1 + \rho e''(a_1^N)\sigma^2} \tag{2.78}$$

To achieve the level of effort $a_1^N$ that satisfies this equality, the principal sets the corresponding $\beta_1^N \equiv e'(a_1^N)$ from (2.76). From (2.78) it is clear that $a_1^N > 0$.

**Case 2**

In Case 2, $u = 0$ and $\beta = 0$.

When $\beta = 0$, the agent will not spend any effort, so $a = 0$, and consequently there will be no cash flows from effort. When both $u$ and $\beta$ are equal to zero, however, the manager will be indifferent between all levels of investment, and I assume that he chooses the level that is best for the principal, which is $b = b^{FB}$.

To summarize (subscripts denote case 1 or 2):

$$\text{Case 1} \quad : \quad u_1^N = 0, \beta_1^N > 0, b_1^N = \underline{b}, a_1^N > 0 \tag{2.79}$$

$$\text{Case 2} \quad : \quad u_2^N = 0, \beta_2^N = 0, b_2^N = b^{FB}, a_2^N = 0 \tag{2.80}$$

Which of these cases will be optimal for the principal, depends on the relative importance of effort and investment in his expected payoffs. She will choose case 1 if

$$W^N(u_1^N, \beta_1^N, b_1^N, a_1^N) \geq W^N(u_2^N, \beta_2^N, b_2^N, a_2^N) \tag{2.81}$$

and otherwise case 2. (2.81) can be rewritten as:

$$a_1^N - \underline{b} + m(\underline{b}) - e(a_1^N) - \rho\frac{1}{2}\beta^2\sigma^2 \geq -b^{FB} + m(b^{FB}) \tag{2.82}$$

In the no signal case, the principal will choose the best of Case 1 aand Case 2. If there exists a signal, the principal will only choose Case 1 or Case 2 if one of these gives a higher expected payoff than the interior solution (where $u > 0$ and $\beta > 0$).

## 2.5.2   Full disclosure

Recall that the manager's incentive constraint for investment is given by (2.49) Thus, if there is full disclosure, the principal's optimization problem will be:

$$E_0\left[(c_1 - s) + c_2\right] \tag{2.83}$$

subject to

$$CE_0 \geq 0 \tag{2.84}$$

$$\beta = e'(a) \tag{2.85}$$

$$\beta = um'(b) \tag{2.86}$$

The principal maximizes her net cash flows, subject to the agent's participation constraint, and his two incentive constraints for effort and investment. I substitute for the participation constraint, and the maximization problem becomes:

$$\max W^F \equiv a - b + m(b) - e(a) - \frac{1}{2}\rho\left(\beta^2\sigma^2 + u^2 \cdot \sigma_\mu^2\right) - \kappa \tag{2.87}$$

subject to the two incentive constraints.

Dutta and Reichelstein (2005)[11] show in a similar setting that investment will be below first best. This is because it is costly, in terms of risk being imposed on the agent, to give investment incentives.

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[11] Contrary to this paper, Dutta and Reichelstein (2005) assume normally distributed noise $\mu$, they have interim participation constraints between periods, and they use a more general t-period model. They also have an asset value in their incentive contract.

I first rearrange (2.86):

$$u = \frac{\beta}{m'(b)} \tag{2.88}$$

The principal chooses which levels of $a$ and $b$ to induce by maximizing $W^F$

$$
\begin{aligned}
W^F &= a - b + m(b) - e(a) - \kappa - \rho \frac{1}{2}(\beta^2 \sigma^2 + u^2 \cdot \sigma_\mu^2) \\
&= a - b + m(b) - e(a) - \kappa - \frac{1}{2}\rho(\beta^2 \sigma^2 + \left(\frac{\beta}{m'(b)}\right)^2 \cdot \sigma_\mu^2)
\end{aligned}
\tag{2.89}
$$

I differentiate with respect to $b$ and get the principal's first-order condition for investment:

$$-1 + m'(b) + \rho \underbrace{\left[ \frac{\beta^2}{[m'(b)]^2} \right]}_{u^2} \cdot \underbrace{\frac{m''(b)}{m'(b)}}_{sensitivity} \cdot \underbrace{\frac{1}{3}\bar{\mu}^2}_{varPF} = 0 \tag{2.90}$$

Since $-1 + m'(b^{FB}) = 0$ defines the first best level of investment $b^{FB}$, and the *sensitivity* term in (2.90) is negative (and $m'(b) > 1$), the level of investment with full disclosure will be below the first best; $b^F < b^{FB}$

I note that the FOC for effort is given by:

$$\frac{\partial W^F}{\partial a} = 1 - e'(a) - \rho e'(a) e''(a) \left( \sigma^2 + \left[ \frac{1}{m'(b)} \right]^2 \cdot \sigma_\mu^2 \right) = 0 \tag{2.91}$$

or equivalently

$$e'(a^F) = \frac{1}{1 + \rho e''(a^F) \left( \sigma^2 + \left[ \frac{1}{m'(b)} \right]^2 \cdot \sigma_\mu^2 \right)} \tag{2.92}$$

The term $a^F$ is defined as the value of $a$ that satisfies this equation. I have assumed $e(a)$ is convex, and $e''(a) > 0$. First best effort $a^{FB}$ is given by $e'(a^{FB}) = 1$, and with full disclosure effort $a^F$ will be below first best; $a^F < a^{FB}$. I can compare the effort level in (2.78) which is the no disclosure, lowest investment case, with the full disclosure effort level in (2.92). The denominator in (2.92) is higher than in (2.78) because of the last term in the brackets in (2.92).

When the denominator is higher, the fraction is smaller, and $e'(a_1^N)$ is smaller in (2.92) than in (2.78). I have assumed that $e'(a)$ is increasing, so this means that effort is lower with full disclosure than in the no signal, lowest investment case (Case 1):

$$a^F < a_1^N$$

With full disclosure, there is a positive level of investment, as well as effort, in the optimum. The incentive constraint in (2.88) shows that increasing effort (and therefore $\beta$) increases the necessary stock bonus $u$, and stock bonus imposes risk on the agent. This causes a trade-off between inducing effort and investment. Inducing effort is more costly to the principal when she also wants to induce investment. Therefore, optimal effort level is lower in the full disclosure case than in the no signal, lowest investment case.

### 2.5.3 Example: First best solution, full disclosure solution and possible corner solutions

Before presenting the principal's problem and the optimal (interior) solution, I will present the first best solutions, possible corner solutions and the full disclosure solution.

**First best solution**

I find the first best level of effort and investment.

$$\max_b \left(-b + m(b)\right) = -b + 2b - \frac{1}{2}b^2 \tag{2.93}$$

$$\max_a \left(a - e(a)\right) = a - \frac{2}{5}a^2 \tag{2.94}$$

I differentiate and set equal to zero

$$
\begin{aligned}
-1 + 2 - b &= 0 \\
b^{FB} &= 1
\end{aligned}
\tag{2.95}
$$

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$$1 - \frac{4}{5}a = 0$$

$$\frac{4}{5}a = 1$$

$$a^{FB} = \frac{5}{4} \tag{2.96}$$

The principal's expected payoff is:

$$W^{FB} = -b^{FB} + 2b^{FB} - \frac{1}{2}\left(b^{FB}\right)^2 + a^{FB} - \frac{2}{5}\left(a^{FB}\right)^2 \tag{2.97}$$

$$= -1 + 2 - \frac{1}{2} + \frac{5}{4} - \frac{2}{5}\left(\frac{5}{4}\right)^2 \tag{2.98}$$

$$= \frac{9}{8} \tag{2.99}$$

**Full disclosure solution**

With full disclosure, the disclosure cost is always realized. The agent maximizes

$$\max CE_0 = \alpha + \beta(a - b) - \frac{2}{5}a^2 - \frac{1}{2} \cdot \frac{1}{2}\beta^2 \cdot \frac{36}{25} \tag{2.100}$$
$$+ u\left(f - \kappa\right)$$
$$-\frac{1}{2}\frac{1}{2}u^2 \cdot \frac{144}{75}$$

I differentiate:

$$\frac{\partial CE_0}{\partial b} = -\beta - u \cdot (2 - b) = 0$$

$$u = \frac{\beta}{2 - b} \tag{2.101}$$

$$\frac{\partial CE_0}{\partial a} = \beta - \frac{4}{5}a = 0$$

$$\beta = \frac{4}{5}a \qquad (2.102)$$

The principal maximizes

$$\max_{a,b} W^F = a - b + 2b - \frac{1}{2}b^2 - \frac{2}{5}a^2 - \frac{1}{4} - \frac{1}{4}\left(\left(\frac{4}{5}a\right)^2 \frac{36}{25} + \left(\frac{\frac{4}{5}a}{2-b}\right)^2 \frac{144}{75}\right) \qquad (2.103)$$

I differentiate with respect to $a$ and $b$ and get two first order conditions:

$$1 - b - \left(\frac{\frac{4}{5}a}{(2-b)}\right)^2 \frac{1}{2-b}\frac{24}{25} = 0$$

$$1 - \frac{4}{5}a - \frac{2}{25}a\left(\frac{144}{25} + \frac{192}{25}\frac{1}{(2-b)^2}\right) = 0$$

The optimal effort and investment levels with full disclosure are:

$$a = 0.576\,40$$

$$b = 0.861\,63$$

The principal's expected payoff equals $W^F = 0.52863$ in this case. The payoff in this solution, which is an interior solution, is higher than the payoff in the corner solutions shown below, so the principal prefers the interior solution.

**Corner solutions**

**Case 1:** $\beta > 0, u = 0$  In this corner solution, the principal induces effort, but no investment. The problem turns into the well-known effort-problem.

The principal maximizes

$$\max\left(a - \frac{2}{5}a^2 - \frac{1}{2}\cdot\frac{1}{2}\beta^2\frac{36}{25}\right) \qquad (2.104)$$

s.t.

$$a \in \arg\max \left( \beta \cdot a - \frac{2}{5}a^2 - \frac{1}{2} \cdot \frac{1}{2}\beta^2 \frac{36}{25} \right) \tag{2.105}$$

The agent's FOC is:

$$\beta - \frac{4}{5}a = 0 \tag{2.106}$$

$$\beta = \frac{4}{5}a \tag{2.107}$$

The principal's unconstrained optimization problem becomes:

$$\max \left( a - \frac{2}{5}a^2 - \frac{1}{2} \cdot \frac{1}{2}\beta^2 \frac{36}{25} \right) = a - \frac{2}{5}a^2 - \frac{1}{2} \cdot \frac{1}{2}\left(\frac{4}{5}a\right)^2 \frac{36}{25} = a - \frac{2}{5}a^2 - \left(\frac{4}{5}a\right)^2 \frac{36}{100}$$

$$= a - \frac{394}{625}a^2 \tag{2.108}$$

I differentiate and get the optimal effort level:

$$1 - \frac{788}{625}a = 0$$

$$a = \frac{625}{788} = 0.793147 \tag{2.109}$$

The principal's expected payoff is :

$$W = a - \frac{394}{625}a^2$$

$$= \frac{625}{788} - \frac{394}{625}\left(\frac{625}{788}\right)^2$$

$$= \frac{625}{1576} = 0.396\,57 \tag{2.110}$$

**Case 2:** $\beta = 0, u = 0$ With flat compensation, the agent will excert no effort. He has no incentives to under-(or over-)invest. I assume when indifferent he chooses the first best level of investment. He will also have no incentives to disclose the signal. Expected payoff to the

principal in this case is

$$
\begin{aligned}
W^V &= -b^{FB} + m(b^{FB}) \\
&= -1 + 2 - \frac{1}{2} \cdot 1^2 \\
&= \frac{1}{2}
\end{aligned}
\tag{2.111}
$$

This corner solution gives the principal a higher expected payoff than the former where $\beta > 0$ and $u = 0$. The best interior solution should then be compared to that corner solution to see whether an interior or corner solution is optimal. In both of these cases, there is no disclosure. The corner solution in Case 2 (with $W = 0.5$) does quite well compared to the full disclosure solution ($W = 0.52863$), but is inferior to it. Even with no effort, the company's payoff are quite high, and this is because investment is relatively important compared to effort in this example.

## 2.6    The principal's problem: Voluntary disclosure

In section 2.4.4 I studied the agent's optimization problem with voluntary disclosure and found the agent's first order condition for investment. In this section I study the principal's problem with voluntary disclosure. I start by presenting the principal's optimization problem and I then compare the full disclosure and voluntary solutions in the general model. I then present the optimal solution in the numerical example and compare the optimal solutions for voluntary and full disclosure.

I solve the principal's maximization problem by finding the levels of effort and investment that the principal wants to induce. I then use the agent's two incentive constraints to find the contract parameters that are needed to induce these specific effort and investment levels.

Before I present the maximization problem, I will make a few comments. When the agent makes his investment decision, he takes the market's conjecture $\hat{b}$ as given, because he cannot influence this value. The principal, on the other hand, influences both $b$ and $\hat{b}$ through her choice of bonus parameters. A rational principal will assume that the market is rational (I assume all parties have rational expectations) and can infer the agent's choice of $b$, given the

bonus parameters. For the principal, then, the conjectured value $\hat{b}$ and the real value $b$ will be the same. This simplifies several of the factors in the principal's optimization problem, including $\Pi, var(P)$ and $Z$. The probability $\Pi$ from (2.56) is now given by[12]

$$\Pi = \frac{\kappa}{\bar{\mu}} \tag{2.112}$$

I note that the principal does not influence this probability through her choice of contract parameters. Since $\hat{b} = b$ in equilibrium, inducing the agent to change $b$ will change the market's conjecture $\hat{b}$ in exactly the same magnitude. The higher the disclosure cost $\kappa$ (a priori uncertainty $\bar{\mu}$), the smaller (higher) the probability of disclosure $(1 - \Pi)$ is. Similarly, with $\hat{b} = b$, the variance of the stock price is given by

$$varP^V = (1 - \Pi)^3 (\frac{1}{3} + \Pi)\bar{\mu}^2 \tag{2.113}$$

### 2.6.1   Maximization problem

I now turn to the maximization problem. The principal maximizes her expected cash flows net of the manager's compensation subject to three constraints:

$$E_0 \left[ (c_1 - s) + c_2 \right] \tag{2.114}$$

subject to

$$CE_0 \geq 0 \tag{2.115}$$

$$\beta = e'(a) \tag{2.116}$$

---

[12]Since this is a probability, it only makes sense to have $\Pi \in [0, 1]$ implying $\frac{\kappa}{\bar{\mu}} \in [0, 1]$. I only look at settings where this is true. If $\frac{\kappa}{\bar{\mu}} > 1$, then there will never be disclosure, because the disclosure costs are too high.

$$-\beta + uZ(u)m'(b) = 0$$

Here $Z(b)$ is given by (2.60). The first constraint is the agent's participation constraint, and the next two are the agent's first-order conditions for optimal effort choice and investment.

After using $Z(b)$ from (2.60), I can rewrite the first-order condition for investment as:

$$-\beta + u\big((1 - \Pi) - \rho u(1 - \Pi)^2 \Pi\overline{\mu}\big)\,m'(b) = 0 \tag{2.117}$$

### 2.6.2   The agent's required stock bonus

I solve this second-order equation and find the bonus $u$, and I use the fact that $\Pi\overline{\mu} = \frac{\kappa}{\mu}\,\overline{\mu} = \kappa$:

$$u = \frac{-1 \pm \sqrt{1 - \frac{4\rho\beta\kappa}{m'(b)}}}{-2\rho\kappa(1 - \Pi)} > 0 \tag{2.118}$$

This is the bonus $u$ that the principal must pay the agent in order to achieve a given level of investment $b$:

$$u = \frac{1 - \sqrt{1 - \frac{4\rho\beta\kappa}{m'(b)}}}{2\rho\kappa(1 - \Pi)} \tag{2.119}$$

In the last equation, I assume that when choosing among two values of $u$ that induce the same investment level, the principal chooses the smallest one, as $u$ increases the risk premium the principal must pay to the agent. The square root in (2.119) is non-negative (by definition) and less than one, making the numerator positive. The denominator is also positive, and therefore $u > 0$.

I differentiate (2.119) and find $\frac{\partial u^V}{\partial b}$:

$$\frac{\partial u^V}{\partial b} = -\frac{m''(b)}{[m'(b)]^2} \cdot \frac{\beta}{(1 - \Pi)} \cdot \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{-\frac{1}{2}} \tag{2.120}$$

I do the same for the full disclosure case:

$$\frac{\partial u^F}{\partial b} = -\frac{m''(b)}{[m'(b)]^2} \cdot \beta \tag{2.121}$$

Comparing the two, I find that

$$\frac{\partial u^V}{\partial b} > \frac{\partial u^F}{\partial b}$$

The inverse must also be true:

$$\frac{\partial b}{\partial u^V} < \frac{\partial b}{\partial u^F} \tag{2.122}$$

A marginal increase in bonus implies a smaller increase in investment with voluntary disclosure than with full disclosure.

I rewrite (2.119), to find an expression that is easier to analyze. I multiply by $\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)$ in both the numerator and denominator[13]. I get:

$$
\begin{aligned}
u^V &= \frac{\left(1 - \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)}{2\rho\kappa(1-\Pi)} \cdot \frac{\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)}{\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)} \\
&= \left(1 - \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)\right) \cdot \frac{1}{2\rho\kappa(1-\Pi)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \\
&= \frac{4\rho\beta\kappa}{m'(b)} \cdot \frac{1}{2\rho\kappa(1-\Pi)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \\
u^V &= \frac{2}{(1-\Pi)} \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \tag{2.123}
\end{aligned}
$$

There exists a maximum level of investment that the principal can induce. This level, which

---

[13] This calculation is similar in nature to what Feltham and Wu (2001) do in their Proof of Lemma 2.

I call $b^{\mathrm{max}}$, is given by:

$$1 - \frac{4\rho\beta\kappa}{m'(b^{\mathrm{max}})} = 0$$

$$\Downarrow$$

$$m'(b^{\mathrm{max}}) = 4\rho\beta\kappa \tag{2.124}$$

The value of $b^{\mathrm{max}}$ is decreasing in both the agent's risk-aversion, the disclosure cost, and the first period cash flow bonus coefficient.

### 2.6.3  Some remarks on voluntary disclosure vs full disclosure

Before I move on to solve the principal's mazimization problem, I will make a few remarks about the differences between the situation with full disclosure and voluntary disclosure. These concern the strength of using stock-based incentive, the change in the variance, and the expected disclosure cost.

*Remark* 1. Voluntary disclosure changes the strength of stock-based incentives. Specifically, to induce any given level of investment, the stock bonus must be higher with voluntary disclosure than with full disclosure:

$$u^V(b) > u^F(b) \tag{2.125}$$

for any given $b \in \left[\underline{b}, \overline{b}\right]$. Recall that the full disclosure bonus is $u^F = \frac{\beta}{m'(b)}$. I use this in (2.123) and rewrite:

$$u^V = u^F \frac{2}{(1 - \Pi)} \cdot \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \tag{2.126}$$

The last factor here, which I define as $\Delta$, has a value between $\frac{1}{2}$ and one:

$$\Delta \equiv \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \in \left[\frac{1}{2}, 1\right] \tag{2.127}$$

The term $2 \cdot \Delta$ therefore has a value $\in [1, 2]$. The value of $\frac{1}{(1-\Pi)}$ has a value between one and infinity. This proves that

$$u^V > u^F \tag{2.128}$$

This holds for all values of $b$. It must then be true that to achieve any given level of $b$, the stock bonus $u$ must be higher with voluntary disclosure than with full disclosure. This demonstrates that the stock price gives stronger incentives to invest when there is full disclosure compared with voluntary disclosure.

*Remark* 2. Comparison of stock price variances in (2.48) for full disclosure and (2.113) for voluntary disclosure makes it clear that stock price variance, for a given contract, is weakly lower with voluntary disclosure than with full disclosure:

$$(1 - \Pi)^3(\frac{1}{3} + \Pi)\bar{\mu}^2 \leq \frac{1}{3}\bar{\mu}^2$$

The term $(1 - \Pi)^3(\frac{1}{3} + \Pi)$ has a value $\in \left[0, \frac{1}{3}\right]$ when $\Pi \in [0, 1]$, so:

$$var P^V \leq var P^F \tag{2.129}$$

The two variances are equal only when $\Pi = 0$, that is when the manager always chooses to disclose even with voluntary disclsoure. The lower the probability of disclosure is, the lower is $var P^V$, both in absolute terms and relative to $var P^F$. With voluntary disclosure, the effective compensation contains a flat part, with no variance, and total variance is lower. For a given $u$, the risk premium is lower with voluntary disclosure.

*Remark* 3. The principal pays the disclosure cost only with probability $(1 - \Pi)$ if there is voluntary disclosure, but with probability 1 if there is full disclosure. This means that the expected disclosure cost is lower with voluntary disclosure.

### 2.6.4 Solving the principal's maximization problem

Going back to the principal's optimization problem, I substitute for the participation constraint in the principal's expected payoff. The maximand $W^V$ becomes

$$W^V \equiv a - b + m(b) - e(a) - (1 - \Pi)\kappa \tag{2.130}$$

$$-\frac{1}{2}\rho \left[\beta^2\sigma^2 + u^2(1 - \Pi)^3(\frac{1}{3} + \Pi)\bar{\mu}^2\right]$$

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I use the first order conditions for effort and investment in (2.116) and (2.119) to rephrase (2.130):

$$W^V = a - b + m(b) - e(a) - (1 - \Pi)\kappa \tag{2.131}$$

$$-\frac{1}{2}\rho \left[ \left[e'(a)\right]^2 \sigma^2 + \left[ \frac{1 - \sqrt{1 - \frac{4\rho e'(a)\kappa}{m'(b)}}}{2\rho\kappa(1 - \Pi)} \right]^2 (1 - \Pi)^3 (\frac{1}{3} + \Pi)\bar{\mu}^2 \right]$$

I differentiate $W^V$ with respect to $b$ and set the derivative equal to zero. I then have the first-order condition for the principal's optimal investment level (Appendix 2.A.7):

$$\frac{\partial}{\partial b} = -1 + m'(b) + \rho \cdot \underbrace{(1 - \Pi)^3(\frac{1}{3} + \Pi)\bar{\mu}^2}_{\leq \frac{\bar{\mu}^2}{3}} \cdot \underbrace{\left[ \frac{1 - \sqrt{1 - \frac{4\rho\beta\kappa}{m'(b)}}}{2\rho\kappa(1 - \Pi)} \right]}_{<1}$$

$$\cdot \underbrace{\frac{1}{(1 - \Pi)}}_{\geq 1} \cdot \underbrace{\left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{-\frac{1}{2}}}_{>1} \cdot \underbrace{\frac{\beta}{[m'(b)]^2}m''(b)}_{<0} = 0 \tag{2.132}$$

I denote the solution to (2.132) by $b^{V*}$.

Similarly, $a^{V*}$ solves the first order condition for effort.

$$\frac{\partial}{\partial a} = 1 - e'(a) - \rho e''(a) \left\{ \begin{array}{c} e'(a)\sigma^2 \\ + \left[ \frac{1 - \left(1 - \frac{4\rho e'(a)\kappa}{m'(b)}\right)^{\frac{1}{2}}}{2\rho\kappa(1-\Pi)} \right] \cdot \frac{1}{(1-\Pi)}\left(1 - \frac{4\rho\kappa e'(a)}{m'(b)}\right)^{-\frac{1}{2}}\frac{1}{m'(b)}Var(P^V) \end{array} \right\} = 0 \tag{2.133}$$

CHAPTER 2

### 2.6.5 Characteristics of the optimal solution

These two first order conditions characterize the optimal interior solution[14]. The last term in both first order conditions will be negative. Recall the first best solutions in (2.44) and (2.46). Comparing these with the FOCs above, it is clear that both investment and effort levels are weakly below the first best. Adding the negative term in (2.132), means that $m'(b)$ needs to increase in order to satisfy the equation, and since $m''(b) < 0$, this can only be achieved by reducing $b$. By similar reasoning, effort also has to be lower in (2.133) than in the first best case. In sum:

$$b^{V*} \leq b^{FB} \tag{2.134}$$

$$a^{V*} \leq a^{FB} \tag{2.135}$$

### 2.6.6 Differences between voluntary and full disclosure

To summarize, there are three factors that make the voluntary disclosure case different from the full disclosure case in the principal's problem. The first factor is the incentive effect, which describes the reduced strength of stock-based incentives, $u^V(b) > u^F(b)$. To induce a given level of effort, stock bonus needs to be higher with voluntary disclosure than with full disclosure. The second is the reduced variance effect, which means that the stock price has less variance under voluntary disclosure. The third is the reduced expected disclosure cost effect.

### 2.6.7 Example: The principal's maximization problem

Recall from (2.74) that the agent's first order condition for investment is:

$$-\beta + u(2-b)\frac{43}{48} - u^2 \cdot (2-b)\frac{1849}{18\,432} = 0 \tag{2.136}$$

---

[14]Here I will discuss the interior solutions, where $\beta \neq 0$ and $u \neq 0$. Corner solutions have been discussed earlier.

-------------------------------------------------------------------------------------------------------------------------

I solve for $u$:

$$u = \left( 1 \mp \left( 1 - \frac{1}{2} \cdot \frac{\beta}{2 - b} \right)^{\frac{1}{2}} \right) \frac{192}{43} \tag{2.137}$$

Since $u$ increases the agent's risk premium, the principal will always choose the lower of the two values, and I can write this as

$$u = \frac{192}{43} - \frac{192}{43} \sqrt{1 - \frac{1}{2} \cdot \frac{\beta}{2 - b}} \tag{2.138}$$

I can also solve for $b$ in (2.74):

$$b = 2 - \beta \left( u \left( \frac{43}{48} - \frac{1849}{18432} u \right) \right)^{-1} \tag{2.139}$$

The relationship between $u$ and $b$ in (2.139) is illustrated in Figure 2.5 and Figure 2.6.
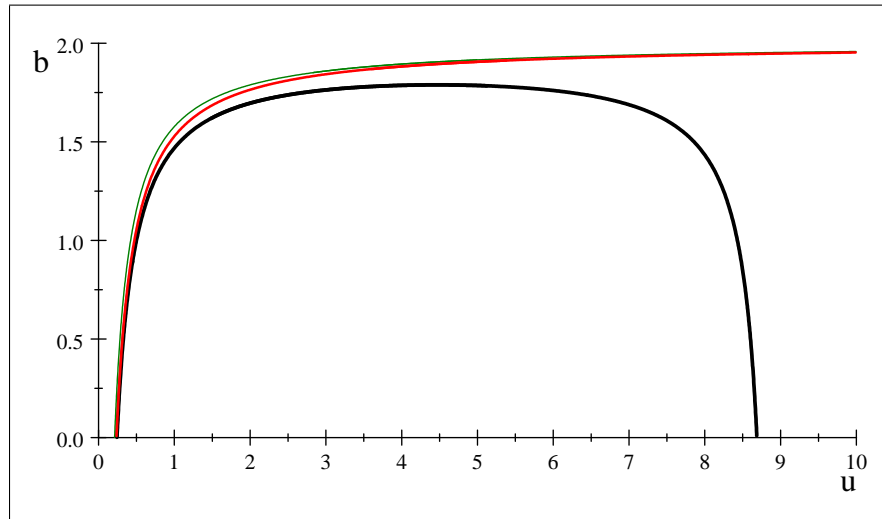


Figure 2.5. The level of investment $b$ induced by stock bonus $u$. The value of $\beta$ is set at $\beta = 0.42271$. The black line is voluntary disclosure. The green line is full disclosure. The red line is voluntary disclosure with risk neutrality ($\rho = 0$).
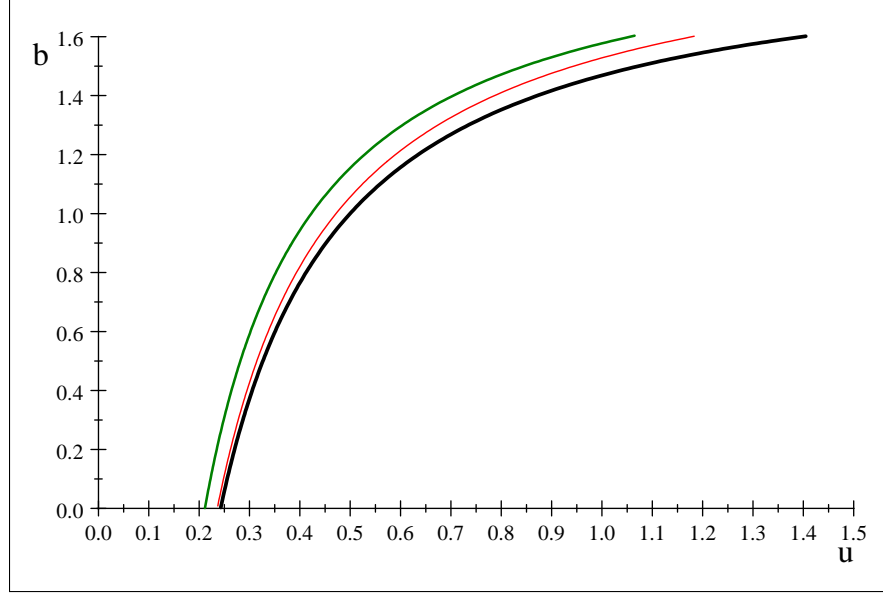
Figure 2.6. A closer look at the relationship between bonus and induced investment.

The curve that represents $b$ as a function of $u$ for voluntary disclosure is concave and reaches a maximum at $u = 4.4651$ (which is $u^{\max}$, see (2.61)) where $b = 1.7886$. I differentiate (2.139):

$$\frac{\partial b}{\partial u} = 0.42271 \left( u \left( \frac{43}{48} - \frac{1849}{18432} u \right) \right)^{-2} \left( \frac{43}{48} - 2 \cdot \frac{1849}{18432} u \right) \qquad (2.140)$$

The second order derivative is

$$\begin{aligned}
\frac{\partial^2 b}{\partial^2 u} &= -0.84542 \left( u \left( \frac{43}{48} - \frac{1849}{18432} u \right) \right)^{-2} \\
&\quad \cdot \left[ \left( u \left( \frac{43}{48} - \frac{1849}{18432} u \right) \right)^{-1} \left( \frac{43}{48} - 2 \cdot \frac{1849}{18432} u \right)^2 + \left( \frac{1849}{18432} \right) \right]
\end{aligned} \qquad (2.141)$$

This is negative, confirming that the curve is concave. For the case where there is voluntary disclosure, but the agent is risk neutral which I denote $\rho = 0$, the function $b$ as a function of $u$ in Figure 2.5 and 2.6 is:

$$b^{\rho=0} \;=\; 2 - \frac{\beta}{u} \cdot \frac{1}{1-\Pi} \tag{2.142}$$

$$=\; 2 - \frac{0.42271}{u} \cdot \frac{48}{43}$$

where I have used (2.72) with $\rho = 0$ and rearranged.

For full disclosure, the function is:

$$b^F \;=\; 2 - \frac{\beta}{u} \tag{2.143}$$

$$=\; 2 - \frac{0.42271}{u} \tag{2.144}$$

I have used (2.101) and rearranged. When $u \to \infty$, the curves for risk neutral voluntary disclosure and full disclosure both move towards $b = 2$ since $\lim_{u\to\infty} b = 2$ in both (2.142) and (2.143). For full disclosure and voluntary disclosure with risk neutrality, the slope of the curve is :

$$\frac{\partial b}{\partial u} \;\Big|\; {}_{\rho=0} = \beta \cdot \frac{1}{1-\Pi} \cdot u^{-2}$$

$$=\; 0.42271 \cdot \frac{48}{43} \cdot u^{-2} \tag{2.145}$$

$$\frac{\partial b}{\partial u^F} \;=\; \beta \cdot u^{-2}$$

$$=\; 0.42271 \cdot u^{-2} \tag{2.146}$$

The difference here is the factor $\frac{48}{43}$ which is $\frac{1}{1-\Pi} > 1$. The curve is steeper for risk neutral voluntary disclosure (red line) than for full disclosure (green line), but they do not cross[15].

If the principal does not want to induce any investment, she can set $u = 0$. The curves cross the x-axis at different values of $u$. I set $b = 0$ and find that

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[15] If they did cross, they could not both have $\lim_{u\to\infty} b = 2$ and $\frac{\partial b}{\partial u}\big|_{\rho=0} > \frac{\partial b}{\partial u^F}$.

$$u^V \quad | \quad _{b=0} = \frac{1}{2\rho\kappa(1-\Pi)} \left[ 1 - \sqrt{1 - \frac{4\rho\beta\kappa}{m'(0)}} \right]$$

$$= \frac{1}{2 \cdot \frac{1}{2} \cdot \frac{1}{4} \cdot \frac{43}{48}} \left[ 1 - \sqrt{1 - \frac{4 \cdot \frac{1}{2} \cdot \frac{1}{4} \cdot 0.42271}{2}} \right]$$

$$= \frac{192}{43} \left[ 1 - \sqrt{1 - 0.105\,68} \right]$$

$$= 0.242\,52 \tag{2.147}$$

$$u^{\rho=0} \quad | \quad _{b=0} = \frac{\beta}{m'(0)} \cdot \frac{1}{1-\Pi}$$

$$= \frac{\beta}{2} \cdot \frac{1}{1-\Pi}$$

$$= \frac{0.42271}{2} \cdot \frac{48}{43}$$

$$= 0.235\,93 \tag{2.148}$$

$$u^F \quad | \quad _{b=0} = \frac{\beta}{m'(0)}$$

$$= \frac{\beta}{2} = \frac{0.42271}{2}$$

$$= 0.211\,36 \tag{2.149}$$

In this example:

$$u^V \mid_{b=0} > u^{\rho=0} \mid_{b=0} > u^F \mid_{b=0} \tag{2.150}$$

To induce $b > 0$, bonus must be higher than $u^V \mid_{b=0} = 0.24252$. For the agent, a marginal increase in $b$ decreases cash flow bonus with $\beta$ times the investment increase. So stock bonus $u$ must at least cover this loss to induce investment, in addition to covering the agent's increase in risk. When $b = 0$, the marginal productivity of investment is equal to 2 $(m'(0) = 2)$. Therefore, the stock bonus $u$ needs only be half of $\beta$ for the agent not to lose money. In addition, stock bonus must cover the marginal increase in risk that follows from an increase in investment (since an increase in investment increases the probability of ending up in the risky disclosure part of

the compensation). If the principal wants to induce investment just above zero, say $b = 0.05$, the necessary stock bonus is $u = 0.248\,92$.

The first order condition for effort is:

$$\beta = \frac{4}{5}a \tag{2.151}$$

With $\hat{b} = b$, the probability of no disclosure is $\Pi = \frac{\kappa}{\mu} = \frac{5}{48} = 0.104$. Stock price variance is given by (2.113), and with $\hat{b} = b$ this reduces to

$$var P^V = \frac{556\,549}{307\,200} \approx 1.8117 \tag{2.152}$$

The principal maximizes her payoff net of the disclosure cost and the agent's compensation, subject to the agent's two incentive constraints. After subsituting for the agent's participation constraint and incentive constraints, I restate the problem as an unconstrained optimization problem:

$$\begin{aligned}
\max_{a,b} W^V =\ & a - b + 2b - \frac{1}{2}b^2 - \frac{2}{5}a^2 - \frac{43}{192} \\
& - \frac{1}{4}\left( \left(\frac{4}{5}a\right)^2 \frac{36}{25} + \left(\frac{192}{43} - \frac{192}{43}\sqrt{1 - \frac{1}{2}\cdot\frac{\beta}{2-b}}\right)^2 \frac{556\,549}{307\,200} \right)
\end{aligned} \tag{2.153}$$

I differentiate $W^V$ with respect to $a$ and $b$, set this equal to zero and solve the two equations together. The optimal levels of $a$ and $b$ are:

$$a = 0.52839 \tag{2.154}$$

$$b = 0.84702 \tag{2.155}$$

Recall that the first best levels of investment and effort are $b = 1$ and $a = \frac{5}{4}$, so both investment and effort are below the first best levels. I use these values of $a$ and $b$ in (2.151) and (2.138) to find the optimal bonus parameters:

$$\beta \quad = \quad 0.42271 \tag{2.156}$$

$$u \quad = \quad 0.42996 \tag{2.157}$$

The fixed component of the compensation is the value of $\alpha$ that satisfies the agent's participation constraint. Using the values of $u, \beta$ and $b$ from the optimal solution, and assuming rational expectations so that $\hat{b} = 0.84702$, I can recalculate the agent's CE. I solve for the $\alpha$ that makes the CE equal to zero and find that the fixed component of compensation is $\alpha = -0.0834$. The optimal contract now looks like

$$s = -0.0834 + 0.42271 \cdot c_1 + 0.42996 \cdot P \tag{2.158}$$

Graphically, the agent's certainty equivalent with the optimal contract can be represented as in Figure 2.7. To illustrate this in a two-dimensional graph, the effort level is set at the optimum from above, $a = 0.52839$. The agent's maximum certainty equivalent is at the investment level that the principal intended to induce: $b = 0.84702$, and it then reaches its maximum level of zero, which is just enough to make the agent willing to accept the contract.

In order to study the role of the market's expectations about $b$ in influencing the actual chosen value of $b$, I show graphically in Figure 2.8 the agent's choice of $b$ as a function of the market's expectation $\hat{b}$ (the curved line). The straight line is the values where $\hat{b} = b$, satisfying the rational expectations equlibrium. This occurs when $b = 0.84702$, which again confirms that this is the equilibrium value.

Figure 2.9 shows how the principal's net payoff depends on the investment level (for effort fixed at $a = 0.52839$). The maximum expected wealth for the principal is $W^V = 0.533$.
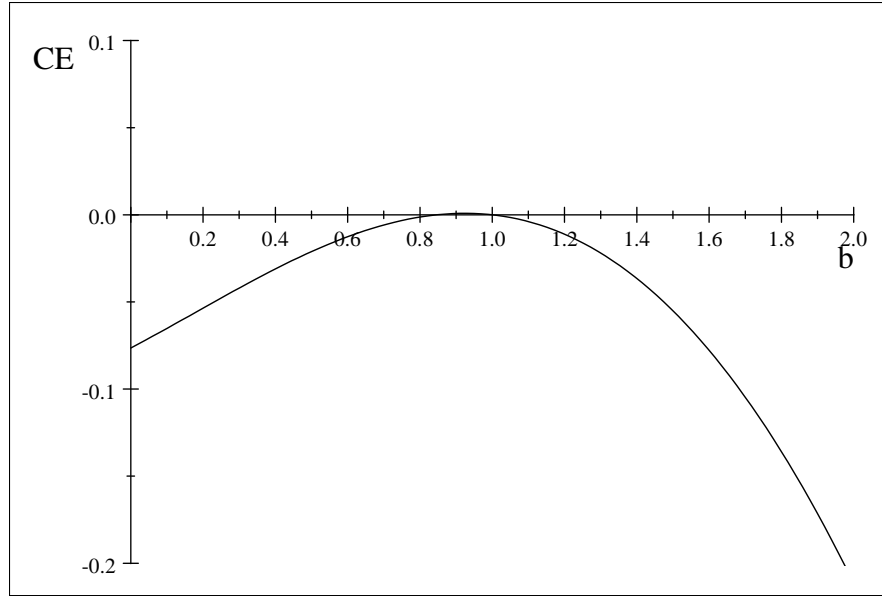
Figure 2.7. The agent's certainty equivalent $CE$ and his choice of investment level $b$. The agent maximizes his certainty equivalent (in the optimal contract) by choosing investment level $b = 0.84702$.
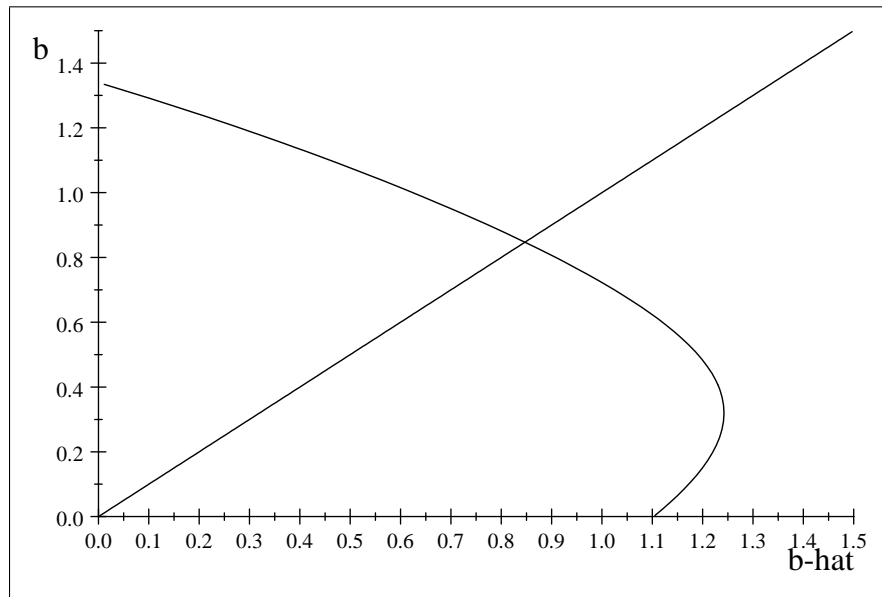


Figure 2.8. The agent's choice of investment $b$ as a function of the market's expectations about his investment choice $\hat{b}$. The equlibrium value of investment is $b = 0.84702$.
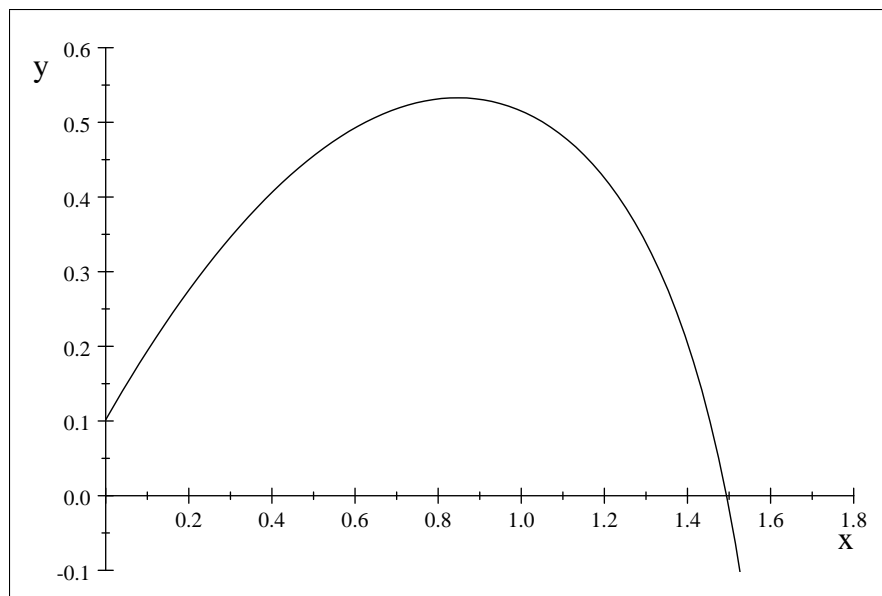
Figure 2.9. The principal's expected payoff $W^V$ as a function of investment $b$. The principal

maximizes her expected payoff by choosing a contract that induces investment level

$$b = 0.84702.$$

**Comparing voluntary disclosure and full disclosure**

Table 2.2 presents the optimal parameters with voluntary disclosure, and also compares voluntary disclosure with full disclosure.

|  | F | V | Difference (V-F) |
|---|---|---|---|
| a | 0.57640 | 0.52839 | -0.4801 |
| b | 0.86163 | 0.84702 | -0.1461 |
| $\beta$ | 0.46112 | 0.42271 | -0.3841 |
| u | 0.40507 | 0.42996 | 0.02489 |
| Principal's expected wealth | 0.52863 | 0.53300 | 0.00437 |
| Prob. of disclosure | 1 | 0.896 | -0.104 |
| Var (P) | 1.92 | 1.8117 | -0.11 |

Table 2.2. Voluntary (V) and full (F) disclosure. Optimal solution and optimal parameters.

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Table 2.2 shows that both effort and investment are lower with voluntary disclosure than with full disclosure. The lower level of effort is achieved with a lower value of cash bonus $\beta$. The stock bonus $u$, on the other hand, is higher with voluntary disclosure. This means that even if stock bonus is higher, a lower investment is induced. This has to do with the reduced effectiveness of using stock-based compensation discussed previously. Because there is a 10.4% probability of no disclosure in which case stock price does not depend on investment, the manager's incentives to invest are weaker with voluntary disclosure. The flat part of the compensation (see Figure 2.2) is also why stock price variance decreases from 1.92 to 1.81.

In the example, the principal is better off with voluntary disclosure than with full disclosure. A result like this has two potential explanations; the principal can save on disclosure cost and/or that the risk premium related to stock based compensation is lower. To analyze which of these explanations is valid here, I decompose this difference in expected wealth in Table 2.3.

The principal's expected wealth is 0.53300 with voluntary disclosure and 0.52863 with full disclosure, meaning expected payoff is 0.00437 higher with voluntary disclosure. The difference in expected disclosure cost is 0.02604 (see Table 2.3). This is higher than the change in expected wealth, and this means that in this case it is the difference in expected disclosure cost that makes the principal better off with voluntary disclosure.

| | F | V | Difference (V-F) |
|---|---|---|---|
| Principal's expected wealth | 0.52863 | 0.53300 | 0.00437 |
| Expected discl.cost | 0.25 | 0.22396 | -0.02604 |
| Cash flow from effort | 0.44351 | 0.41671 | -0.0268 |
| Cash flow from investment | 0.49043 | 0.48831 | -0.00212 |
| Risk premium | 0.15531 | 0.14806 | -0.00725 |
| | | | |

Table 2.3. The principal's expected wealth, and the components of expected wealth with voluntary (V) and full (F) disclosure.

In this example, it is optimal to reduce effort more than investment when moving from full to voluntary disclosure. Effort is reduced by 0.4801 while investment is reduced by 0.1461. This is why the reduction is cash flow from reducing effort (Table 2.3) is higher than for investment (-0.0268 as opposed to -0.00212).

Risk premium is lower with voluntary disclosure than with full disclosure, 0.14806 compared to 0.1553. To further analyze this, I divide total risk premium $RP$ into two components $RP(\beta)$ and $RP(u)$

$$
\begin{aligned}
RP &= \frac{1}{2}\rho\left(\beta^2 Var(c_1) + u^2 VarP\right) \\
&= \frac{1}{2}\rho\beta^2 Var(c_1) + \frac{1}{2}\rho u^2 VarP \\
&\equiv RP(\beta) + RP(u)
\end{aligned} \tag{2.159}
$$

By decomposing the risk premium into risk premium from cash bonus ($RP(\beta)$ above) and risk premium from stock bonus ($RP(u)$), I show which factors cause the difference in risk premium in the voluntary and full disclosure settings. This is illustrated in Table 2.4.

| | F | V | Difference (V-F) |
|---|---|---|---|
| Risk premium | 0.15531 | 0.14806 | -0.00725 |
| *cash bonus RP | 0.07655 | 0.06433 | -0.01222 |
| *stock bonus RP | 0.07876 | 0.08373 | 0.00497 |

Table 2.4. Decomposing the risk premium (RP) into two parts; risk premium from cash bonus and risk premium from stock bonus.

The total difference may seem quite small (-0.00725), but this is the net effect of the changes in these two risk premiums. $Var(c_1)$ is the same in the two cases, but since effort and $\beta$ are scaled down with voluntary disclosure, the risk premium related to cash flow is lower with voluntary disclosure than with full disclosure. So some of the reduced cash flows from effort is

balanced by reduced risk premium; lower $RP(\beta)$. Risk premium from using stock bonus, $RP(u)$, is higher with voluntary disclosure than with full disclosure. Even if stock price variance $VarP$ is lower with voluntary disclosure, the stock bonus is higher, and the net effect is a higher risk premium. Remember that the resulting investment is lower, so a lower level of investment costs more in terms of risk premium with voluntary disclosure than a higher investment with full disclosure.

Risk premium from using stock bonus, $RP(u)$, is higher with voluntary than with full disclosure, and this means that it is more expensive to use $u$ to induce investment with voluntary disclosure. However, the agent's first order condition in (2.74) or (2.139) shows that the agent will increase investment either when $u$ is increased or when $\beta$ is decreased. In this example, it is optimal for the principal to reduce $\beta$, even if this reduces payoff from effort . When stock bonus becomes less effective and more expensive to use, the principal balances effort and investment incentives by reducing both induced effort and investment, but the cash flow effect is higher for effort than for investment (as seen in Table 2.3).

In sum, voluntary disclosure has lower expected disclosure cost $E(\kappa)$, reduced total risk premium $RP$, and weaker incentives. This gives lower output (effort and investment).

## 2.7 Comparative statics

In this section I present comparative statics analyses. I study how the agent's incentives change when the parameters $\kappa, \rho$ and $\overline{\mu}$ change, and I also look at how the principal's problem changes when $\kappa$ and $\overline{\mu}$ change. Recall that the agent's first order condition for investment is

$$u^V = \frac{2}{(1-\Pi)} \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \tag{2.160}$$

where $(1-\Pi) = \left(1 - \frac{\kappa}{\overline{\mu}}\right)$ is the probability of disclosure, and $m(b)$ is the production function for investment.

As noted earlier, the full disclosure bonus is

$$u^F = \frac{\beta}{m'(b)} \tag{2.161}$$

I use this in the expression above:

$$u^V = u^F \frac{2}{(1-\Pi)} \cdot \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \tag{2.162}$$

### 2.7.1 Changes in the disclosure cost

**How does stock bonus depend on the disclosure cost ?**

The required stock bonus depends on the disclosure cost $\kappa$. When $\kappa \to 0$, the disclosure cost becomes insignificant, and the setting moves towards full disclosure, and the bonus moves towards $u^F$:

$$u^V \mid_{\kappa \to 0} = \frac{\beta}{m'(b)} = u^F \tag{2.163}$$

As $\kappa$ increases, it moves towards one of two upper limits. The two possible limits are $\kappa^{\mathrm{max}} \equiv \frac{1}{4u\frac{\beta}{m'(b)}}$ and $\overline{\mu}$. The first value, $\kappa^{\mathrm{max}}$ comes from the feasability constraint, and can be seen from (2.162). It is parallell to the $b^{\mathrm{max}}$ found in (2.124), but the constraint is here defined in terms of $\kappa$ rather than $b$. It is the maximum value that $\kappa$ can have when it is possible to induce a given $b$. The higher the investment $b$ is, the lower the value of $\kappa^{\mathrm{max}}$.

The second value is defined by the probability of disclosure; $1 - \Pi = 1 - \frac{\kappa}{\mu}$. Since this is a probability, it has to be between 0 and 1, implying that $\kappa \leq \overline{\mu}$. When $\kappa$ increases above this value, there is no disclosure. Moving towards no disclosure, the stock bonus loses its incentive effect and the manager will not be willing to invest.

To see how the stock bonus changes when the disclosure cost increases in a general way, I differentiate $u$:

$$\frac{\partial u}{\partial \kappa} = 2u^F \left( \begin{array}{c} \frac{1}{\overline{\mu}} \cdot \frac{1}{(1-\Pi)^2} \cdot \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \\ + \frac{1}{(1-\Pi)} \cdot \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-2} \cdot \left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}} \cdot 2\rho u^F \end{array} \right) \tag{2.164}$$

$$= 2u^F \frac{1}{(1-\Pi)} \cdot \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \cdot$$

$$\left( \frac{1}{\overline{\mu}} \cdot \frac{1}{(1-\Pi)} + \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \cdot \left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}} \cdot 2\rho u^F \right)$$

$$= u^V \left( \frac{1}{\overline{\mu}} \cdot \frac{1}{(1-\Pi)} + \left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1} \cdot \left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}} \cdot 2\rho u^F \right) > 0$$

The stock bonus increases when the disclosure cost increases. When the disclosure cost increases, the cut-off level of disclosure increases, and there is less disclosure. With less disclosure, the incentive effect of the stock bonus decreases. To induce a given investment level, the stock bonus has to increase. For a given $u$ the inverse result is that when $\kappa$ increaes, the induced investment decreases: $\frac{\partial b}{\partial \kappa} < 0$ (calculations are in Appendix 2.A.8).

**Example**   I use the numerical values from the example I have used earlier (see Table 2.5 for a summary of assumptions and results).

| Variable | Value |
|----------|---------|
| $a$ | 0.52839 |
| $\beta$ | 0.42271 |
| $b$ | 0.84702 |
| $u$ | 0.42996 |
| $\kappa$ | 0.25 |
| $\bar{\mu}$ | 2.4 |
| $\sigma$ | 1.2 |
| $\rho$ | 0.5 |
| Table 2.5. | |

I then fix all variables at the values indicated in the table, except $u$ and $\kappa$, and I find the required stock bonus for different values of $\kappa$. Figure 2.10 illustrates the relationship between $u$ and $\kappa$.

When $\kappa \to 0$, the stock bonus is $0.366\,62$.

$$u^V \mid_{\kappa \to 0} = u^F = 0.366\,62 \tag{2.165}$$

This value of $u^F$ ( and $u^V$) is the full disclosure bonus needed to induce an investment level of $b = 0.84702$, which is the optimal investment in the voluntary disclosure case. The derivative at this point is:

$$\frac{\partial u}{\partial \kappa} \mid_{\kappa \to 0} = u^F \left( \frac{1}{\bar{\mu}} + \rho u^F \right) = 0.366\,62 \left( \frac{1}{2.4} + 0.5 \cdot 0.366\,62 \right) = 0.219\,96 \tag{2.166}$$

The highest value that $\kappa$ can have when it is possible to induce an investment level of $b = 0.84702$ is given by $\kappa^{\max}$ :

$$1 - 4\rho u^F \kappa^{\max} \geq 0 \tag{2.167}$$

I rearrange and use the numerical values

$$\kappa^{\max} = \frac{1}{4u^F \rho} = \frac{1}{4 \cdot \frac{1}{2} \cdot 0.366\,62} = 1.\,363\,8 \tag{2.168}$$

If the disclosure cost is higher than $1.\,363\,8$, it is not possible to induce $b = 0.84702$. As $\kappa$ moves toward this value, the bonus moves toward $1.\,698\,3$, which is the maximum value of $u$ in the figure.

$$u^V \mid_{\kappa \to \kappa^{\max}} = 1.\,698\,3 \tag{2.169}$$
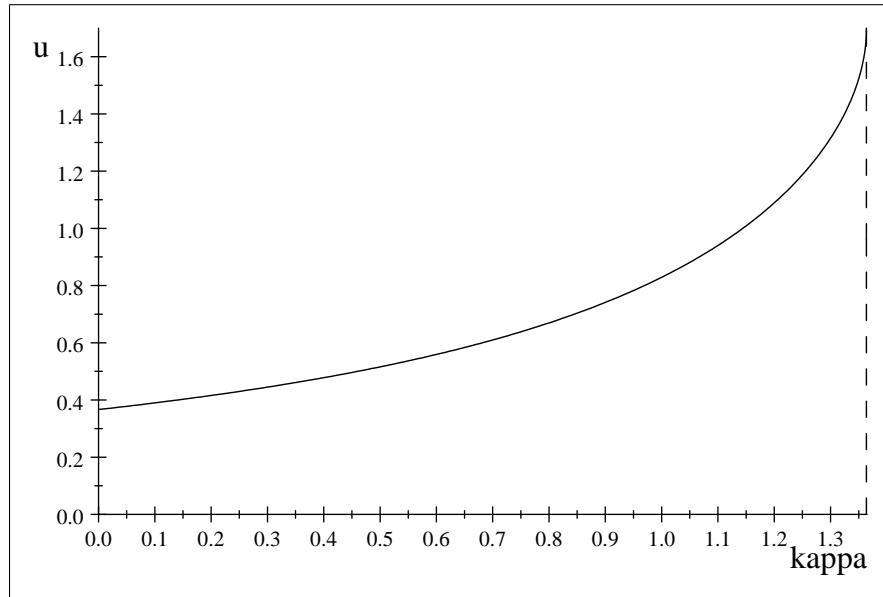


Figure 2.10. The relationship between stock bonus $u$ and the disclosure cost $\kappa$, for a given investment level. $\overline{\mu} = 2.4$ and $\kappa^{\max} = 1.\,363\,8$.

In this example $\kappa^{\max} < \overline{\mu} = 2.4$, so the binding upper limit is $\kappa^{\max} = 1.\,363\,8$. If, on the other hand, $\overline{\mu}$ were lower, say $\overline{\mu} = 1$, the result would be different. In this case $\overline{\mu} < \kappa^{\max}$ and $\overline{\mu}$ would be the binding upper limit on $\kappa$. Figure 2.11 illustrates this. As $\kappa$ approaches $\overline{\mu} = 1$, the bonus loses all its incentive power.
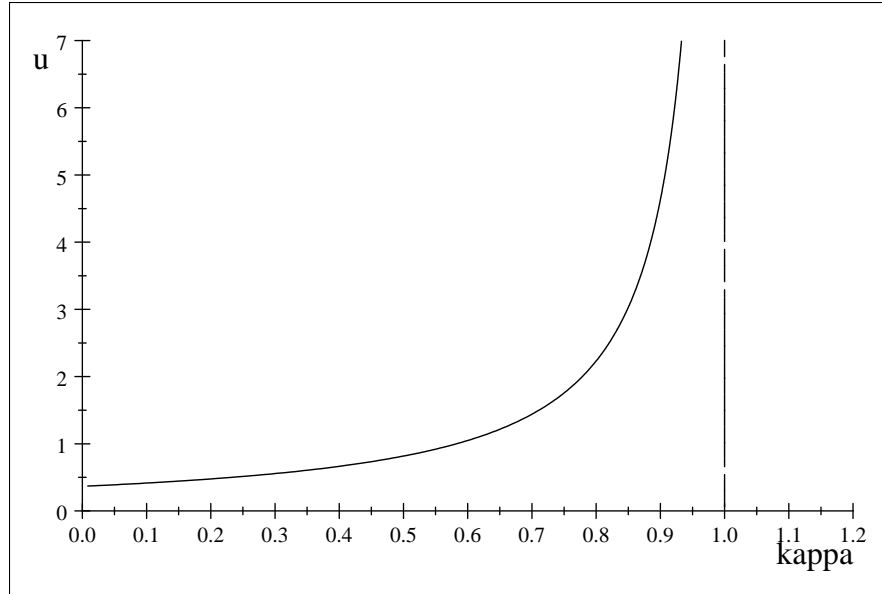
Figure 2.11. The relationship between stock bonus $u$ and the disclosure cost $\kappa$, when $\overline{\mu} = 1$

and $\kappa^{\max} = 1.363\,8$.

It is worth noting that the principal will prefer a corner solution to this interior solution when $\kappa$ is above a certain level.

## How does the principal's problem depend on the disclosure cost?

To see how the level of the disclosure cost influences the principal's problem, I have calculated optimal solutions for different levels of $\kappa$. These are presented in Table 2.6. I start with a low value of $\kappa$ ( $\kappa = 0.0001$), then increase $\kappa$ to 0.05, then study increments of $\kappa$ of 0.05, going up to $\kappa = 0.5$.

A few comments are in order. Table 2.6 shows that in this example a corner solution becomes optimal when the disclosure cost is above a certain level. From $\kappa \geq 0.3$, it is optimal to have $a = 0$ (corner solution). In this case, it is optimal to set $\beta = 0$ and have $a = 0$, because the first best investment can then be achieved with no bonus, no risk premium, and no disclosure cost. The benefit from setting $\beta = 0$ is that the agent has no incentive to underinvest. Even with $u = 0$, the agent will choose first best investment $b^{FB} = 1$ (assuming the agent will choose what is best for the principal if he is indifferent). With no bonus, there is no risk for the agent, he receives only a flat wage, there is no risk premium and there is also no disclosure. This

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alternative becomes attractive when the disclosure cost is high, because a higher amount is then saved from not disclosing.

I will focus on the cases where $\kappa \leq 0.30$, where interior solutions are optimal, and the following analysis concerns these cases.

With full disclosure the optimal contract is independent of the level of the disclosure cost. The disclosure cost in this case only reduces the principal's payoff, but has no effect on incentives. With voluntary disclosure, both effort and investment decreases as the disclosure cost increases. This is related to the analysis of stock price risk premium $RP(u)$ above. The higher the disclosure cost, the lower the probability of disclosure. This lowers the effect of stock based compensation, which has to be increased to maintain a given investment level. Even if stock price variance decreases, stock price risk premium increases with increased disclosure cost. This makes it more expensive to induce investment, and optimal investment is lower with higher $\kappa$.

The (total) risk premium $RP$ decreases with higher $\kappa$. Because lower effort requires lower $\beta$, cash flow risk premium $RP(\beta)$ is lower. This reduction outweighs the incease in $RP(u)$, and total risk premium is lower with higher disclosure cost.

From the table, it is clear that the principal is better off with full disclosure for some (low) values of $\kappa$, and the reverse is true for other (high) values of $\kappa$. For higher values of $\kappa$, there is more to save by not disclosing (with voluntary disclosure), in addition to lower $RP$. These effects dominate the negative cash flow effects from inducing lower effort and investment levels.

For the principal, apart from the obvious effect on $E(\kappa)$, changing $\kappa$ is a parallell to changing the kink-point in a piecewise linear contract. Increasing $\kappa$ moves the kink-point to the right (higher up), since $f^{CO}$ increases with $\kappa$ (see 2.30) The principal is (still disregarding $E(\kappa)$) better off with a linear contract (F) than a piecewise linear contract (V), since the effect from $E(\kappa)$ is what makes the principal's payoff higher with voluntary disclosure than full disclosure. This is illustrated in the last two columns of Table 2.5, which show that the principal's expected payoff disregarding the disclosure cost is always higher with full disclosure than voluntary disclosure in this example.

| Ex.no. | κ | $W^V$ | $W^ℱ$ | $(W^V-W^ℱ)$ | $RP^V$ | $RP^ℱ$ | $(RP^V-RP^ℱ)$ | $a^V$ | $b^V$ | $u^V$ | $β^V$ | Pr. discl. | $VarP^V$ | $RP(β)$ | $RP(u)$ | $W^V+E(κ)$ | $W^ℱ+κ$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0,0001 | 0,779 | 0,779 | -0,00001 | 0,155 | 0,155 | -0,0001 | 0,576 | 0,862 | 0,405 | 0,461 | 1,000 | 1,920 | 0,077 | 0,079 | 0,77862 | 0,77863 |
| 2 | 0,05 | 0,725 | 0,729 | -0,00373 | 0,154 | 0,155 | -0,0013 | 0,566 | 0,858 | 0,409 | 0,453 | 0,979 | 1,915 | 0,074 | 0,080 | 0,77386 | 0,77863 |
| 3 | 0,10 | 0,673 | 0,679 | -0,00514 | 0,153 | 0,155 | -0,0026 | 0,556 | 0,855 | 0,414 | 0,445 | 0,958 | 1,901 | 0,071 | 0,081 | 0,76932 | 0,77863 |
| 4 | 0,15 | 0,624 | 0,629 | -0,00426 | 0,151 | 0,155 | -0,0041 | 0,547 | 0,852 | 0,419 | 0,437 | 0,938 | 1,879 | 0,069 | 0,082 | 0,76500 | 0,77863 |
| 5 | 0,20 | 0,578 | 0,579 | -0,00109 | 0,150 | 0,155 | -0,0056 | 0,537 | 0,849 | 0,424 | 0,430 | 0,917 | 1,849 | 0,067 | 0,083 | 0,76088 | 0,77863 |
| 6 | 0,25 | 0,533 | 0,529 | 0,00437 | 0,148 | 0,155 | -0,0073 | 0,528 | 0,847 | 0,430 | 0,423 | 0,896 | 1,812 | 0,064 | 0,084 | 0,75695 | 0,77863 |
| 7 | 0,30 | 0,500 | 0,479 | 0,02137 | 0,000 | 0,155 | -0,1553 | 0,000 | 1,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,50000 | 0,77863 |
| 8 | 0,35 | 0,500 | 0,429 | 0,07137 | 0,000 | 0,155 | -0,1553 | 0,000 | 1,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,50000 | 0,77863 |
| 9 | 0,40 | 0,500 | 0,379 | 0,12137 | 0,000 | 0,155 | -0,1553 | 0,000 | 1,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,50000 | 0,77863 |
| 10 | 0,45 | 0,500 | 0,329 | 0,17137 | 0,000 | 0,155 | -0,1553 | 0,000 | 1,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,50000 | 0,77863 |
| 11 | 0,50 | 0,500 | 0,279 | 0,22137 | 0,000 | 0,155 | -0,1553 | 0,000 | 1,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,50000 | 0,77863 |

Table 2. 6. Solutions for different values of the disclosure cost κ

### 2.7.2 Changes in risk aversion: How does stock bonus depend on risk aversion?

In this section I will analyze how the required stock bonus depends on the agent's risk aversion. The maximum possible value of $\rho$ given investment $b$ is given by $\rho^{\max}$. This value is where $\left(1 - 4\rho\kappa u^F\right)$ in (2.162) is zero:

$$\rho^{\max} = \frac{1}{4u^F\kappa} \tag{2.170}$$

I can now calculate $u^V$ for $\rho = 0$ and $\rho = \rho^{\max}$.

$$u^V(\rho = 0) = u^F \cdot \frac{1}{(1 - \Pi)} \tag{2.171}$$

$$u^V(\rho = \rho^{\max}) = u^F \frac{2}{(1 - \Pi)} \tag{2.172}$$

I know that $\frac{1}{1-\Pi} \geq 1$. For both $\rho = 0$ and $\rho = \rho^{\max}$, the value of $u^V$ is higher than $u^F$. With $\rho = \rho^{\max}$, the value of $u^V$ is twice as high as the value when $\rho = 0$. When $\rho = 0$, there are no risk effects, and the only difference between the voluntary and full disclosure cases is the probability of disclosure. The value of $u^V$ needs to be $\frac{1}{(1-\Pi)}$ times higher than $u^F$ since the manager will only be rewarded for investing with probability $(1 - \Pi)$. When $\rho > 0$, the bonus must be higher to compensate for the marginal increase in risk as well.

I now differentiate (2.162) with respect to the risk aversion parameter $\rho$.

$$
\begin{aligned}
\frac{\partial u}{\partial \rho} &= u^F \frac{2}{(1 - \Pi)}(-1)\left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-2}\frac{1}{2}\left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}}(-4)\kappa u^F \\
&= u^V\left(1 + \left(1 - 4\rho\kappa u^F\right)^{\frac{1}{2}}\right)^{-1}2\left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}}\kappa u^F \\
&= u^V \cdot u^V(1 - \Pi)\kappa\left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}} \\
&= (u^V)^2(1 - \Pi)\kappa\left(1 - 4\rho\kappa u^F\right)^{-\frac{1}{2}} > 0 \tag{2.173}
\end{aligned}
$$

The higher the risk aversion, the higher the stock bonus needs to be in order to induce a

given investment level. Increasing investment increases the agent's probability of ending up in the risky part of the compensation. The more risk averse the manager is, the more this will cost him. To compensate for an increase in risk aversion, the stock bonus must be increased to maintain a given investment level. Note, however, that as $\rho$ increases, the principal may prefer a corner solution where $u = 0$, as this reduces the risk that the agent has to bear.

From (2.173) I can calculate $\frac{\partial u}{\partial \rho}$ for different values of $\rho$. I choose to find $\frac{\partial u}{\partial \rho}$ for $\rho = 0$ and for $\rho \rightarrow \rho^{\max} = \frac{1}{4u^F \kappa}$. For $\rho = \rho^{\max}$, the value of $\frac{\partial u}{\partial \rho}$ is not defined, since the denominator in (2.173) is then zero.

$$\frac{\partial u}{\partial \rho} \mid_{\rho=0} = (u^V)^2 (1 - \Pi) \kappa > 0 \tag{2.174}$$

$$\frac{\partial u}{\partial \rho} \mid_{\rho \rightarrow \rho^{\max}} = \infty \tag{2.175}$$

**Example.** To illustrate these results, I use the parameter values from the example, and hold all variables except $u$ and $\rho$ constant. The relationship between $u$ and $\rho$ as given by the agent's FOC for investment is:

$$u^V = \frac{2}{(1 - 0.104)} \cdot 0.366\,62 \cdot \left(1 + (1 - 4 \cdot \rho \cdot 0.366\,62 \cdot 0.25)^{\frac{1}{2}}\right)^{-1} \tag{2.176}$$

I have used the fact that $u^F = 0.366\,62$. I rewrite (2.176) and get:

$$u^V = 0.8183 \left(1 + (1 - 0.366\,62 \cdot \rho)^{\frac{1}{2}}\right)^{-1} \tag{2.177}$$

Figure 2.12 illustrates $u^V$ as a function of $\rho$. The curve is upward-sloping, showing that a higher $\rho$ increases the necessary $u$. The value of $\rho^{\max} = \frac{1}{4u^F \kappa} = \frac{1}{4 \cdot 0.366\,62 \cdot 0.25} = 2.727\,6$. This is the maximum value $\rho$ can have when it is still possible to induce $b = 0.84702$.
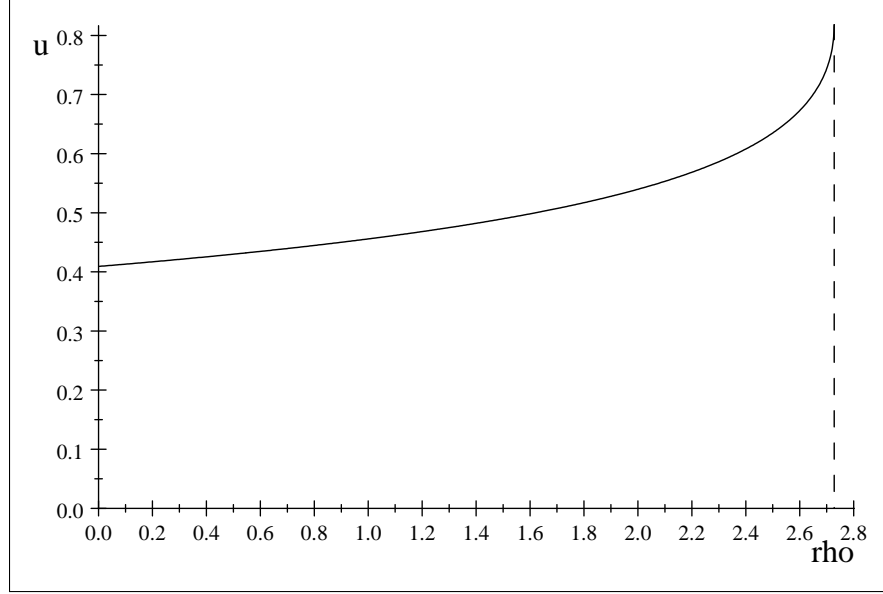
Figure 2.12. The relationship between stock bonus and risk aversion in the agent's FOC.

### 2.7.3   Changes in investment risk

**How does the stock bonus $u$ depend on investment risk $\overline{\mu}$?**

The parameter $\overline{\mu}$ indicates how risky the investment is. A higher $\overline{\mu}$ means a riskier investment. An increase in investment risk will change the agent's incentives to invest. In this section I analyze how the agent's incentives change when there is an increase in $\overline{\mu}$, and I look at how the principal will have to change the stock bonus $u$ to maintain a given investment level.

I first look at the disclosure decision. The cut-off value of disclosure $f^{CO}$ is given by:

$$f^{CO} = m(\hat{b}) - \overline{\mu} + 2\kappa \tag{2.178}$$

I differentiate with respect to $\overline{\mu}$:

$$\frac{\partial f^{CO}}{\partial \overline{\mu}} = -1 \tag{2.179}$$

When uncertainty increases, the treshold value of disclosure decreases. The probability of disclosure is $(1 - \Pi) = 1 - \frac{\kappa}{\mu}$. I differentiate and find:

$$\frac{\partial(1 - \Pi)}{\partial \overline{\mu}} = \frac{\kappa}{\overline{\mu}^2} = \frac{1}{\overline{\mu}}\Pi > 0 \tag{2.180}$$

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The probability of disclosure increases with increased uncertainty. Recall that the cutoff $f^{CO}$ is determined by the relative benefits and costs of disclosing. The no-disclosure stock price $P^0$ has a distribution with lower bound $\left(m(\hat{b}) - \overline{\mu}\right)$ and upper bound $f^{CO}$. So when $\overline{\mu}$ increases, the lower bound moves down, and the value of $P^0$ decreases. When no disclosure becomes relatively less attractive to the manager, he decreases the cut-off for disclosure and increases the probability of disclosure. This result is consistent with Verrecchia (1990, Corollary 4) where disclosure also increases when uncertainty increases.

I next study how the increase in uncertainty and probability of disclosure influence the agent's investment incentives. I differentiate $u$ from (2.160) with respect to $\overline{\mu}$ and use the fact that $\Pi = \frac{\kappa}{\overline{\mu}}$:

$$
\begin{aligned}
\frac{\partial u}{\partial \overline{\mu}} &= 2 \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \cdot \frac{\partial\left(\frac{1}{1-\Pi}\right)}{\partial \overline{\mu}} \\
&= -2 \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \cdot \left(\frac{\Pi}{(1-\Pi)^2}\right) \cdot \left(\frac{1}{\overline{\mu}}\right) \qquad (2.181) \\
&< 0
\end{aligned}
$$

The higher the riskiness of the investment, the lower the necessary stock bonus. With more underlying risk, there is more disclosure. More disclosure makes each unit of stock bonus more powerful, and a smaller amount of stock bonus is needed. The result is that riskiness reduces stock bonus, for a given level of investment.

The smallest value $\overline{\mu}$ can have, is $\overline{\mu} = \kappa$. For lower values of $\overline{\mu}$ than that, the probability of non-disclosure equals 1. Equation (2.160) shows that $\overline{\mu}$ influences $u$ only through the term $\frac{1}{(1-\Pi)}$. The denominator is $(1 - \Pi)$, which is the probability of disclosure. I first find how the probability of disclosure is affected as $\overline{\mu}$ moves towards its two extreme values:

$$
(1 - \Pi) \mid_{\overline{\mu} \to \kappa^+} = \left(1 - \frac{\kappa}{\overline{\mu}}\right) \mid_{\overline{\mu} \to \kappa^+} = 0 \qquad (2.182)
$$

$$
(1 - \Pi) \mid_{\overline{\mu} \to \infty} = \left(1 - \frac{\kappa}{\overline{\mu}}\right) \mid_{\overline{\mu} \to \infty} = 1 \qquad (2.183)
$$

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As $\overline{\mu}$ moves towards $\kappa$, the probability of disclosure moves toward zero. Similarly, when $\overline{\mu}$ moves towards infinity, the probability of disclosure moves towards one.

I find the value of the stock bonus $u^V$ when investment risk moves towards its two extremes:

$$u^V \mid_{\overline{\mu} \to \kappa^+} = \infty \tag{2.184}$$

$$u^V \mid_{\overline{\mu} \to \infty} = 2 \cdot \frac{\beta}{m'(b)} \cdot \left( 1 + \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{\frac{1}{2}} \right)^{-1} \tag{2.185}$$

When $\overline{\mu}$ goes toward its lower boundary, the probability of disclosure moves towards zero, and the neccesary bonus moves towards infitity because the bonus loses all its incentive effects. When $\overline{\mu}$ moves towards infinity, the disclosure probability goes towards one, and the stock bonus moves towards the value in (2.185).

**Example.** I use the parameter values from the example, and fix all variables except $u$ and $\overline{\mu}$. The agent's first order condition for investment is:

$$u^V = \frac{2}{(1 - \frac{0.25}{\overline{\mu}})} \cdot 0.366\,62 \cdot \left( 1 + (1 - 4 \cdot 0.366\,62 \cdot 0.5 \cdot 0.25)^{\frac{1}{2}} \right)^{-1} \tag{2.186}$$

In the example, the relationship between $u$ and $\overline{\mu}$ is as shown in Figure 2.13. The curve is always downward-sloping, because the derivative in (2.181) is negative. Here, stock bonus $u^V$ moves towards its limit value of

$$u^V \mid_{\overline{\mu} \to \infty} = 2 \cdot 0.366\,62 \cdot \left( 1 + (1 - 4 \cdot 0.5 \cdot 0.366\,62 \cdot 0.25)^{\frac{1}{2}} \right)^{-1} \tag{2.187}$$

$$= 0.385\,16$$

when $\overline{\mu}$ moves towards infinity (the horizontal dottet line in the figure). When $\overline{\mu}$ moves towards $\kappa = 0.25$ (the vertical dottet line in the figure) from above, the value of $u$ moves towards infinity. When comparing (2.165) to (2.187), it is clear that the stock bonus when $\overline{\mu} \to \infty$ is different from the full disclosure stock bonus. This is because the last term in the inner brackets above is different from zero (it is zero when $\kappa = 0$). So even when moving

towards full disclosure when $\overline{\mu} \to \infty$, the stock bonus will not be equal to the full disclosure stock bonus. By the same reasoning, it is also clear that the stock bonus is different when $\kappa \to 0$ (see (2.165)) and when $\overline{\mu} \to \infty$, even though the disclosure decision moves towards full disclosure in both cases. The risk effects are different in the two cases. These limit cases show that risk and the disclosure cost influence the stock bonus differently.
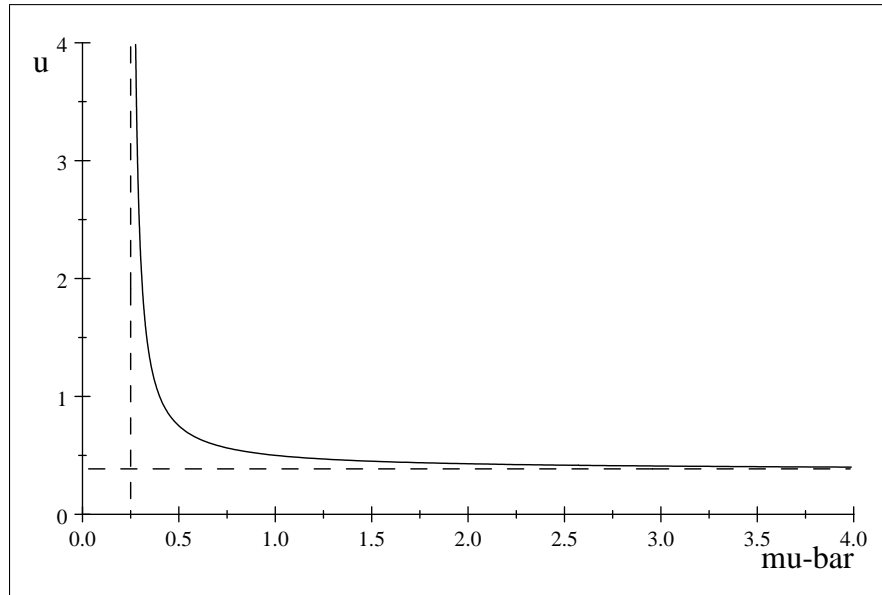


Figure 2.13. The relationship between stock bonus and investment risk, for a given investment level.

**How does the principal's problem depend on the level of investment risk?**

I also study the principal's optimal solution for different values of $\overline{\mu}$. I find how the optimal investment and effort levels change with $\overline{\mu}$ . The results are listed in Table 2.7. I start with a value of $\overline{\mu}$ of 1.90 and use intervals of 0.1 up to $\overline{\mu} = 3.0$.

For $\overline{\mu} \leq 2.8$, interior solutions are optimal. For values of $\overline{\mu}$ higher than this, a corner solution with $u = 0$, $\beta = 0$, and $a = 0$ is optimal. With higher risk, there is more to save in terms of the risk premium by setting the bonuses equal to zero. In the following, my comments concern the interior solutions.

When risk increases, the principal's expected payoff $W^V$ decreases. In contrast, the probability of disclosure increases. The scale of the company's operations decreases as risk increases,

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| Ex.no. | $\bar{\mu}$ | $W^V$ | $W^F$ | $W^V\text{-}W^F$ | $RP^V$ | $RP^F$ | $RP^V\text{-}RP^M$ | $a^V$ | $b^V$ | $u^V$ | $\beta^V$ | $varP^V$ | $RP(\beta)$ | $RP(u)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,90 | 0,574 | 0,562 | 0,012030 | 0,15138 | 0,15620 | -0,00482 | 0,591 | 0,867 | 0,508 | 0,473 | 1,099 | 0,080 | 0,071 |
| 2 | 2,00 | 0,565 | 0,555 | 0,010070 | 0,15092 | 0,15625 | -0,00533 | 0,578 | 0,862 | 0,491 | 0,462 | 1,228 | 0,077 | 0,077 |
| 3 | 2,10 | 0,557 | 0,548 | 0,008350 | 0,15035 | 0,15619 | -0,00584 | 0,565 | 0,858 | 0,474 | 0,452 | 1,364 | 0,074 | 0,082 |
| 4 | 2,20 | 0,549 | 0,542 | 0,006840 | 0,14969 | 0,15601 | -0,00632 | 0,553 | 0,854 | 0,459 | 0,442 | 1,506 | 0,070 | 0,087 |
| 5 | 2,30 | 0,541 | 0,535 | 0,005520 | 0,14938 | 0,15571 | -0,00633 | 0,547 | 0,850 | 0,449 | 0,438 | 1,656 | 0,069 | 0,092 |
| 6 | 2,40 | 0,533 | 0,529 | 0,004370 | 0,14806 | 0,15531 | -0,00725 | 0,528 | 0,847 | 0,430 | 0,423 | 1,812 | 0,064 | 0,096 |
| 7 | 2,50 | 0,525 | 0,522 | 0,003370 | 0,14710 | 0,15478 | -0,00768 | 0,516 | 0,844 | 0,417 | 0,413 | 1,974 | 0,061 | 0,101 |
| 8 | 2,60 | 0,518 | 0,516 | 0,002500 | 0,14605 | 0,15415 | -0,00810 | 0,504 | 0,842 | 0,404 | 0,404 | 2,144 | 0,059 | 0,095 |
| 9 | 2,70 | 0,511 | 0,509 | 0,001750 | 0,14492 | 0,15341 | -0,00849 | 0,493 | 0,839 | 0,392 | 0,394 | 2,320 | 0,056 | 0,089 |
| 10 | 2,80 | 0,504 | 0,503 | 0,001100 | 0,14370 | 0,15257 | -0,00887 | 0,481 | 0,837 | 0,380 | 0,385 | 2,503 | 0,053 | 0,090 |
| 11 | 2,90 | 0,500 | 0,497 | 0,003380 | 0,00000 | 0,15162 | -0,15162 | 0,000 | 1,000 | 0,000 | 0,000 | 2,692 | 0,000 | 0,000 |
| 12 | 3,00 | 0,500 | 0,490 | 0,009540 | 0,00000 | 0,15058 | -0,15058 | 0,000 | 1,000 | 0,000 | 0,000 | 2,888 | 0,000 | 0,000 |

Table 2.7. Optimal solution for different values of the risk parameter $\bar{\mu}$.

since both $a$ and $b$ decrease. Lower effort requires a lower cash bonus $\beta$. A lower investment level, combined with a higher probability of disclosure that makes stock bonus more powerful, reduces the required stock bonus as risk increases. The stock price variance increases with $\overline{\mu}$, both because the underlying investment risk increases and because the probability of disclosure increases. The stock bonus risk premium $RP(u)$ increases as risk increases up to $\overline{\mu} = 2.5$, and then it decreases. $RP(u)$ is the product of stock bonus and stock price variance, and the first decreases and the latter increases with $\overline{\mu}$. For $\overline{\mu} = 2.5$ and higher, the decrease in bonus dominates the increase in variance, and the stock price risk premium goes down. The total risk premium, however, goes down as $\overline{\mu}$ increases since effort $a$ and cash bonus $\beta$ also decrease with $\overline{\mu}$.

## 2.7.4   Conclusion

Table 2.8 sums up how the manager's stock bonus depends on the different parameters; to achieve a given investment level $b$, the necessary stock bonus $u^V$ increases when $\rho$ goes up, when $\overline{\mu}$ goes down, and/or when $\kappa$ goes up. These effects arise because of the kink in the compensation that voluntary disclosure creates. When there is full disclosure, there is no kink, and all these effects disappear.

| | V | F |
|---|---|---|
| Disclosure cost $\kappa$ | $\dfrac{\partial u^V}{\partial \kappa} > 0$ | $\dfrac{\partial u^F}{\partial \kappa} = 0$ |
| Risk aversion measure $\rho$ | $\dfrac{\partial u^V}{\partial \rho} > 0$ | $\dfrac{\partial u^F}{\partial \rho} = 0$ |
| Investment risk measure $\overline{\mu}$ | $\dfrac{\partial u^V}{\partial \overline{\mu}} < 0$ | $\dfrac{\partial u^F}{\partial \overline{\mu}} = 0$ |

Table 2.8. The table shows how the stock bonus required to induce a given investment level changes with three parameters

## 2.8    Conclusion

In this chapter I show how a manager's control of information will change the incentive problems inside the firm. I do so in a model where the manager exerts costly effort and has incentives to underinvest in a project. The manager controls information about the future outcome of the investment, and in the disclosure equilibrium that follows, he will hide bad outcomes and only reveal good outcomes. This reduces his downside risk, but it will also reduce the effectiveness of stock bonus. Stock bonus becomes less powerful in inducing investment, compared to the full disclosure case. This means that to achieve a given level of investment, the stock bonus needs to be higher with voluntary disclosure than with full disclosure. A higher bonus, on the other hand, increases the manager's risk, and is therefore costly.

The model assumes linear compensation contracts, but the disclosure decision makes the manager's compensation convex and piecewise linear. When increasing investment, the manager increases the probability of disclosure as well as increasing both the mean and the riskiness of his compensation. The owner's optimal level of effort and investment will typically be different in the voluntary disclosure case compared to full disclosure.

CHAPTER 2

## 2.A  Appendix to Chapter 2

### 2.A.1  The agent's certainty equivalent

(i) In order to find the agent's certainty equivalent, I calculate the unconditional time-0 mean and variance of the stock price and the disclosure cost: $E_0(P)$ and $Var_0(P)$.

(ii) I first look at the stock price, as seen from time 0. Since the agent does not know $\mu$ at time 0, he does not know what the exact value of the stock price in the event of disclosure will be, because this stock price is a function of $\mu$ (through $f$), see (2.13). But this stock price is only realized if $f \geq f^{CO}$. The distribution of the stock price, given that $f \geq f^{CO}$, is still uniform, but has a support that is truncated from below by $\left[ f^{CO} - \kappa \right]$.

**The mean of the stock price**

The agent's probability distribution of $P^1$ with this truncated distribution for $f$ is uniform and characterized by

$$P^1(b) \sim U\left[ f^{CO} - \kappa, (m(b) + \overline{\mu}) - \kappa \right] \tag{2.188}$$

This means that the expected stock price, for a given b, is

$$
\begin{aligned}
& E_0\left[ P \mid f \geq f^{CO} \right] && \text{(2.189)} \\
=\ & E_0\left[ f \mid f \geq f^{CO} \right] - \kappa \\
=\ & \frac{1}{2}(m(b) + \overline{\mu} + f^{CO}) - \kappa \\
=\ & \frac{1}{2}(m(b) + m(\hat{b}))
\end{aligned}
$$

The last equation comes from using (2.30).

The variance of the stock price, given $f \geq f^{CO}$ :

$$var(P^1 \mid f \geq f^{CO}) \tag{2.190}$$

$$= var(f \mid f \geq f^{CO})$$

$$= \frac{1}{12}(m(b) + \overline{\mu} - f^{CO})^2$$

$$= \frac{1}{12}(m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2$$

If $f < f^{CO}$ , expected stock price is

$$E_0(P \mid f < f^{CO}) = \frac{1}{2}\left[m(\hat{b}) - \overline{\mu} + \hat{f}^{CO}\right] \tag{2.191}$$

$$= m(\hat{b}) + \kappa - \overline{\mu}$$

and variance is

$$Var_0(P \mid f < f^{CO}) = 0 \tag{2.192}$$

The unconditional time-0 mean of the stock price is given as:

$$E_0(P) = E\left[E(P \mid f)\right]$$

$$= (1 - \Pi(f^{CO})) \cdot E(P \mid f \geq f^{CO})$$

$$+\Pi(f^{CO}) \cdot E(P \mid f < f^{CO})$$

$$= (1 - \Pi(f^{CO})) \cdot \left[\frac{1}{2}(m(b) + m(\hat{b}))\right]$$

$$+\Pi(f^{CO}) \cdot \left[m(\hat{b}) + \kappa - \overline{\mu}\right] \tag{2.193}$$

**The variance of the stock price**

The unconditional variance is given by:

$$Var_0(P) = E\left[var(P \mid f)\right] + var\left[E(P \mid f)\right] \tag{2.194}$$

For a reference on conditional variances, see Mood, Graybill and Boes (1974), p. 159.

To derive the components of this variance, I calculate $E\left[var(P \mid f)\right]$ and $var\left[E(P \mid f)\right]$:

$$E\left[var(P \mid f)\right] \tag{2.195}$$

$$= (1 - \Pi(f^{CO})) \cdot Var(P \mid f \geq f^{CO}) + \Pi(f^{CO}) \cdot Var(P \mid f < f^{CO}) \tag{2.196}$$

$$= (1 - \Pi(f^{CO})) \cdot \frac{1}{12}(m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2$$

$$Var\left[E(P \mid f)\right] \tag{2.197}$$

$$= (1 - \Pi(f^{CO})) \cdot \left[E(P \mid f \geq f^{CO}) - E_0(P)\right]^2$$
$$+\Pi(f^{CO}) \cdot \left[E(P \mid f < f^{CO}) - E_0(P)\right]^2$$

$$= (1 - \Pi(f^{CO})) \cdot \left\{ \begin{array}{c} \left[\frac{1}{2}(m(b) + m(\hat{b}))\right] - \\ \left[ \begin{array}{c} (1 - \Pi(f^{CO})) \cdot \left[\frac{1}{2}((m(b) + m(\hat{b}))\right] \\ \\ +\Pi(f^{CO}) \cdot \left[m(\hat{b}) + \kappa - \overline{\mu}\right] \end{array} \right] \end{array} \right\}^2$$

$$+\Pi(f^{CO}) \cdot \left\{ \begin{array}{c} \left[m(\hat{b}) + \kappa - \overline{\mu}\right] - \\ \left[ \begin{array}{c} (1 - \Pi(f^{CO})) \cdot \left[\frac{1}{2}(m(b) + m(\hat{b}))\right] \\ \\ +\Pi(f^{CO}) \cdot \left[m(\hat{b}) + \kappa - \overline{\mu}\right] \end{array} \right] \end{array} \right\}^2$$

$$\tag{2.198}$$

$$= \frac{1}{4}\left[\Pi(f^{CO}) - \Pi^2(f^{CO})\right] \cdot \left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right]^2$$

I can now find the variance of $P$ :

$$
\begin{aligned}
Var_0(P) &= E\left[var(P \mid f)\right] + var\left[E(P \mid f)\right] \\
&= (1 - \Pi(f^{CO})) \cdot \frac{1}{12}(m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2 \\
&\quad + \frac{1}{4}\left[\Pi(f^{CO}) - \Pi^2(f^{CO})\right] \cdot \\
&\quad \left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right]^2 \\
&= \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2
\end{aligned}
\tag{2.199}
$$

**The certainty equivalent**

The full certainty equivalent can now be written as:

$$
\begin{aligned}
CE_0 &= \alpha + \beta(a - b) - e(a) - \frac{1}{2}\rho\beta^2\sigma^2 \\
&\quad + u\left\{ \begin{array}{c} (1 - \Pi(f^{CO})) \cdot \left[\frac{1}{2}(m(b) + m(\hat{b}))\right] \\ \\ + \Pi(f^{CO}) \cdot \left[m(\hat{b}) + \kappa - \overline{\mu}\right] \end{array} \right\} \\
&\quad - \frac{1}{2}\rho RP
\end{aligned}
\tag{2.200}
$$

Where RP is defined as the agent's risk premium (2.64) :

$$
RP \equiv u^2 \left\{ \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa)^2 \right\}
\tag{2.201}
$$

## 2.A.2 Effects of a marginal increase in investment

I want to find how a marginal increase in investment changes the agent's probability of disclosure, the disclosure stock price, and first period cash bonus.

-------------------------------------------------------------------------------------------------------------------------

I use the expected disclosure stock price from (2.189). I find the effect on the agent's expected future disclosure stock price, from a marginal increase in investment:

$$\frac{\partial E_0(P^1)}{\partial b} = \frac{1}{2}m'(b) > 0 \tag{2.202}$$

If the agent increases investment, he increases the disclosure stock price.

To find the effect on the probability of disclosure, I differentiate (2.56):

$$\frac{\partial (1 - \Pi(f^{CO}))}{\partial b} = \frac{m'(b)}{2\overline{\mu}} > 0 \tag{2.203}$$

If the agent increases investment, he increases the probability of disclosure.

I find the change in the variance of the agent's compensation:

$$\frac{\partial Var_0(P)}{\partial b} = m'(b) \left\{ \begin{array}{c} \frac{1}{4}\frac{1}{2\overline{\mu}} \left[ (\frac{1}{3} + \Pi(f^{CO})) - (1 - \Pi(f^{CO})) \right] \cdot \left[ m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa \right]^2 \\ + \frac{1}{2}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot \left[ m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa \right] \end{array} \right\}$$

$$= m'(b) \left\{ \begin{array}{c} \frac{1}{4\overline{\mu}} \left( \Pi(f^{CO}) - \frac{1}{3} \right) \cdot \left[ (m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa \right]^2 \\ + \frac{1}{2}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot \left[ m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa \right] \end{array} \right\} \tag{2.204}$$

If the agent increases investment, he changes the variance of his compensation.

The direct effect on the cash flow bonus is given by:

$$\frac{\partial \beta c_1}{\partial b} = -b < 0 \tag{2.205}$$

If the agent increases investment, his cash-based compensation decreases.

### 2.A.3  The agent's first order condition for investment

To find the marginal effect on the agent's certainty equivalent of increasing investment I need to find $\frac{\partial E_0(P)}{\partial b}$ and $\frac{\partial Var_0(P)}{\partial b}$. Noting that $\frac{\partial \Pi}{\partial b} = -\frac{m'(b)}{2\overline{\mu}}$, the marginal effect of an increase in investment is:

$$\frac{\partial E_0(P)}{\partial b} = -\frac{\partial \Pi(f^{CO})}{\partial b} \cdot \left[\frac{1}{2}(m(b) + m(\hat{b}))\right]$$

$$+ (1 - \Pi(f^{CO})) \cdot \frac{1}{2} m'(b) + \frac{\partial \Pi(f^{CO})}{\partial b} \cdot \left[m(\hat{b}) + \kappa - \overline{\mu}\right]$$

$$= \left\{\frac{1}{2\overline{\mu}} \cdot \frac{1}{2}\left[(m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right] + (1 - \Pi(f^{CO})) \cdot \frac{1}{2}\right\} m'(b)$$

$$= \left(\frac{m(b) - m(\hat{b}) - 2\kappa + 2\overline{\mu}}{2\overline{\mu}}\right) m'(b) \tag{2.206}$$

This is the sum of the following effects: an increase in the probability of disclosure, an increase in the disclosure stock price, and a decrease in the probability of the non-disclosure stock price being realized.

The total derivative of the certainty equivalent is:

$$\frac{\partial CE_0}{\partial b} = -\beta + uZ(b)m'(b) \tag{2.207}$$

where $Z(b)$ is defined as

$$Z(b) \equiv \left(\frac{m(b) - m(\hat{b}) - 2\kappa + 2\overline{\mu}}{2\overline{\mu}}\right) \tag{2.208}$$

$$-\frac{1}{2}\rho u \left\{ \begin{array}{l} \frac{1}{4\overline{\mu}}\left(\Pi(f^{CO}) - \frac{1}{3}\right) \cdot \left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right]^2 \\ + \frac{1}{2}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot \left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right] \end{array} \right\}$$

I can now use the fact that in equilibrium, $\hat{b} = b$ and

$$\Pi(f^{CO}) = \frac{\kappa}{\overline{\mu}} \tag{2.209}$$

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$Z(b)$ then reduces to

$$Z(b) = 1 - \Pi(f^{CO}) - u\rho \left[1 - \Pi(f^{CO})\right]^2 \Pi(f^{CO})\overline{\mu} \qquad (2.210)$$

where $\Pi(f^{CO})$ is the equilibrium value in (2.209).

## 2.A.4 The function $uZ$

The function $uZ$ has a maximum at:

$$\frac{\partial(uZ)}{\partial u} = 0$$

$$\frac{\partial}{\partial u}\left[u\left(1 - \Pi - u\rho\left[1 - \Pi\right]^2 \Pi\overline{\mu}\right)\right] = 0$$

$$1 - \Pi - 2u\rho\left[1 - \Pi\right]^2 \Pi\overline{\mu} = 0$$

$$u = \frac{1 - \Pi}{2\rho\left[1 - \Pi\right]^2 \Pi\overline{\mu}}$$

$$u^{\text{max}} \equiv \frac{1}{2\rho\left(1 - \Pi\right)\Pi\overline{\mu}}$$

The second derivative is:

$$\frac{\partial}{\partial u}\left(1 - \Pi - 2u\rho\left[1 - \Pi\right]^2 \Pi\overline{\mu}\right)$$

$$= -2\rho\left[1 - \Pi\right]^2 \Pi\overline{\mu} < 0$$

This shows that $uZ$ is concave.

I use the value of $u^{\max}$ in $uZ$ and find

$$
\begin{aligned}
& u^{\max} \cdot Z(u^{\max}) \\
= \quad & \frac{1}{2\rho \left(1 - \Pi\right) \Pi \overline{\mu}} \cdot \left[1 - \Pi - \frac{1}{2\rho \left(1 - \Pi\right) \Pi \overline{\mu}} \cdot \rho \left[1 - \Pi\right]^2 \Pi)\overline{\mu}\right] \\
= \quad & \frac{1}{2\rho \left(1 - \Pi\right) \Pi \overline{\mu}} \cdot \left[1 - \Pi - \frac{1}{2} \cdot \left[1 - \Pi\right]\right] \\
= \quad & \frac{1}{2\rho \left(1 - \Pi\right) \Pi \overline{\mu}} \cdot \frac{1}{2} \left(1 - \Pi\right) \\
= \quad & \frac{1}{4\rho \Pi \overline{\mu}}
\end{aligned}
$$

### 2.A.5 The agent's second-order condition

In order for the first-order approach to be valid, the agent's second-order derivative for investment has to be negative.

The first-order derivative was

$$
\frac{\partial CE_0}{\partial b} = -\beta + m'(b)uZ(b) \tag{2.211}
$$

where $Z(b)$ was defined as

$$
\begin{aligned}
Z(b) \quad \equiv \quad & \left(\frac{m(b) - m(\hat{b}) - 2\kappa + 2\overline{\mu}}{2\overline{\mu}}\right) \\
& -\frac{1}{2}\rho u \left\{ \begin{array}{l} \frac{1}{4\overline{\mu}} \left(\Pi(f^{CO}) - \frac{1}{3}\right) \cdot \left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right]^2 \\ +\frac{1}{2}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot \left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right] \end{array} \right\}
\end{aligned} \tag{2.212}
$$

The second-order derivative is:

$$
\frac{\partial^2 CE_0}{\partial^2 b} = u \left[Z'(b)m'(b) + Z(b)m''(b)\right] \tag{2.213}
$$

where

$$Z'(b) = \frac{m'(b)}{2\overline{\mu}} - \frac{1}{2}\rho u m'(b) \left\{ \begin{array}{c} -\frac{1}{8\overline{\mu}^2}\left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right]^2 \\[2mm] +\frac{1}{\overline{\mu}}\left(\Pi(f^{CO}) - \frac{1}{3}\right)\left[m(b) - m(\hat{b}) + 2\overline{\mu} - 2\kappa\right] \\[2mm] +\frac{1}{2}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \end{array} \right\} \tag{2.214}$$

In equilibrium, when $\hat{b} = b$, $Z'(b)$ reduces to :

$$Z'(b) = \frac{m'(b)}{2\overline{\mu}} - \frac{1}{2}\rho u m'(b)(\Pi - 1)(1 - 3\Pi) \tag{2.215}$$

The second derivative can be written as:

$$\frac{\partial^2 CE_0}{\partial^2 b} = u \left\{ \begin{array}{c} \left(\frac{m'(b)}{2\overline{\mu}} - \frac{1}{2}\rho u m'(b)(\Pi - 1)(1 - 3\Pi)\right)m'(b) \\[2mm] + \left(1 - \Pi(f^{CO}) - \rho u \left[1 - \Pi(f^{CO})\right]^2 \Pi(f^{CO})\overline{\mu}\right)m''(b) \end{array} \right\} \tag{2.216}$$

This has to be negative in the relevante range $b \in [\underline{b}, \overline{b}]$.

## 2.A.6   Investment with full disclosure and voluntary disclosure

Full disclosure:

$$-\beta + u m'(b) = 0 \tag{2.217}$$

Rearranging:

$$m'(b) = \frac{\beta}{u} \tag{2.218}$$

Voluntary disclosure:

$$-\beta + u Z(b)m'(b) = 0 \tag{2.219}$$

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$$m'(b) = \frac{\beta}{uZ(b)} \tag{2.220}$$

Since $Z(b) < 1$:

$$m'(b^F) = \frac{\beta}{u} < \frac{\beta}{uZ(b^V)} = m'(b^V) \tag{2.221}$$

Since $m'(b)$ is concave, and $m'(b^F) < m'(b^V)$, it must be the case that

$$b^V < b^F \tag{2.222}$$

### 2.A.7 The principal's first-order condition

Differentiating the principal's expected wealth with respect to $b$ gives.

$$
\begin{aligned}
\frac{\partial W}{\partial b} &= -1 + m'(b) \\
&\quad - \left\{
\begin{array}{l}
\frac{1}{2}\rho(1-\Pi)^3(\frac{1}{3}+\Pi)\overline{\mu}^2 \cdot 2 \left[ \frac{1-\sqrt{1-\frac{4\rho\beta\kappa}{m'(b)}}}{2\rho\kappa(1-\Pi)} \right] \\
\cdot \frac{-1}{2\rho\kappa(1-\Pi)} \frac{1}{2} \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{-\frac{1}{2}} (-4)\rho\beta\kappa \frac{-1}{[m'(b)]^2} m''(b)
\end{array}
\right\} \\
&= 0
\end{aligned}
\tag{2.223}
$$

Rearranging this implies

$$
\frac{\partial W}{\partial b} = -1 + m'(b) + \left\{
\begin{array}{l}
\rho \cdot \underbrace{(1-\Pi)^3(\frac{1}{3}+\Pi)\overline{\mu}^2}_{<\frac{\overline{\mu}^2}{3}} \cdot \underbrace{\left[ \frac{1 - \sqrt{1 - \frac{4\rho\beta\kappa}{m'(b)}}}{2\rho\kappa(1-\Pi)} \right]}_{>0} \\
\cdot \underbrace{\frac{1}{(1-\Pi)}}_{>0} \cdot \underbrace{\left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{-\frac{1}{2}}}_{>1} \cdot \underbrace{\frac{\beta}{[m'(b)]^2} m''(b)}_{<0}
\end{array}
\right\}
\tag{2.224}
$$

## 2.A.8 Extensions: How does stock bonus depend on the disclosure cost?

The value of $\kappa^{\max}$ is defined as

$$\kappa^{\max} \equiv \frac{1}{4u\frac{\beta}{m'(b)}} \tag{2.225}$$

I differentiate this with respect to $b$ :

$$\frac{\partial \kappa^{\max}}{\partial b} = \frac{1}{4u\beta}\frac{\partial m'(b)}{\partial b} = \frac{1}{4u\beta}m''(b) < 0 \tag{2.226}$$

The higher the investment level, the lower is the value of $\kappa^{\max}$.

To find $\frac{\partial b}{\partial \kappa}$ I use implicit differentiation on (2.160), given by:

$$u^V = \frac{2}{(1-\Pi)} \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \tag{2.227}$$

Implicit differentiation with respect to $\kappa$ gives:

$$\frac{2}{(1-\Pi)}\beta \left( \begin{array}{c} -\frac{1}{(m'(b))^2}m''(b)\frac{\partial b}{\partial \kappa}\cdot\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \\ +\frac{1}{m'(b)}(-1)\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-2}\frac{1}{2}\left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{-\frac{1}{2}}(-4\beta\rho)\frac{m'(b)-\kappa\cdot m''(b)\frac{\partial b}{\partial \kappa}}{(m'(b))^2} \end{array} \right)$$
$$= 0 \tag{2.228}$$

I rearrange

$$-m''(b)\frac{\partial b}{\partial \kappa}\cdot\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-1} \tag{2.229}$$

$$+\frac{1}{m'(b)}(-1)\left(1 + \left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{\frac{1}{2}}\right)^{-2}\cdot\frac{1}{2}\left(1 - \frac{4\rho\beta\kappa}{m'(b)}\right)^{-\frac{1}{2}}(-4\beta\rho)\,m'(b) - \kappa\cdot m''(b)\frac{\partial b}{\partial \kappa}$$

$$= 0$$

Rearranging again gives

$$\frac{\partial b}{\partial \kappa} \left( -m''(b) \cdot \left( 1 + \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{\frac{1}{2}} \right)^{-1} - \kappa \cdot m''(b) \right)$$

$$+ \left( 1 + \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{\frac{1}{2}} \right)^{-2} \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{-\frac{1}{2}} 2\beta\rho$$

$$= \quad 0 \tag{2.230}$$

I solve for $\frac{\partial b}{\partial \kappa}$ :

$$\frac{\partial b}{\partial \kappa} = -\left( 1 + \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{\frac{1}{2}} \right)^{-2}$$

$$\cdot \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{-\frac{1}{2}} 2\beta\rho \left( -m''(b) \cdot \left( 1 + \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{\frac{1}{2}} \right)^{-1} - \kappa \cdot m''(b) \right)^{-1}$$

$$< \quad 0 \tag{2.231}$$

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# Chapter 3

# Voluntary disclosure and investment incentives when risk increases with investment

## 3.1 Introduction

In this chapter I study how a manager's voluntary disclosure decision changes his investment incentives in the case where the investment's risk increases with the size of the investment. As in Chapter 2, the manager has stock-based compensation, and he can decide whether to disclose his private information or not. I find that in some cases a lower stock bonus is needed with voluntary disclosure than with full disclosure. In a numerical analysis, I show that the principal may be better off with voluntary disclosure than with full disclosure. The reason is that in some cases it is cheaper to induce investment with voluntary disclosure than with full disclosure.

The basic setting of the model is the same as in Chapter 2; a manager is hired for one period and chooses short-term effort and long-term investment. He receives a signal that perfectly reveals the future cash flows from investment, and he then decides whether or not to disclose this signal. What is new in this chapter, is the form of the investment risk. In this chapter, I assume that risk increases with investment. This means that when the amount invested

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increases, the cash flow that the investment creates, has higher variance. So when there is more at risk, the total risk increases.

I then look at how the manager's choice of disclosure influences his investment incentives ex ante. It turns out that the form of investment risk I have here, will influence the manager's investment incentives in a different way than the constant investment risk in Chapter 2. The fact that the manager's investment decision not only influences the mean of the investment payoff but also the variance, can in some cases make it easier (cheaper) for the principal to induce a given investment level. This is due to what I call the option effect (what Ross (2004) calls the convexity effect in his option setting).

To understand this, recall from Chapter 2 that when the manager receives compensation that is linear in stock price and when he at the same time can voluntarily disclose his information, his final compensation will be piecewise linear and convex, like a call option. The disclosure equilibrium will show that his compensation will be flat for low stock prices (no disclosure) and increasing in stock price for higher stock prices (the disclosure region)[1]. This convexity causes the manager in some cases (when he is not too risk averse) to prefer a higher investment level because this increases investment risk. With this convex compensation, he will be rewarded for good outcomes but protected from bad outcomes. Since risk increases with investment, the manager may in some cases have a preference for higher investment, and it will therefore be cheaper for the principal to induce the manager to invest.

This is different from the model in Chapter 2, because there the manager could not influence investment risk. A factor that remains the same, is that the flat part of the compensation (the no disclosure region) will reduce the manager's investment incentives compared to the full disclosure case, where there is no flat part.

I analyze the required stock bonus needed to achieve a given investment level in two steps: I first compare the stock bonus with increasing investment risk (from this chapter) to the stock bonus with constant investment risk (the setting in Chapter 2). I then compare the stock bonus with increasing investment risk for voluntary disclosure and full disclosure. I show that the required stock bonus may be lower when the risk is increasing in investment compared

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[1]This is similar to the disclosure quilibrium in Chapter 2 and also to the disclosure equilibrium in Verreccia (1983).

to the constant-risk case. I also show that when risk increases with investment, the required stock bonus may be lower with voluntary disclosure than with full disclosure. I also show that the principal can be better off with voluntary disclosure than with full disclosure. I show this with a numerical example, since the analytical model becomes intractable at this point. The principal can be better off with voluntary disclosure because this saves on the disclosure cost (as in Chapter 2) and because the option effect described earlier can make it cheaper to induce a given investment level with voluntary disclosure compared to full disclosure. This last effect was not present in the model in Chapter 2, since the manager could not influence investment risk there, and consequently there was no option effect. An implication of this is that it may be efficient to leave the disclosure decision to the agent and not to make full disclosure mandatory.

This chapter contributes to the literature on managerial incentives and the literature on voluntary disclosure. In the model the manager is compensated based on cash flows and stock price. Research shows that stock-based incentives are widely used in practice[2]. I analyze how the manager's control of information can influence the strength of stock-based incentives. With voluntary disclosure the manager can hide information, and I show two effects of this; the no-disclosure choice flattens the compensation and reduces incentives, while the resulting convexity of the compensation can increase the power of stock-based incentives because of the option effect.

There also exists a lot of research on voluntary disclosure (see for instance Verrecchia (2001) and Dye (2001) for overviews), but little has been done to analyze voluntary disclosure in an agency context. Beyer, Cohen, Lys and Walther (2010) point out the need for resarch that takes incentive issues and real decisions (such as effort and investment) into a voluntary disclosure setting. This is what I analyse, as I look at the interaction between voluntary disclosure and effort and investment incentives.

Because of the convexity of the compensation when there is voluntary disclosure, and because I in this Chapter introduce the assumption that the manager influences investment risk, the chapter is also related to the options literature. Some papers argue that options are an optimal form of compensation when the manager influences risk[3] (Feltham and Wu (2001),

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[2] See Hall and Liebman (1998) and Bünn, Rapp, Schwanecke and Wolff (2010) for analyes on US and European data, respectively.

[3] Others argue that options are optimal for other reasons, including Oyer (2004) where options are used to

Flor, Frimor, and Munk (2011) and Dittmann and Yu (2010). One of the main arguments is that options will make managers more willing to take on risk[4]. This is familiar from Jensen and Meckling (1976) who see stock owners as options holders with a strike price of zero and discuss how owners (as opposed to bond holders) will prefer more risk, even when this comes at the expense of expected output. The argument for this is found in any finance textbook and is the same as in my model; the convexity of the options makes the option owner prefer more volatility in the underlying asset. Empirical studies generally agree with the idea that option compensation will increase managerial risk-taking (Rajgopal and Shevlin (2002), Coles, David and Naveen (2006), Low (2009), and Armstrong and Vashishtra (2011).

The chapter is organized as follows. Section 3.2 presents the model. In Section 3.3 I discuss the agent's decision problems; first the disclosure decision and then the effort and investment decisions. In Section 3.4 I present the explicit expressions for the required stock bonus to achieve a given investment level, first for voluntary disclsoure and then for full disclosure, and I then compare the two. The principal's problem of choosing optimal effort and investment level is presented in Section 3.5. Section 3.6 concludes.

## 3.2   Model

### 3.2.1   Timing and cash flows

In this section I present the model. The essentials of the model are the same as in Chapter 2, the only difference is that investment risk now increases with investment. Many of the basic elements of the model follow from Dutta and Reichelstein (2005), which I also use in Chapter 2. The timing in the model follows the timing in Chapter 2:

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retain employees, Dittmann, Armstrong, Larcker and Su (2007) who assume power utility and limited liability, Kadan and Swinkels (2008) where there is bankruptcy risk, Edmans and Gobaix (2009) with dynamic contracting, and Dittmann, Maug and Spalt (2010) where the manager has a loss averse utility function,.

[4]Counterarguments for this can be found in Carpenter (2000), Ross (2004) and Levellen (2006).
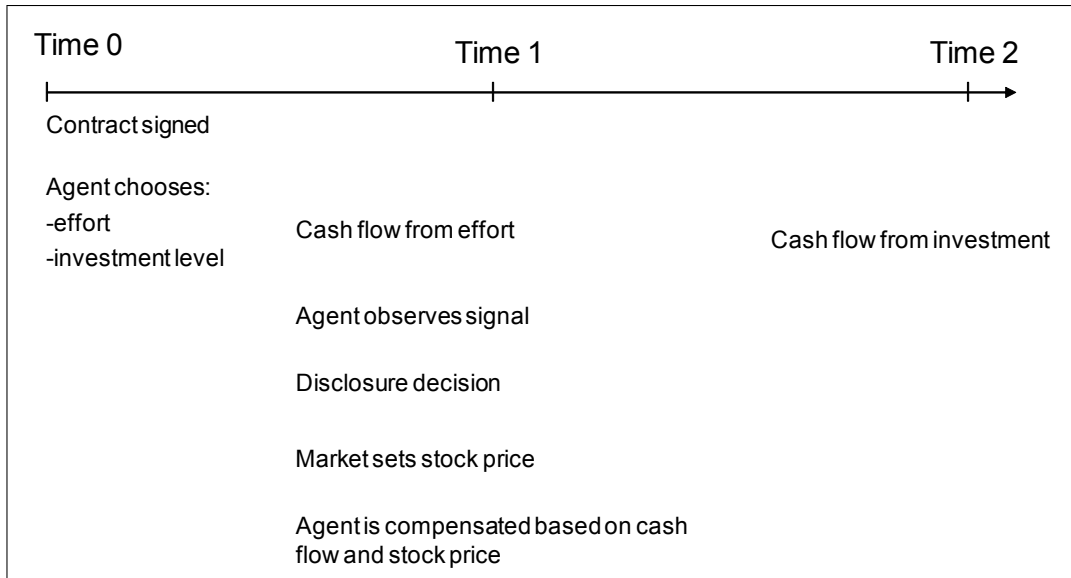
Figure 3.1. Timeline.

I will discuss only the main aspects of the model here, since much is familiar from Chapter 2.

The agent first makes effort and investment decisions, at time 0. At time 1, the cash flow from effort is realized. The agent also privately observes a signal about the (long-term) cash flow from investment. He can choose whether to disclose this signal to the principal and to the stock market. The stock market incorporates all available information into the stock price. The manager is then compensated based on two performance measures; the first period cash flow and the stock price. Finally, at time 2, the cash flow from investment is realized and paid to owners.

First period cash flow is:

$$c_1 = a + \varepsilon - b \tag{3.1}$$

where $a$ is effort, $b$ is investment, and $\varepsilon$ is uncertainty regarding cash flows from effort. The uncertainty parameter $\varepsilon$ is normally distributed with mean zero variance $\sigma^2$

$$\varepsilon \sim N(0, \sigma^2) \tag{3.2}$$

Both effort and investment (and uncertainty) are unobservable to outsiders (the principal and the stock market). As in Chapter 2, I assume that this aggregate of investment cost and cash flow from effort is available for contracting, and not its separate components.

Cash flow in period 2 is

$$c_2 = m(b) + \mu - d \cdot \kappa \tag{3.3}$$

where $m(b)$ is the investment production function, assumed to be increasing and concave and with the following properties: $m'(b) > 1$ when $b \rightarrow \underline{b}$ and $m'(b) \rightarrow 0$ when $b \rightarrow \overline{b}$, where $b \in [\underline{b}, \overline{b}]$. The term $d \in \{0, 1\}$ reflects the manager's disclosure decision, where $d = 1$ describes disclosure and $d = 0$ non-disclosure. I assume that the company incurs a cost in the case of disclosure, and this cost is $\kappa$.

### 3.2.2  Investment risk

Investment risk is reflected in the term $\mu$. In the previous chapter investment risk was constant. I now assume that the investment risk depends on the level of investment. Specifically, I assume that higher investment implies higher risk. When more capital is invested, it may be natural to assume there is both more to lose and more to gain[5].

The distribution of $\mu$ is still uniform, but the support is now a positive function of the investment level:

$$\mu \sim U(-\overline{\mu}(b), \overline{\mu}(b)) \tag{3.4}$$

I assume that the relationship between investment and risk takes the following form:

$$\overline{\mu}(b) = \lambda + \tau b \tag{3.5}$$

with $\overline{\mu}'(b) = \tau \geq 0$. With $\tau = 0$, we are back to the basic model, and with $\tau > 0$, an increase in investment $b$ by $\Delta b$ increases the upper and lower boundaries of the distribution by $\tau \cdot \Delta b$.

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[5]In this and other papers of managerial incentives (e.g. , Feltham and Wu (2001), Lambert and Larcker (last section) (2004), Flor, Frimor and Munk (2011), and Dittman and Yu (2009)) the manager makes a decision that simultaneously affects the mean and variance of outcome. Alternatively, the risk decision could be taken completely separately, as in Hirshleifer and Suh (1992).

The expected value of $\mu$ is zero for a given $b$, as before, and the variance $\sigma_\mu^2$ is now equal to

$$var(\mu) \equiv \sigma_\mu^2 = \frac{1}{12}(2\overline{\mu}(b))^2 = \frac{1}{3}\overline{\mu}(b)^2 = \frac{1}{3}(\lambda + \tau b)^2 \qquad (3.6)$$

An increase in investment increases the variance by

$$\frac{\partial var(\mu)}{\partial b} = \frac{2}{3}(\lambda + \tau b)\tau \qquad (3.7)$$

$$> 0$$

The principal and the stock market do not observe $\mu$ or $b$, so they do not know the value of the variance. They use their conjectured value of $b$; $\hat{b}$, to form beliefs about the variance. They believe that $\overline{\mu}$ is equal to $\overline{\mu}(\hat{b})$, and their beliefs about the probability distribution are:

$$\mu(\hat{b}) \sim U(-\overline{\mu}(\hat{b}), \overline{\mu}(\hat{b})) \qquad (3.8)$$

### 3.2.3   The forward-looking signal and the agent's preferences

The signal $f$ that the manager observes at time 1 is a perfect signal about future cash flows from investment:

$$f = m(b) + \mu \qquad (3.9)$$

This has the following distribution:

$$f \sim [m(b) - \overline{\mu}(b), m(b) + \overline{\mu}(b)] \qquad (3.10)$$

where $E(f) = m(b)$ and $Var(f) = Var(\mu) = \frac{1}{3}(\lambda + \tau b)^2$. The manager now influences both the mean and the variance of the distribution when choosing investment level. The market's belief about the distribtion of $f$ is

$$\hat{f} \sim \left[m(\hat{b}) - \overline{\mu}(\hat{b}), m(\hat{b}) + \overline{\mu}(\hat{b})\right] \qquad (3.11)$$

The manager's compensation is assumed to be linear in first-period cash flow and the stock price $P$:

$$s = \alpha + \beta c_1 + \hat{u}P \tag{3.12}$$
$$= \alpha + \beta(a + \varepsilon - b) + \hat{u}P$$

where $\alpha$ is the fixed part of compensation, $\beta$ is the cash flow bonus, and $\hat{u}$ is the stock price bonus. Note that in this case when $\tau > 0$, I denote the stock bonus $\hat{u}$, and when $\tau = 0$ I keep the notation $u$. The principal is risk neutral, while the agent has mean-variance preferences. His certainty equivalent at time 0 is:

$$CE_0 = E(s) - e(a) - \frac{1}{2}\rho \cdot var(s) \tag{3.13}$$

Risk aversion is reflected in the term $\rho$. The agent's personal cost of effort is $e(a)$, where $e(\cdot)$ is monotonically increasing, twice differentiable, and strictly convex, and $e(0) = 0$.

## 3.3 The agent's decision problems

The agent makes an effort and an investment decision at time 0 and a disclosure decision at time $1^-$. In this section I use backwards induction and start by describing the disclosure decision and the disclosure equilibrium. I then find the agent's certainty equivalent at time 0 and solve for his optimal effort and investment decisions.

### 3.3.1 The disclosure decision at time $1^-$

The disclosure equilibrium is similar to the case analyzed in Chapter $2^6$, with some adjustments. The disclosure decision is unaffected by actual risk, but is affected by the market's beliefs about the risk. The market's beliefs about risk will influence the no-disclosure stock price, since the market uses its probability distribution with $\overline{\mu}(\hat{b})$ to form their expectations about firm value.

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[6] The equilibrium is also similar to Verrecchia (1983) in several respects.

For the agent, risk is resolved at the time of the disclosure decision, so the time 0 variance in investment returns do not influence his disclosure decision.
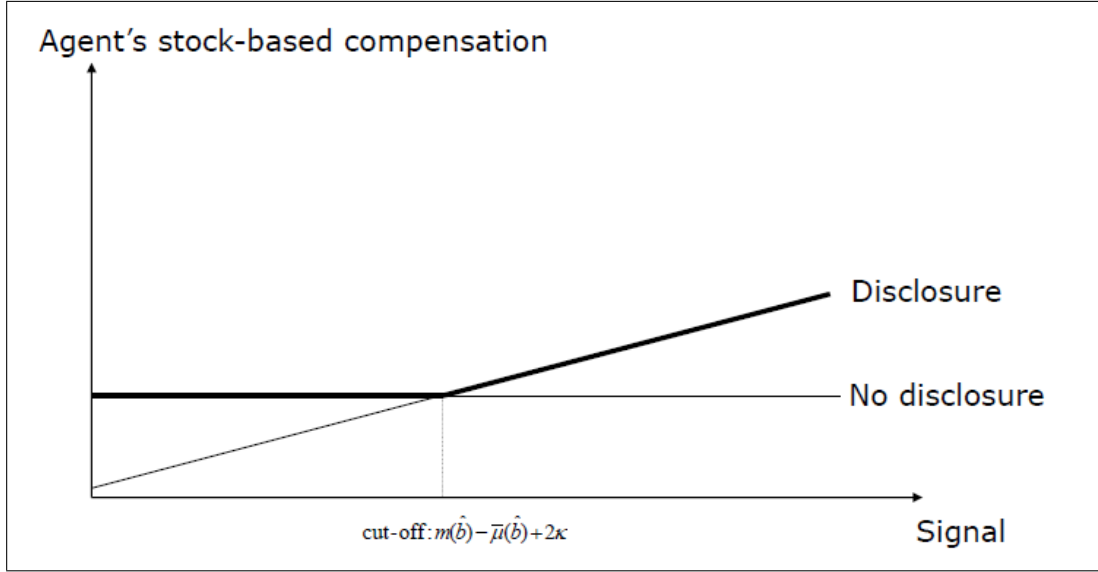


Figure 3.2. The disclosure equilibrium.

More specifically, the no-disclosure stock price[7] $P^0$ is the mean of the cumulative distribution of $\hat{f}$ below the (conjectured) treshold $\hat{f}^{CO}$:

$$P^0 = E_{1-}\left[\hat{f} \mid \hat{f} < \hat{f}^{CO}\right] \tag{3.14}$$
$$= \frac{1}{2}\left(m(\hat{b}) - \overline{\mu}(\hat{b}) + \hat{f}^{CO}\right)$$

The disclosure stock price is $P^1 = f - \kappa$ as before. The agent discloses the signal if $P^1 > P^0$:

$$P^1 > P^0 \tag{3.15}$$
$$f - \kappa > \frac{1}{2}\left(m(\hat{b}) - \overline{\mu}(\hat{b}) + \hat{f}^{CO}\right)$$

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[7] Cash flows may become negative. To assure a positive stock price, I assume that there exist assets in place (not modelled here) so that the value of the company is always positive.

The equilibrium occurs when $\hat{f}^{CO} = f^{CO}$, where the market's conjectured cutoff is equal to the agent's chosen cut-off:

$$f^{CO} - \kappa = \frac{1}{2}\left(m(\hat{b}) - \overline{\mu}(\hat{b}) + f^{CO}\right)$$

$$f^{CO} = m(\hat{b}) - \overline{\mu}(\hat{b}) + 2\kappa \tag{3.16}$$

The disclosure equilibrium is illustrated in Figure 3.2.

### 3.3.2 The effort and investment decisions at time 0

**The probability of disclosure**

At time 0, the agent's probability of disclosure $(1 - \Pi)$ is given by the cumulative distribution above the cut-off $f^{CO}$:

$$
\begin{aligned}
(1 - \Pi(f^{CO})) &= \int_{f^{CO}}^{m(b)+\overline{\mu}(b)} \frac{1}{2\overline{\mu}(b)} df \\
&= \frac{m(b) + \overline{\mu}(b) - \left(m(\hat{b}) - \overline{\mu}(\hat{b}) + 2\kappa\right)}{2\overline{\mu}(b)} \\
&= \frac{m(b) - m(\hat{b}) + \overline{\mu}(b) + \overline{\mu}(\hat{b}) - 2\kappa}{2\overline{\mu}(b)} \\
&= \frac{m(b) - m(\hat{b}) + (\lambda + \tau b) + \left(\lambda + \tau\hat{b}\right) - 2\kappa}{2\left(\lambda + \tau b\right)}
\end{aligned}
\tag{3.17}
$$

This is the agent's probability at time 0 of disclosing the signal at time $1^-$. This probability is affected both by the actual risk and the conjectured risk, measured by $\overline{\mu}(b)$ and $\overline{\mu}(\hat{b})$.

The agent's certainty equivalent is:

$$CE_0 = \alpha + \beta c_1 - e(a) + \hat{u}E_o(P) - \frac{1}{2}\rho(\beta^2\sigma^2 + \hat{u}^2 \cdot Var_o(P)) \tag{3.18}$$

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**The agent's certainty equivalent**

I use the explicit expressions for expected stock price and variance and rewrite (calculations are in Appendix 3.A.1):

$$CE_0 = \alpha + \beta(a-b) - e(a) - \frac{1}{2}\rho\beta^2\sigma^2 \tag{3.19}$$

$$+ \hat{u}\left((1-\Pi(f^{CO}))\cdot\frac{1}{2}\left(m(b) + m(\hat{b}) + \overline{\mu}(b) - \overline{\mu}(\hat{b})\right) + \Pi(f^{CO})\cdot\left(m(\hat{b}) + \kappa - \overline{\mu}(\hat{b})\right)\right)$$

$$- \frac{1}{2}\rho\hat{u}^2\cdot\frac{1}{4}(1-\Pi(f^{CO}))(\frac{1}{3}+\Pi(f^{CO}))\cdot(m(b) - m(\hat{b}) + \overline{\mu}(\hat{b}) + \overline{\mu}(b) - 2\kappa)^2$$

**The agent's first order condition**

I find the agent's FOCs, then set $\hat{b} = b$ in equilibrium, and I have the first order conditions for effort and investment (calculations in Appendix 3.A.2) :

$$\beta = e'(a) \tag{3.20}$$

$$-\beta + \hat{u}\cdot m'(b)Z(b) + \hat{u}\cdot\tau Y(b) = 0 \tag{3.21}$$

where

$$\Pi(b) = \frac{\kappa}{\overline{\mu}(b)} \tag{3.22}$$

$$Z(b) = (1-\Pi(b)) - \rho\hat{u}\left[1-\Pi(b)\right]^2\Pi(b)\overline{\mu}(b) \tag{3.23}$$

$$Y(b) = \underbrace{(1-\Pi(b))\Pi}_{\text{option effect}} - \underbrace{\rho\hat{u}(1-\Pi(b))^2\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)}_{\text{variance effect}} \tag{3.24}$$

With $\tau = 0$, the FOC is the same as in the previous section. The factor $Z$ here is the same as before, with the difference that the variance factor $\overline{\mu}$ now depends on $b$; $\overline{\mu}(b)$. Since the effect of $Z$ is the same as in Chapter 2, I will not discuss it further here. The new term is $Y(b)$. This

factor describes the effects on the manager's CE of the marginal increase in investment risk that comes from increasing investment. I will analyze $Y$ in more detail.

**Effects of an increase in investment for the agent**

I note that an increase in investment now has two effects on the probability distribution of $f$, and on the probability of disclosure. Figure 3.3 illustrates this. Panel A shows the distribution of $f$ for a given investment level $b_1$. The probability of disclosure is the cumulative distribution above $f^{CO}$ and is the area called $(1 - \Pi)$. Panel B shows the same distribution with $b$ equal to $b_2$, where $b_2 > b_1$. With a higher investment, the distribution is shifted upwards (to the right), and it also widens since $\tau > 0$. The lower bound for disclosure is still $f^{CO}$, since this is independent of $b$ ($f^{CO}$ is fixed, since it depends on $\hat{b}$ not $b$). The distribution becomes flatter. This reduces the probability for any outcome within the support. So even though there is now a positive probability of ending up with very high outcomes, the good, but more mediocre outcomes have lower probabilities. Panel C compares the two distributions. The probability of disclosure can in some cases decrease when investment increases[8].

**Option effect**    The first term in $Y(b)$ is the effect of increased variance from $\tau$ on the expected value of the stock price and agent's compensation, and it is positive. When the agent increases investment, the payoff distribution widens, as noted. Figure 3.4 shows the effect of an increase in $b$ on the distribution (as seen from time 0) of the disclosure stock price $P^1$ (the stock price conditional on disclosure). The disclosure stock price $P^1$ has the uniform distribution $P^1 \sim \left[ f^{CO} - \kappa, m(b) + \bar{\mu}(b) - \kappa \right]$. When investment increases, the expected disclosure stock price (a conditional expectation) increases because it reflects the mean of a distribution. Since the support widens only upwards (the lower bound is reflected by the value $\left( f^{CO} - \kappa \right)$, which is unaffected by an increase in actual investment), the mean increases. Panel A shows the distribution with investment $b_1$ and panel B the distribution with the higher investment level $b_2$. In Panel B the distribution is shifted upwards (but with the same lower bound $f^{CO}$) and

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[8] The probability increases when (shown in the Appendix)

$$\frac{m'(b)}{\tau} > 1 - 2\Pi$$

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is flatter. So by increasing investment at time 0, the agent not only moves the distribution upwards, but also widens the (upper) support.

This effect is similar in nature to the change in the value of a stock option when the risk of the underlying stock increases. As risk increases, the probability of extreme outcomes increases. The buyer of an option is protected from the downside risk but gains all the upside benefits from the increased probability of having extremely good outcomes. Therefore increased risk increases the value of an option[9]. I will later refer to this (how an increase in $b$ increases $\bar{\mu}(b)$ and increases $P^1$) as the stock option effect. The effect of options on managerial effort incentives when the manager can influence risk is discussed in Feltham and Wu (2001). As Panel C shows, the mean of the distribution increases when $b$ increases, which is a result of both the expected value of the investment increasing, but also because of this option effect.

**Variance effect**    The second term (the variance term) in $Y(b)$ is the effect from $\tau$ on the variance of the agent's compensation. The term $(1 - \Pi)^2 \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right)$ is positive. When $\tau > 0$, an increase in investment increases investment risk, and also stock price risk. I call this the variance effect. Even though the probability of disclosure might decrease with investment when $\tau > 0$, and this leads to less stock price variance, the increase in the investment risk dominates. Stock price variance increases when the investment increases.

In sum, when the agent increases investment, both the expected stock price and the stock price risk increases, and they both increase more when $\tau > 0$ than when $\tau = 0$.

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[9]This result can be found in any standard finance textbook, see for instance Hull (1993), or simply use the Black-Scholes formulae for an option value and differentiate the value with respect to volatility (risk).

Panel A

$$\Pi \qquad (1-\Pi)$$

$$\frac{1}{2\overline{\mu}(b_1)}$$

$$f$$

$$m(b_1)-\overline{\mu}(b_1) \qquad f^{co} \qquad m(b_1)+\overline{\mu}(b_1)$$

Panel B

$$\Pi \qquad (1-\Pi)$$

$$\frac{1}{2\overline{\mu}(b_2)}$$

$$f$$

$$m(b_2)-\overline{\mu}(b_2) \qquad f^{co} \qquad m(b_2)+\overline{\mu}(b_2)$$

Panel C

$$\Pi \qquad (1-\Pi)$$

$$\frac{1}{2\overline{\mu}(b_2)}$$

$$f$$

$$m(b)-\overline{\mu}(b) \qquad f^{co} \qquad m(b)+\overline{\mu}(b)$$
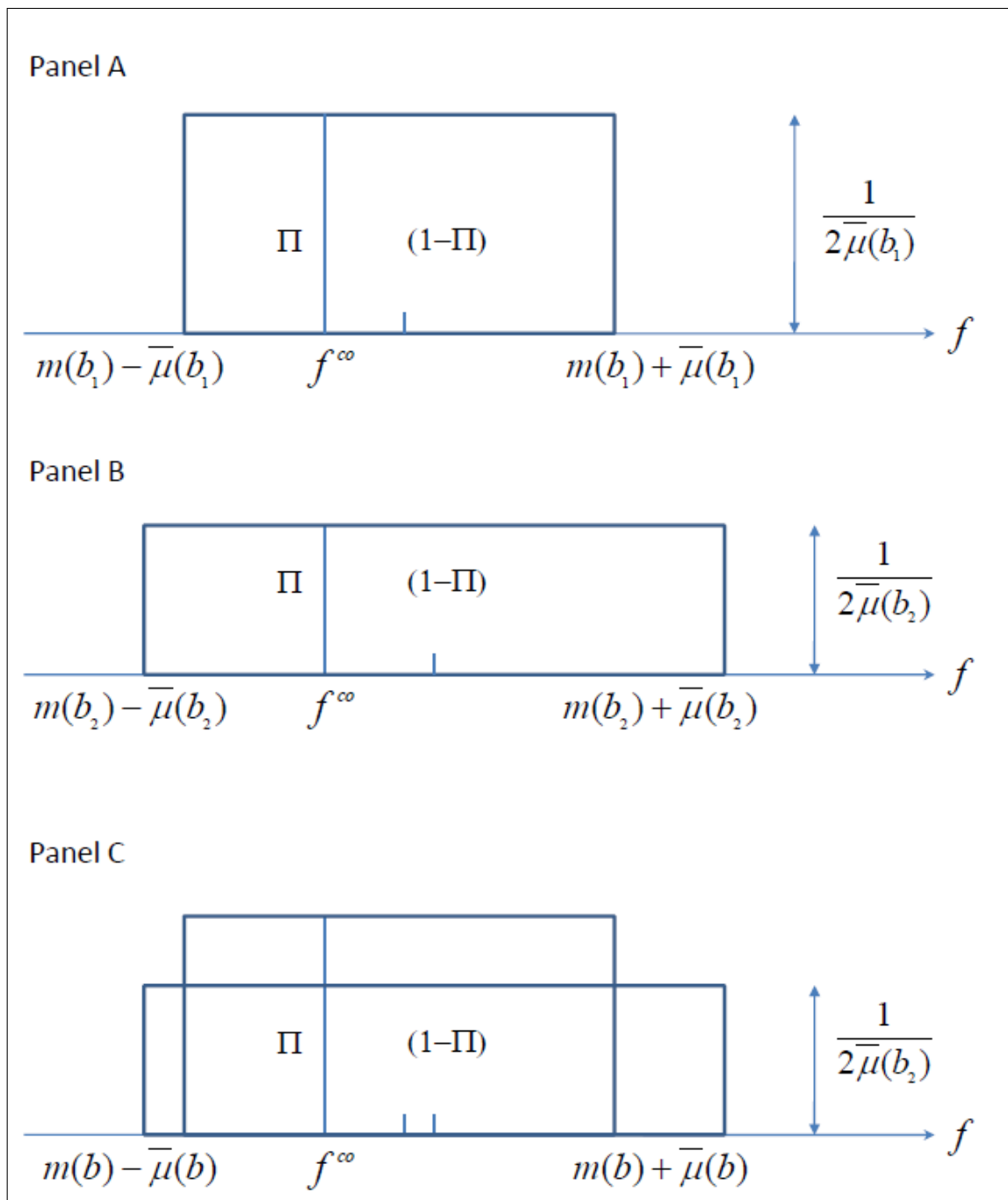
Figure 3.3. The value of output $f$ and the probability of disclosure $(1-\Pi)$ as a function of investment $b$. Investment is higher in Panel B than in Panel A $(b_2 > b_1)$. In Panel B the distribution is flatter and has moved to the right.

**Panel A.**

$$\frac{1}{m(b_1)+\overline{\mu}(b_1)-f^{co}}$$

$$P^1$$

$$f^{co}-\kappa \qquad E(P^1) \quad m(b_1)+\overline{\mu}(b_1)-\kappa$$

**Panel B.**

$$\frac{1}{m(b_2)+\overline{\mu}(b_2)-f^{co}}$$

$$P^1$$

$$f^{co}-\kappa \qquad E(P^1) \quad m(b_2)+\overline{\mu}(b_2)-\kappa$$

**Panel C.**

$$\frac{1}{m(b_2)+\overline{\mu}(b_2)-f^{co}}$$

$$P^1$$

$$f^{co}-\kappa \qquad E(P^1) \quad m(b)+\overline{\mu}(b)-\kappa$$

Figure 3.4. The distribution of the disclosure stock price $P^1$.

## 3.4  The stock bonus

In this section I study the stock bonus with voluntary disclosure and with full disclosure. I compare the stock bonus with and without the risk effect, and I compare the stock bonus with voluntary disclosure to the full disclosure stock bonus.

### 3.4.1  The  stock bonus with voluntary disclosure

In this section I will study more closely the effect that stock bonus $\hat{u}$ has on investment incentives. First, I find the required stock bonus for a given investment level. I then compare the stock bonus with and without the risk effect ($\tau > 0$ vs.$\tau = 0$).

From the agent's first order condition in (3.21), I find the necessary stock bonus $\hat{u}$ to induce a given investment $b$, see Appendix 3.A.3.
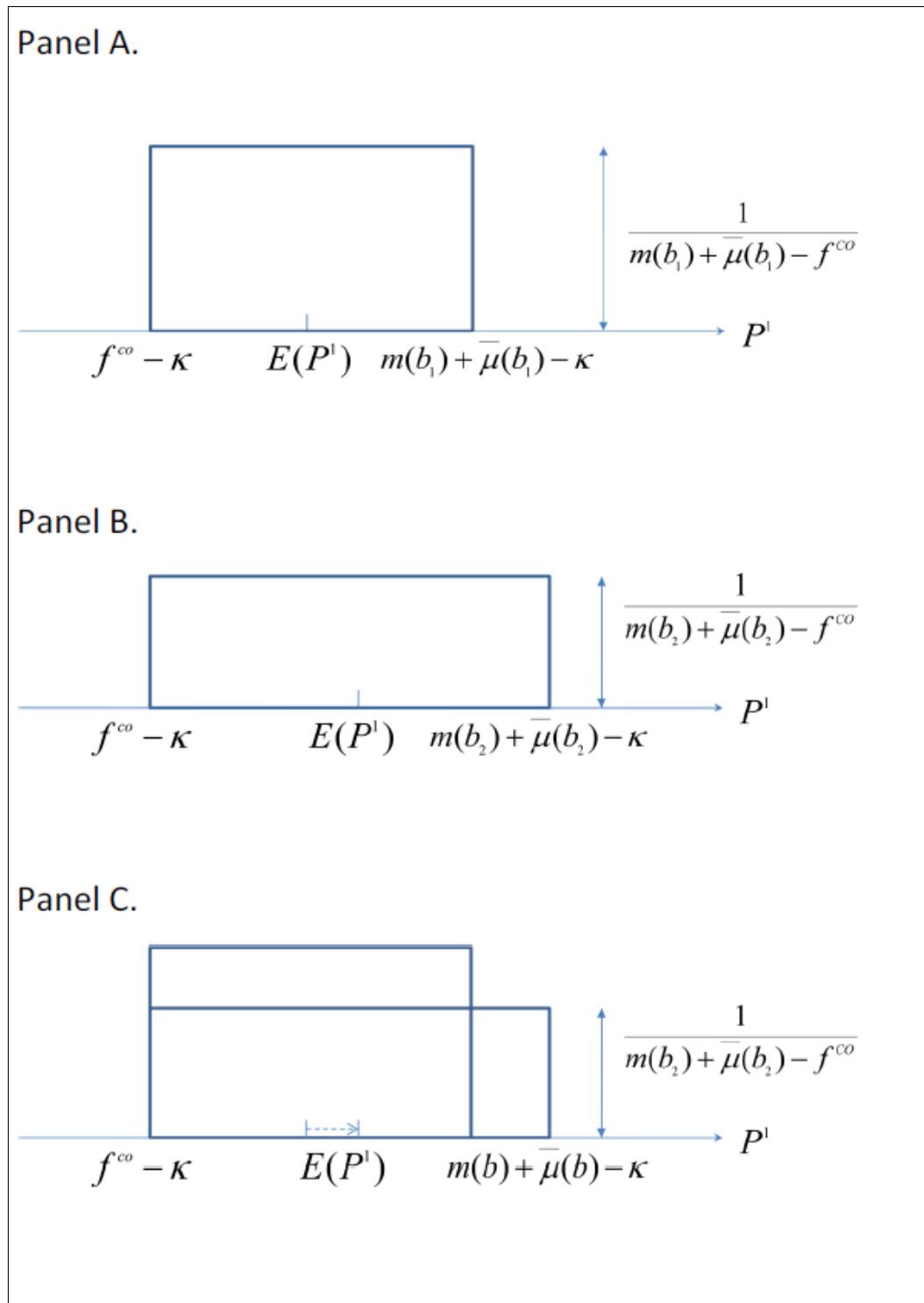
$$\hat{u}^V = \frac{2}{(1 - \Pi)} \frac{\beta}{(m'(b) + \Pi\tau)} \tag{3.25}$$

$$\cdot \left( 1 + \left( 1 - 4\beta\rho \frac{\left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)^{-1}$$

I will first analyze this stock bonus (where $\tau > 0$) in relation to the stock bonus where $\tau = 0$.

**Comparing stock bonus with $\tau = 0$ and $\tau > 0$**

Recall that the stock bonus  in Chapter 2 (when $\tau = 0$)  was

$$u^V = \frac{2}{(1 - \Pi)} \cdot \frac{\beta}{m'(b)} \cdot \left( 1 + \left( 1 - \frac{4\rho\beta\kappa}{m'(b)} \right)^{\frac{1}{2}} \right)^{-1} \tag{3.26}$$

If I set $\tau = 0$ in (3.25), then the stock bonus becomes the bonus $u^V$ from earlier, as in (3.26) when the manager can not influence investment risk. I find that an increase in $\tau$ may either increase or decrease the necessary bonus $\hat{u}^V$, and this indicates that the required bonus may be either higher or lower with $\tau > 0$ compared to $\tau = 0$. As discussed earlier, both expected

stock price and stock price variance increases with investment when $\tau > 0$. The agent has mean variance preferences, and these two factors move the necessary stock bonus in different directions. Which effect will dominate depends on the parameters in the model.

The simplest case is when the agent is risk neutral, $\rho = 0$. The only effect from $\tau > 0$ will be the option effect. The stock bonuses are:

$$\hat{u}^V \mid_{\rho=0} = \frac{1}{(1 - \Pi)} \cdot \frac{\beta}{(m'(b) + \Pi\tau)} \tag{3.27}$$

and

$$u^V \mid_{\rho=0} = \frac{1}{(1 - \Pi)} \cdot \frac{\beta}{m'(b)} \tag{3.28}$$

This implies that when $\rho = 0$, $\Pi > 0$ and $\tau > 0$:

$$\hat{u}^V \mid_{\rho=0} < u^V \mid_{\rho=0} \tag{3.29}$$

With risk neutral agent, the necessary stock bonus to achieve a given investment, is lower when $\tau > 0$ than when $\tau = 0$. When the agent is risk neutral, he cares only about the expected stock price (not the variance). When $\tau > 0$, an increase in investment increases the expected value of the disclosure stock price through an increase in the variance of the underlying investment (the option effect). This effect is not present when $\tau = 0$ and is an additional benefit by increasing investment when $\tau > 0$. This option effect increases expected stock price and the agent's compensation. This makes one unit of stock bonus more powerful when $\tau > 0$ than when $\tau = 0$. A lower stock bonus is needed to implement a given investment when $\tau > 0$ than when $\tau = 0$.

When $\rho > 0$, the stock bonuses in (3.25) and (3.26) are more complicated to compare. In the numerical example presented next, I show in Figure 3.5 that $\hat{u}^V < u^V$ holds for small, but positive, values of $\rho$.

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### 3.4.2 Numerical example: presentation

I next introduce a numerical example. It is the example from Chapter 2 with some modifications. I am not able to solve this model analytically, so I will use this example to analyze results when $\tau > 0$ in more detail in the rest of this chapter. The investment production function and cost of effort function are the same as before:

$$m(b) = 2b - \frac{1}{2}b^2 \tag{3.30}$$

$$e(a) = \frac{2}{5}a^2 \tag{3.31}$$

The disclosure cost is still $\kappa = 0.25$, the first period cash flow uncertainty is still measured at $\sigma^2 = 1.44$, but the parameter $\rho$ which measures the manager's risk aversion, is set lower, at $\rho = 0.2$. The investment risk is

$$\mu(b) = 1 + 1.75 \cdot b \tag{3.32}$$

which means that $\lambda = 1$ and $\tau = 1.75$ (see (3.5)).
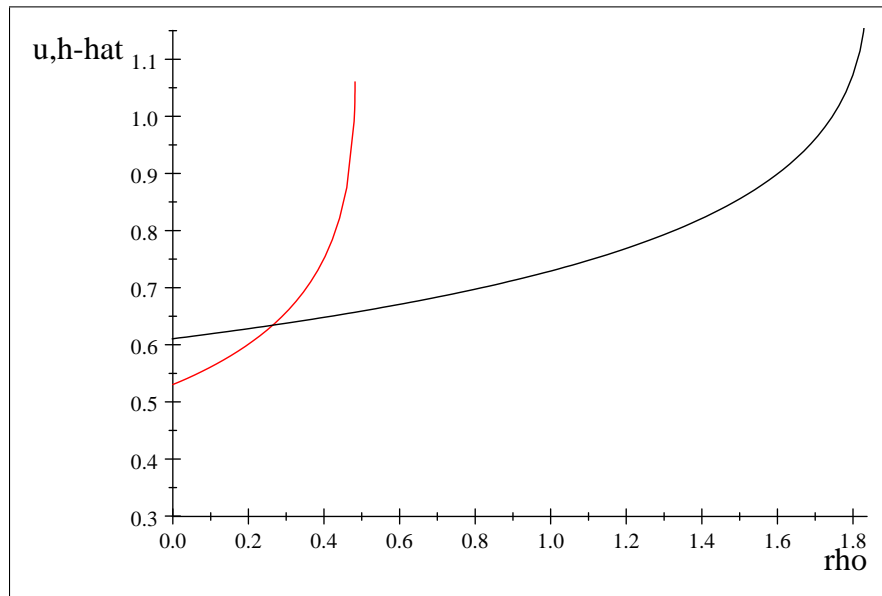


Figure 3.5. Voluntary disclosure. The relationship between $\rho$ and the required stock bonus to achieve an investment of $b = 0.75703$. The black line is with $\tau = 0$, and the red line is with $\tau = 1.75$.

Using these numerical values and fixing investment at $b = 0.75703$, I find that the maximum value that $\rho$ can have when the principal wants to induce $b$ is (I find this by requiring that the term in the "square root" in (3.25) has to be positive):

$$\rho^{\max} = \frac{(m'(b) + \Pi\tau)^2}{4\beta\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)} \tag{3.33}$$

When $\tau = 1.75$, this is

$$\rho^{\max} = 0.482 \tag{3.34}$$

When $\tau = 0$, I find that $\rho^{\max} = 1.84$. The two graphs in Figure 3.5 go towards these two values asymptotically.

Generally with $\tau > 0$, in addition to the option effect, more risk is imposed on the agent, and this will make him more reluctant to invest. This increases the necessary stock bonus. The stock bonus with $\tau > 0$ will reflect the sum of these two effects, and the bonus may be either higher or lower with $\tau > 0$ compared to $\tau = 0$.

### 3.4.3 The stock bonus with full disclosure

I first find the stock bonus with full disclosure with $\tau > 0$, and I compare the full disclosure stock bonus with risk effect and without risk effect; $\tau > 0$ and $\tau = 0$.

I denote by $\hat{u}^F$ the full disclosure stock bonus when $\tau > 0$ and keep the notation $u^F$ for the case when $\tau = 0$. The stock bonus with full disclosure is (see Appendix 3.A.5):

$$\hat{u}^F = 2 \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1} \tag{3.35}$$

**Comparing the full disclosure stock bonus with $\tau = 0$ and $\tau > 0$**

When $\tau = 0$, the full disclosure stock bonus is

$$u^F = \frac{\beta}{m'(b)} \tag{3.36}$$

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From comparing (3.35) and (3.36), I find that

$$\hat{u}^F \geq u^F \qquad\qquad (3.37)$$

With full disclosure, there is no kink in the compensation as with voluntary disclosure, and therefore no option effect. But with $\tau > 0$, there is the increase in risk from increasing investment (variance effect), and this makes the risk-averse manager more reluctant to invest. So when $\tau > 0$, the manager will require a higher stock bonus to invest a given amount than when $\tau = 0$.
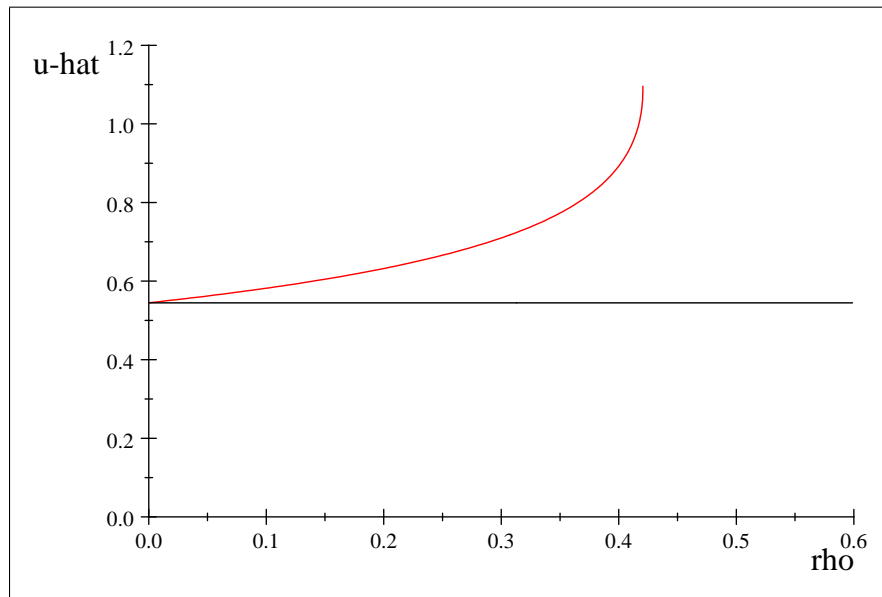


Figure 3.6. Full disclosure: The relationship between $\rho$ and the required stock bonus to achieve an investment of $b = 0.75703$. The black line is with $\tau = 0$, and the red line is with

$$\tau = 1.75.$$

I also find that the required stock bonus is monotonically increasing in $\tau$ and in $\rho$. The relationship between $\hat{u}^F$ and $\rho$ is illustrated in Figure 3.6. When $\tau = 0$, the required stock bonus is independent of $\rho$, but with $\tau > 0$, a higher $\rho$ implies a higher necessary stock bonus.

Figure 3.7 illustrates the relationship between stock bonus and the induced investment level with full disclosure. In contrast to the earlier case when $\tau$ was zero, the graph for full disclosure is now downward-sloping above some point. There is a maximum level of investment that it is possible to induce: $b^{F\max} = 1.0523$, where $\hat{u}^F = 1.39$.

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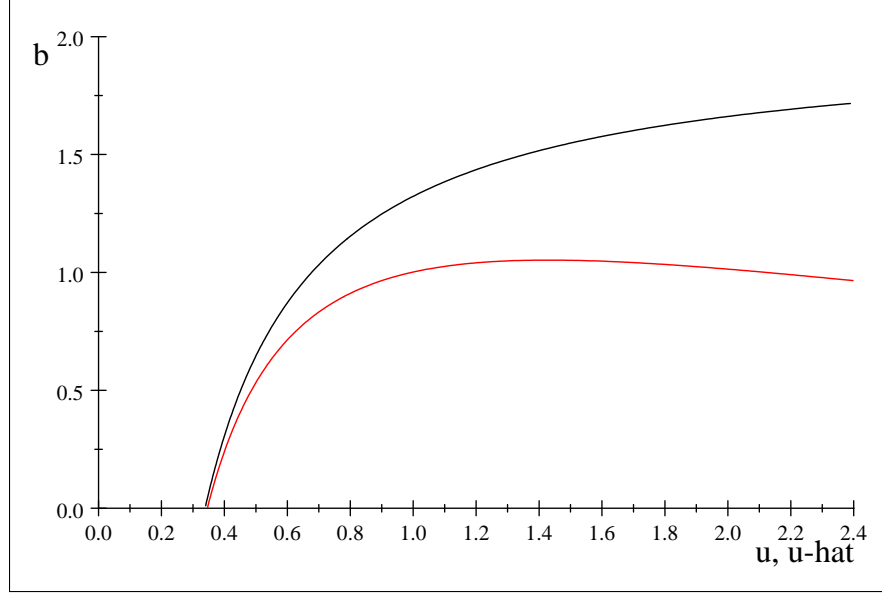


Figure 3.7. The relationship between stock bonus $u^F$ and investment $b$ with full disclosure.

$\rho = 0.2$. The black line is with $\tau = 0$, and the red line is with $\tau = 1.75$.

### 3.4.4 Comparing stock bonus with full disclosure and voluntary disclosure when $\tau > 0$

In this section I use the analysis above and compare the voluntary disclosure stock bonus with the full disclosure stock bonus.

I start with the simplest case where $\rho = 0$. I use (3.27) and (3.35) and find the stock bonuses with full disclosure and voluntary disclosure when $\rho = 0$,:

$$\hat{u}^F \mid_{\rho=0} = \frac{\beta}{m'(b)} \tag{3.38}$$

$$\hat{u}^V \mid_{\rho=0} = \frac{\beta}{(m'(b) + \Pi\tau)} \frac{1}{(1 - \Pi)} \tag{3.39}$$

I compare the two bonuses for $\rho = 0$ , and find that:

$$\hat{u}^V \mid_{\rho=0} < \hat{u}^F \mid_{\rho=0} \tag{3.40}$$

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when

$$\tau \cdot (1 - \Pi) > m'(b) \tag{3.41}$$

Recall that when $\tau = 0$, I found that $u^V > u^F$ always holds; the required stock bonus is always higher with voluntary disclosure than with full disclosure (also with $\rho = 0$). When $\tau > 0$, however, the required stock bonus may in some cases be lower with voluntary disclosure than with full disclosure. When $\rho = 0$, stock incentives are stronger with voluntary disclosure than with full disclosure ($\hat{u}^V < \hat{u}^F$) when the option effect from $\tau > 0$ is stronger than the negative effect from the signal not always being disclosed, $\Pi > 0$. When $\tau$ is high, or the probability of disclosure is high, the condition in (3.41) is easier to satisfy, consistent with this explanation.

When $\rho > 0$, the stock bonus may be either higher or lower with voluntary disclosure than with full disclosure, depending on the parameter values.
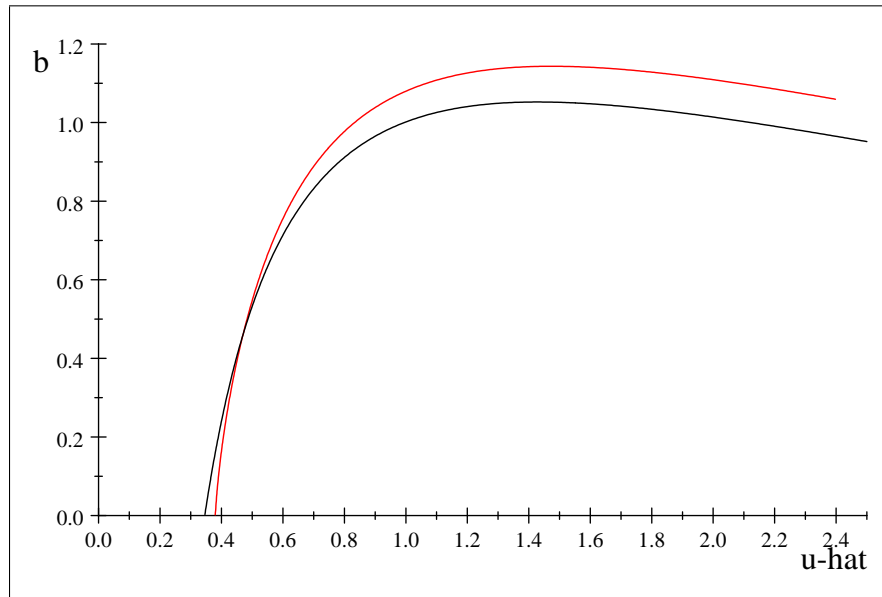


Figure 3.8. The relationship betwen stock bonus $\hat{u}$ and investment $b$. The black line is full disclosure and the red line is voluntary disclosure. The parameters are set at $\tau = 1.75$, $\lambda = 1, \rho = 0.2$.

Figure 3.8 shows the relationship between stock bonus $\hat{u}$ and investment level $b$, for full disclosure (black graph) and voluntary disclosure (red graph). For levels of investment higher than $b > 0.459$, a lower stock bonus is required with voluntary disclosure than with full disclosure. Stock bonus with voluntary disclosure is more powerful in inducing investment than with

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full disclosure.

In the example, the maximum value that it is possible for the principal to induce with voluntary disclosure, is given by $b^{V \max}$ :

$$b^{V \max} = 1.14 \tag{3.42}$$

This level of investment is induced with $\hat{u}^V = 1.44$, which is the maximum of the red graph in Figure 3.8. Recall that $b^{F \max}$ from page 136 is $b^{F \max} = 1.0523$. In this example it is possible to achieve a higher investment with voluntary disclosure than with full disclosure: $b^{V \max} > b^{F \max}$. The maximum investment is the level where the agent's marginal increase in expected income cannot dominate the marginal increase in the agent's risk premium.

With constant investment risk ($\tau = 0$), the agent did not influence his risk premium through investment in the full disclosure case. Now, however, an increase in investment increases investment risk, because $\tau > 0$ (see (3.5)), and $\frac{\partial Var P^F}{\partial b} > 0$ when $\tau > 0$ (see Appendix 3.A.5). An increase in investment also increases future investment payoff ($m'(b) > 0$). But above some level, the increase in risk premium dominates the increase in expected income for the agent.

Using the same numerical values as in Figure 3.8, I show in Figure 3.9 how the necessary stock bonus to achieve a given investment (set at $b = 0.757$) varies with $\tau$, for both voluntary and full disclosure. For values of $\tau$ higher than $\tau = 1.3799$ the necessary stock bonus is lower with voluntary disclosure than with full disclosure.

To sum up, in this section I study how the agent's incentives work when risk increases with investment, $\tau > 0$. I find that a marginal increase in investment increases both the expected stock price (the option effect) and the stock price risk (the variance effect) , and they both increase more when $\tau > 0$ than when $\tau = 0$. I find that the stock bonus may be more effective with voluntary disclosure compared to full disclosure, which is in contrast to the result when $\tau = 0$.
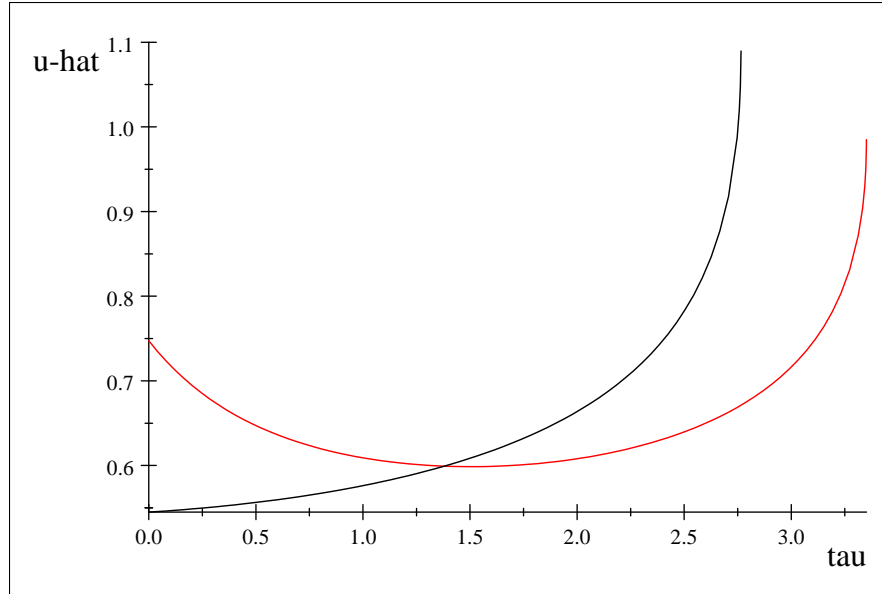
Figure 3.9. The relationship between $\tau$ and the required stock bonus to induce an investment of $b = 0.757033$. The black line is full disclosure and the red line is voluntary disclosure.

## 3.5 The principal's problem

In this section I show how the principal's maximization problem looks with voluntary and full disclosure. I start with the analytical model, but because of the complexity of the problem, I am not able to find the principal's optimal solution analytically. I will instead do a numerical analysis to illustrate some results. Numerically I compare the optimal solution for voluntary disclosure with the one for full disclosure.

### 3.5.1 The analytical setup

**Voluntary disclosure**

The principal's problem is to maximize his payoff from investment and effort, net of the expected disclosure cost and the manager's compensation, subject to the manager's participation and incentive constraints. This can be reduced to an unconstrained optimization problem where the principal maximizes net cash flows from investment and effort, minus of the agent's cost of effort, the company's disclosure cost, and the manager's risk premium.

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The principal chooses $a$ and $b$ to maximize $W^V$ :

$$W^V \equiv a - b + m(b) - e(a) - E(\kappa) - \frac{1}{2}\rho\beta^2\sigma^2 - RP(\hat{u}^V) \tag{3.43}$$

$$= a - b + m(b) - e(a) - (1 - \Pi(b))\kappa$$

$$- \frac{1}{2}\rho\left[\beta^2\sigma^2 + \hat{u}^{V2}(1 - \Pi(b))^3(\frac{1}{3} + \Pi(b))\overline{\mu}(b)^2\right]$$

where $RP(\hat{u}^V) = \frac{1}{2}\rho\left(\hat{u}^V\right)^2 VarP^V$, and $\hat{u}^V$ is given by (3.25), and $VarP^V$ is calculated in Appendix 3.A.1 and 3.A.6.

Ideally, I would find the solution by differentiating $W^V$ with respect to $a$ and $b$ and setting equal to zero. Generally, the first order condition for investment is:

$$\frac{\partial W^V}{\partial b} = -1 + m'(b) - \kappa\frac{\partial(1 - \Pi(b))}{\partial b} - \frac{\partial RP(\hat{u}^V)}{\partial b} = 0 \tag{3.44}$$

How will a marginal increase in investment $b$ influence the principal's payoff? First, there is the effect on cash flows, which gives a net increase of $(-1 + m'(b))$. But in contrast to the case with constant risk, a higher investment level now increases the probability of disclosure:

$$\frac{\partial(1 - \Pi(b))}{\partial b} = -\frac{\partial\Pi(b)}{\partial b} = -\frac{\partial\frac{\kappa}{\overline{\mu}(b)}}{\partial b} = \frac{\kappa \cdot \tau}{\overline{\mu}(b)^2} > 0 \tag{3.45}$$

where $\Pi(b)$ is taken from the equilibrium value in (3.22): $\Pi(b) = \frac{\kappa}{\overline{\mu}(b)}$. Higher investment means higher investment risk, and higher investment risk (relative to the disclosure cost) means a higher probability of disclosure. Because the probability of disclosure increases with investment, the principal's expected disclosure cost, $(1 - \Pi(b))\kappa$, also increases with investment:

$$\frac{\partial(1 - \Pi(b))\kappa}{\partial b} = -\kappa\frac{\partial\Pi(b)}{\partial b} = -\kappa\frac{\partial\frac{\kappa}{\overline{\mu}(b)}}{\partial b} = \frac{\kappa\tau^2}{\overline{\mu}(b)^2} > 0 \tag{3.46}$$

If the principal wants to induce the manager to invest more, this has the cost of increasing the expected disclosure cost. This reduces the optimal investment level.

The term $\frac{\partial RP(\hat{u}^V)}{\partial b}$ would be calculated as:

$$\frac{\partial RP^V(\hat{u}^V)}{\partial b} = \frac{1}{2}\rho\left(2 \cdot \hat{u}^V \cdot \frac{\partial\hat{u}^V}{\partial b} \cdot VarP^V + \left(\hat{u}^V\right)^2 \cdot \frac{\partial VarP^V}{\partial b}\right) \tag{3.47}$$

In general, it is too complicated to find $\frac{\partial RP(\hat{u}^V)}{\partial b}$. When $\tau > 0$, the calculations for $\frac{\partial \hat{u}^V}{\partial b}$ and $\frac{\partial VarP^V}{\partial b}$ get more complicated than when $\tau = 0$. I therefore study the principal's problem in a numerical analysis later.

**Full disclosure**

With full disclosure, the principal maximizes $W^F$, given by:

$$W^F = a - b + m(b) - e(a) - \kappa - \rho\frac{1}{2}\beta^2\sigma^2 - RP(\hat{u}^F)$$

$$= a - b + m(b) - e(a) - \kappa - \frac{1}{2}\rho\left(\beta^2\sigma^2 + \left(2 \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1}\right)^2 \cdot \frac{1}{3}(\lambda + \tau b)^2\right)$$

$$(3.48)$$

I have used $\hat{u}^F$ from (3.35) and $VarP^F = Var(\mu)$ from (3.6).

Generally, the first order condition for investment is:

$$\frac{\partial W^F}{\partial b} = -1 + m'(b) - \frac{\partial RP^F(\hat{u}^F)}{\partial b} = 0 \tag{3.49}$$

which gives

$$-1 + m'(b) - \frac{1}{2}\rho\left(2 \cdot \hat{u}^F \cdot \frac{\partial \hat{u}^F}{\partial b} \cdot VarP^F + \left(\hat{u}^F\right)^2 \cdot \frac{\partial VarP^F}{\partial b}\right) = 0 \tag{3.50}$$

I will study the principal's problem further, for both voluntary and full disclosure, in the numerical example.

### 3.5.2  Numerical analysis

I use the example in the numerical analysis to study the optimal solution. I use Solver in Excel to find the optimal parameters. I will first characterize the first best solution and the two possible corner solutions.

The first best level of investment and effort are the levels that maximize

$$a - b + m(b) - e(a) \tag{3.51}$$

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When I substitue for the functions, I get

$$a - b + \left(2b - \frac{1}{2}b^2\right) - \frac{2}{5}a^2 \tag{3.52}$$

The first best solution is characterized by:

$$a^{FB} = 1.25 \tag{3.53}$$

$$b^{FB} = 1 \tag{3.54}$$

$$W^{FB} = 1.125 \tag{3.55}$$

There are two possible corner solutions (see Case 1 and 2 in Chapter 2). One possible corner solution (Case 1) is to set $b = 0, a > 0, \hat{u}^V = 0, \beta > 0$, where the effort level is the one that maximizes:

$$a - \frac{2}{5}a^2 - \frac{1}{2}\rho\beta^2\sigma^2 \tag{3.56}$$

s.t.

$$\beta = e'(a) \tag{3.57}$$

The unconstrained problem in the example is to maximize:

$$a - \frac{2}{5}a^2 - \frac{1}{2} \cdot 0.2 \cdot \left(\frac{4}{5}a\right)1.44 \tag{3.58}$$

The solution is to set $a = 1.02$ and $\beta = 0.81$. This gives an expected payoff of $W = 0.508$.

The other corner solution (Case 2) is characterized by $b = b^{FB}, \hat{u}^V = 0, a = 0, \beta = 0$. The principal's expected payoff is:

$$W = -b^{FB} + \left(2b^{FB} - \frac{1}{2}\left(b^{FB}\right)^2\right) = 0.5 \tag{3.59}$$

This is lower than the first corner solution and the principal will therefore prefer the first of the two corner solutions, Case 1. However, an interior solution gives even higher expected payoffs.

**Results**

Table 3.1 presents the optimal solution to the principal's problem for both voluntary and full disclosure. The fixed component of compensation is $\alpha = -0.25029$ with voluntary disclosure and the optimal contract looks like this

$$s = -0.25029 + 0.67729 \cdot c_1 + 0.60088 \cdot P \tag{3.60}$$

With this contract, the agent's certainty equivalent as a function of investment $b$ is shown in Figure 3.10. It is concave and reaches its maximum value of zero at $b = 0.75703$.
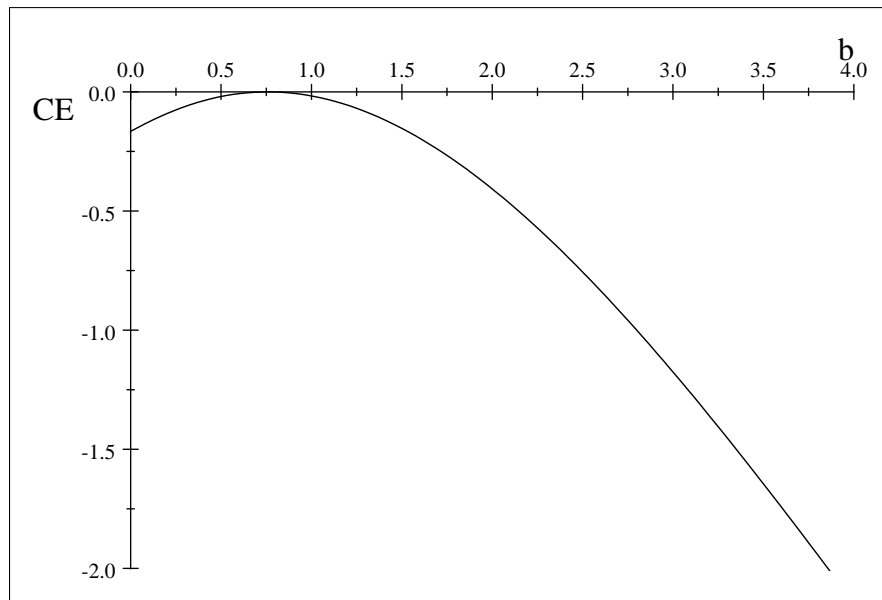


Figure 3.10. The agent's certainty equivalent CE as a function of investment level $b$.

I will now compare the optimal solution with full disclosure and voluntary disclosure in Table 3.1. With voluntary disclosure the probability of disclosure is 89%. In this example, both the optimal effort level and investment level are higher with voluntary disclosure than with full disclosure. A higher effort level with voluntary disclosure requires a higher stock bonus, but a higher investment level requires a *lower* stock bonus with voluntary disclosure ($\hat{u}^V = 0.60088$ compared to $\hat{u}^F = 0.60653$). Going back to Figure 3.8, it is clear that with an  investment level of $b = 0.75703$, the necessary stock bonus is lower with voluntary disclosure than full disclosure. Table 3.1 shows that even when $b^F$ is lower than $b^V$, a lower stock bonus is needed to induce a higher investment level in the voluntary disclosure case than with full disclosure.

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| | F | V | Difference (V-F) |
|---|---|---|---|
| a | 0.82865 | 0.84661 | 0.01796 |
| b | 0.74412 | 0.75703 | 0.01291 |
| $\beta$ | 0.66292 | 0.67729 | 0.01509 |
| û | 0.60653 | 0.60088 | -0.0065 |
| Principal's expected wealth | 0.64297 | 0.68007 | 0.03773 |
| Prob. of disclosure | 1 | 0.89 | -0.11 |
| Var (P) | 1.76673 | 1.69378 | -0.07295 |

Table 3.1. Voluntary (V) and Full (F) disclosure. Optimal solution and optimal parameters.

The principal's expected wealth is higher with voluntary disclosure than with full disclosure, and the stock price variance is lower with voluntary disclosure. I decompose the elements in the principal's expected wealth in Table 3.2.

| | F | V | Difference (V-F) |
|---|---|---|---|
| Principal's expected wealth | 0.64297 | 0.68007 | 0.03710 |
| Expected discl.cost | 0.25 | 0.22312 | -0.02688 |
| Cash flow from effort | 0.55399 | 0.55991 | 0.00593 |
| Cash flow from investment | 0.46726 | 0.47048 | 0.00322 |
| Risk premium | 0.12828 | 0.12721 | -0.00107 |
| | | | |

Table 3.2. The principal's expected wealth, and the components of expected wealth with voluntary (V) and full (F) disclosure.

Since effort and investment are higher with voluntary disclosure than full disclosure, the cash flows from these are also higher. The expected disclosure cost is of course lower with

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| | F | V | Difference (V-F) |
|---|---|---|---|
| Risk premium | 0.12828 | 0.12721 | -0.00107 |
| *cash bonus RP | 0.06328 | 0.06606 | 0.00276 |
| *stock bonus RP | 0.06500 | 0.06116 | -0.00383 |

Table 3.3. Decomposing the risk premium (RP) into two parts; risk premium from cash bonus and risk premium from stock bonus.

voluntary disclosure.

The risk premium is lower with voluntary disclosure than with full disclosure. In Table 3.3 I decompose the risk premium into two parts, risk premium from cash flow bonus (which induces effort), $RP(\beta)$, and from stock bonus (which induces investment), $RP(\hat{u})$. Since optimal effort is higher with voluntary disclosure, the resulting $RP(\beta)$ is also higher. However, since a lower stock bonus is needed to induce investment, the risk premium from stock bonus is lower. This means that it is cheaper for the principal to induce investment with voluntary disclosure than full disclosure. So even if I disregard the savings in the disclosure cost, the principal is better off with voluntary disclosure than with full disclosure.

**Comparing results for different levels of $\tau$**

The term $\tau$ is a measure of investment risk. When $\tau$ increases, the boundaries of the uniform distribution widens, and variance increases. I show the results for different values of $\tau$ in Table 3.4. I start with $\tau = 0$, which is the constant risk case. I then set $\tau = 0.5$. From $\tau = 0.75$ to $\tau = 1$, I use increments of 0.05, while for $\tau = 1$ to 2.5, I use increments of 0.25. Generally, when $\tau$ increases, the principal's expected payoff is decreasing. An increase in $\tau$ means an increase in investment risk, and the agent's risk premium increases. This is also why optimal investment decreases in $\tau$. Even though investment decreases, the stock price variance $VarP$ increases. This is because $Var(\mu)$ increases when $\tau$ increases, and for voluntary disclosure also because the probability of disclosure increases. The stock bonus $u$ decreases for both full and voluntary

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disclosure. One reason is the decline in induced investment, which requires a lower stock bonus. In addition, with voluntary disclosure there is the increase in the probability of disclosure and the option effect discussed earlier, which make the stock bonus more powerful and reduce the required stock bonus further. The stock price risk premium $RP(\hat{u}^V)$ is determined by risk aversion, stock bonus and $VarP$. While stock bonus goes down, stock price variance increases and the effect of this increase dominates, so the stock price risk premium increases with $\tau$. I also calculate the principal's net payoff disregarding the disclosure cost, $W^V + E(\kappa)$ and $W^F + \kappa$. These also decrease with $\tau$ because of the increased risk.

I will now compare the optimal solutions for full disclosure and voluntary disclosure for different values of $\tau$. For all the $\tau$-values in the table, the principal's payoff is higher with voluntary disclosure than with full disclosure. The table also shows that for values of $\tau$ weakly higher than $\tau = 1.25$ the optimal investment level is higher with voluntary disclosure than with full disclosure. This occurs when the sum

$$-\kappa \frac{\partial (1 - \Pi(b))}{\partial b} - \frac{\partial RP^V(\hat{u}^V)}{\partial b} \tag{3.61}$$

from (3.44) has higher value (smaller absolute value) than

$$-\frac{\partial RP^F(\hat{u}^F)}{\partial b} \tag{3.62}$$

from (3.49) and (3.50). This means that

$$\frac{\partial RP^V(\hat{u}^V)}{\partial b} < \frac{\partial RP^F(\hat{u}^F)}{\partial b} \tag{3.63}$$

must hold when the optimal $b^V > b^F$, as is the case when $\tau \geq 1.25$.

I show in Appendix 3.A.6 that $VarP^V \leq VarP^F$, but this only holds when keeping investment $b$ constant. Table 4 shows that $VarP^V \leq VarP^F$ for optimal $b$ for values of $\tau \leq 2.25$. For $\tau = 2.5$ stock price variance is higher with voluntary disclosure than with full disclosure. One reason is that the probability of disclosure increases as $\tau$ increases, so the reduction in stock price variance coming from the no-disclosure states, diminishes. The second reason is that for high $\tau$, the investment is higher with voluntary disclosure than full disclosure, and with higher

investment, the investment risk is higher.

The optimal stock bonus is lower with voluntary disclosure than with full disclosure when $\tau \geq 1.75$. This happens even though investment is higher with voluntary disclosure in these cases. Recall from Figure 3.9 that for some values of $\tau$, a lower stock bonus is needed with voluntary disclosure than full disclosure, and the values where $\hat{u}^V < \hat{u}^F$ in Table 4 is within this range (even if the investment level varies in Table 4, but is constant at $b = 0.7570$ in Figure 3.9).

Lastly, I note that the principal's expected wealth gross of the disclosure cost, is higher with voluntary disclosure than with full disclosure when $\tau \geq 1$ in Table 3.4.

The graphs in Figure 3.11 show how the investment $b$ and the gross payoff decline as $\tau$ increases, for both voluntary and full disclosure. Initially, for small $\tau$, investment and gross payoff are lower with voluntary disclosure. For higher values of $\tau$, gross payoff and investment are higher with voluntary disclosure than with full disclosure. The values of $\tau$ where the two lines cross, however, are different for $b$ and $W$. Optimal investment $b$ is determined by the derivatives $\frac{\partial(1-\Pi(b))\kappa}{\partial b}$ and $\frac{\partial RP^V(\hat{u}^V)}{\partial b}$, but the principal's expected payoff depends on the values of $RP^V(\hat{u}^V)$ and $(1-\Pi(b))\kappa$. But these are of course closely related.

| τ | $W^V$ | $W^F$ | $b^V$ | $b^F$ | $a^V$ | $a^F$ | $varP^V$ | $varP^F$ | $û^V$ | $û^F$ | $RP(û)^V$ | $RP(û)^F$ | $W^V+E(κ)$ | $W^F+κ$ | Pr.discl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0,7924 | 0,7376 | 0,9499 | 0,9635 | 0,9602 | 0,9765 | 0,246 | 0,333 | 1,014 | 0,754 | 0,025 | 0,019 | 0,9799 | 0,9876 | 0,7500 |
| 0,5 | 0,7537 | 0,7153 | 0,8895 | 0,9062 | 0,9285 | 0,9370 | 0,598 | 0,704 | 0,794 | 0,708 | 0,038 | 0,035 | 0,9604 | 0,9653 | 0,8270 |
| 0,75 | 0,7377 | 0,7022 | 0,8623 | 0,8754 | 0,9120 | 0,9151 | 0,803 | 0,915 | 0,736 | 0,686 | 0,043 | 0,043 | 0,9497 | 0,9522 | 0,8482 |
| 0,8 | 0,7346 | 0,6995 | 0,8570 | 0,8677 | 0,9084 | 0,9111 | 0,845 | 0,957 | 0,726 | 0,681 | 0,045 | 0,044 | 0,9475 | 0,9495 | 0,8517 |
| 0,85 | 0,7315 | 0,6967 | 0,8516 | 0,8612 | 0,9050 | 0,9068 | 0,885 | 1,000 | 0,717 | 0,676 | 0,046 | 0,046 | 0,9453 | 0,9467 | 0,8550 |
| 0,9 | 0,7285 | 0,6939 | 0,8463 | 0,8546 | 0,9016 | 0,9023 | 0,932 | 1,043 | 0,708 | 0,672 | 0,047 | 0,047 | 0,9430 | 0,9439 | 0,8581 |
| 0,95 | 0,7255 | 0,6911 | 0,8410 | 0,8481 | 0,8983 | 0,8979 | 0,976 | 1,087 | 0,700 | 0,668 | 0,048 | 0,048 | 0,9408 | 0,9411 | 0,8610 |
| 1 | 0,7225 | 0,6882 | 0,8356 | 0,8415 | 0,8949 | 0,8935 | 1,020 | 1,130 | 0,692 | 0,664 | 0,049 | 0,050 | 0,9385 | 0,9382 | 0,8638 |
| 1,25 | 0,7080 | 0,6736 | 0,8091 | 0,8086 | 0,8784 | 0,8715 | 1,243 | 1,348 | 0,656 | 0,643 | 0,053 | 0,056 | 0,9269 | 0,9236 | 0,8757 |
| 1,5 | 0,6939 | 0,6585 | 0,7829 | 0,7761 | 0,8622 | 0,8498 | 1,469 | 1,561 | 0,626 | 0,624 | 0,058 | 0,061 | 0,9152 | 0,9085 | 0,8850 |
| 1,75 | 0,6801 | 0,6430 | 0,7570 | 0,7441 | 0,8466 | 0,8287 | 1,694 | 1,767 | 0,601 | 0,607 | 0,061 | 0,065 | 0,9032 | 0,8930 | 0,8925 |
| 2 | 0,6665 | 0,6273 | 0,7316 | 0,7130 | 0,8318 | 0,8082 | 1,914 | 1,962 | 0,579 | 0,590 | 0,064 | 0,068 | 0,8912 | 0,8773 | 0,8985 |
| 2,25 | 0,6533 | 0,6115 | 0,7066 | 0,6828 | 0,8178 | 0,7886 | 2,126 | 2,144 | 0,559 | 0,574 | 0,066 | 0,071 | 0,8791 | 0,8615 | 0,9035 |
| 2,5 | 0,6403 | 0,5958 | 0,6822 | 0,6536 | 0,8047 | 0,7699 | 2,330 | 2,313 | 0,542 | 0,560 | 0,068 | 0,072 | 0,8672 | 0,8458 | 0,9076 |

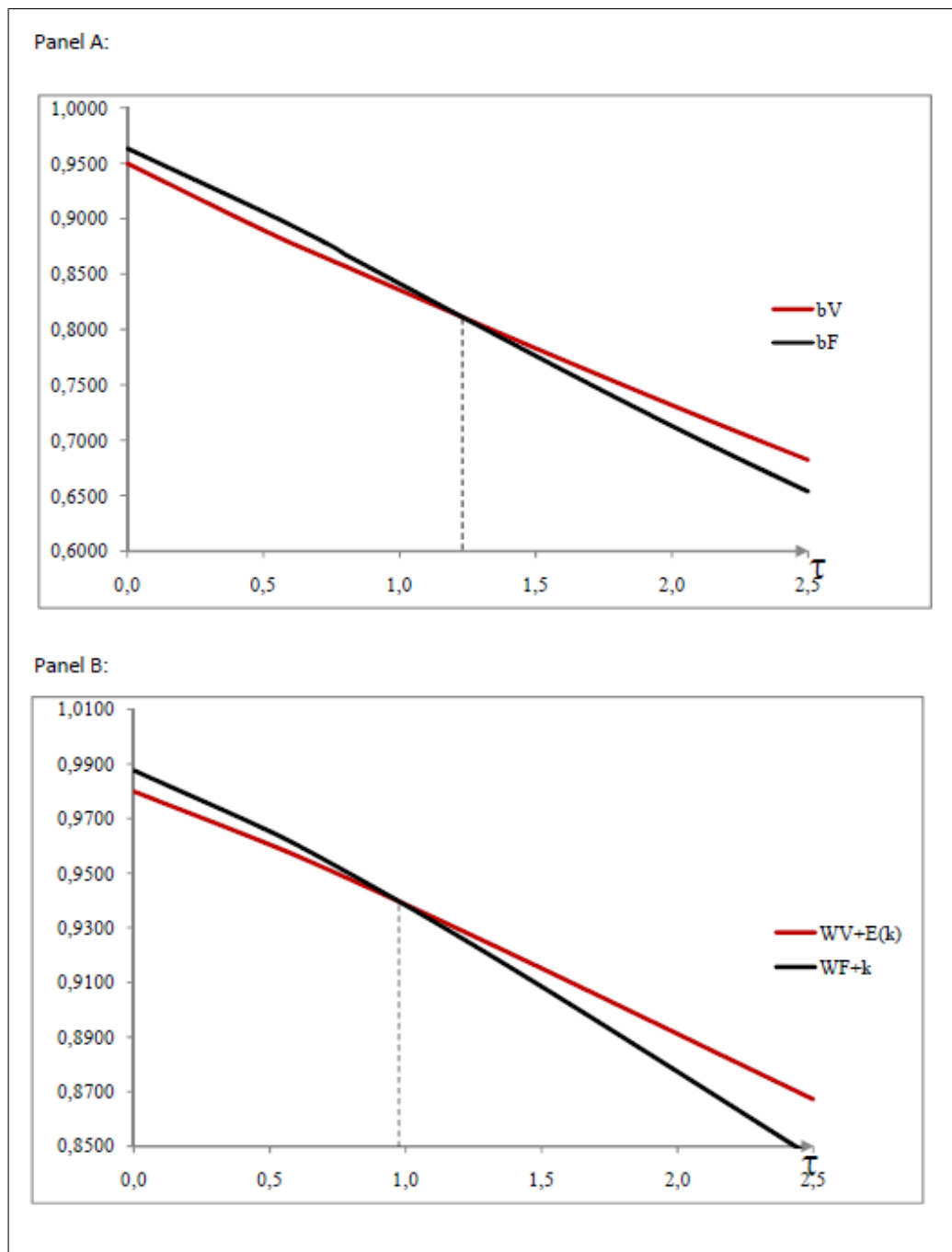Table 3.4. Effects of an increase in the risk parameter τ.

Panel A:

Panel B:

Figure 3.11. Optimal investment (Panel A) and the principal's expected payoff, disregarding the disclosure cost (Panel B), as functions of $\tau$. Red graphs are voluntary disclosure and black graphs are full disclosure.

### 3.5.3 Discussion

The results of this chapter can be compared to the results in Feltham and Wu (2001). Feltham and Wu (FW) study the effectiveness of options vs stock as incentives to induce managerial effort. The second part of their paper focuses on the case where the manager's effort increases firm risk, which is analogous to this chapter where investment increases risk. With options, the manager's compensation is piecewise linear, just as the case is in my model with voluntary disclosure. In FW, there is limited liability, so when the manager is rewarded in stock, there is a limit ($= 0$) to how low the value of the stock can be. Even with stock compensation, the manager's compensation in their case is piecewise linear, but with a lower strike price ($= 0$) than with options (where the strike price is larger than zero). I do not consider limited liability in my model, so with full disclosure, the manager's compensation is linear. I still find it useful to compare my voluntary disclosure model to the option model in FW.

FW study how the principal optimally chooses the strike price. That means that if the optimal strike price is zero, stock compensation is optimal, and when optimal strike price is higher than zero, option compensation is optimal. When the manager influences risk, solving their model becomes analytically intractable, so they compare the special cases of stock compensation and at-the-money options (based on expected payoff with conjectured effort level).

FW find that a high risk parameter (parallell to $\tau$ in my model) makes at-the-money options more effective than stock in inducing effort. Going back to my model and the example, optimal investment is higher with voluntary disclosure than with full disclosure if the risk parameter $\tau$ is above a cut-off, see Panel A of Figure 3.11. Similar to this, in FW there is a cut-off of the risk parameter where optimal effort is higher with at-the-money options than with stock when the risk parameter is above the cut-off. In Panel B in Figure 3.11, the graphs show the principal in my model is better off with voluntary disclosure than with full disclosure when $\tau$ is above a (different) cut-off. In FW, the principal is better of with (at-the-money) option compensation than with stock compensation when the risk parameter is above a given value.

With options the kink in compensation is given by the strike price, which is directly set by the principal. In my model, however, the kink is given by the cut-off $f^{CO}$, see (3.16). This value is set in an equilibrium, and is not set by the principal. Instead, it depends on the disclosure cost, uncertainty, and conjectured investment level (which is indirectly influenced by the stock

bonus $\hat{u}^V$, which is chosen by the principal). So while the cut-off is directly set in FW, it is not in my model. Another difference between the models, is that in my model, there is a (dead-weight) cost of ending up in the risky (kinked) part of the compensation; the disclosure cost. The manager influences the probability of ending up in the disclosure region when he chooses investment, as higher investment increases the probability of disclosure and therefore the expected disclosure cost. The principal must bear this cost in case of disclosure, and this reduces her net payoffs from increased investment. This reduces optimal investment. There is no parallell to this in the FW model, since there is no such cost with options.

The chapter is also related to Lambert and Larcker (2004) and Flor et al.(2011). Lambert and Larker (2004) show that when limited liability is a binding constraint, options or convex piece-wise linear contracts are optimal. This holds when the manager only influences the mean of output distribution. Allowing for the manager to also influence variance gives an additional reason for convexity in the contract. Flor et al. (2011) derive optimal contracts when the manager influences both the mean and variance of output. When restricting the contract to be non-decreasing in output (if for instance the agent can destroy ouput), the optimal contract is closely related to an option contract. Restricting the contract further, to be piece-wise linear, does not cost much in their model. All these three papers give theoretical arguments for using options in contracting. These are piece-wise linear and convex, as the voluntary disclosure compensation is in my model.

Armstrong, Larcker and Su (2007) and Dittmann and Yu (2009) use calibrations with real compensation data to analyze the optimality of options. In their models, the manager's actions influence both the mean and the variance of the stock price. When restricting the compensation to be a linear combination of fixed salary, stock and options, both papers find that their data support the optimality of options. Their models predict that managers should receive relatively large amounts of options. Therefore, convexity is part of the optimal contracts.

## 3.6   Conclusion

In this chapter I study how a manager's voluntary disclosure decision changes his investment incentives when he can influence investment risk. I find that in some cases the necessary stock

bonus is lower in this case compared to the case where investment risk is constant. In some cases, the necessary stock bonus is also lower with voluntary disclosure than with full disclosure. I find that the principal in some settings are better off with voluntary disclosure than with full disclosure, and that the optimal investment level can be higher with voluntary disclosure than with full disclosure. The policy implication of this is that it can be better to leave the disclosure decision to the manager instead of imposing full disclosure regulation.

## 3.A    Appendix to Chapter 3

### 3.A.1    The agent's certainty equivalent

In order to find the agent's certainty equivalent when $\tau > 0$, I use the calculations from $\tau = 0$ and replace $\overline{\mu}$ with $\overline{\mu}(b)$ when $\overline{\mu}$ reflects the agent's decision, and with $\overline{\mu}(\hat{b})$ when it reflects the market's expectations. The main differences are shown below:

- The conditional stock price variance

$$var(P^1 \mid f \geq f^{CO}) \tag{3.64}$$

$$= var(f \mid f \geq f^{CO})$$

$$= \frac{1}{12}(m(b) + \overline{\mu}(b) - f^{CO})^2$$

$$= \frac{1}{12}\left(m(b) + \overline{\mu}(b) - m(\hat{b}) + \overline{\mu}(\hat{b}) - 2\kappa\right) \tag{3.65}$$

$$= \frac{1}{12}(m(b) - m(\hat{b}) + \overline{\mu}(b) + \overline{\mu}(\hat{b}) - 2\kappa)^2$$

- The unconditional mean of the stock price is:

$$E_0(P) = E\left[E(P \mid f)\right]$$

$$= (1 - \Pi(f^{CO})) \cdot E(P \mid f \geq f^{CO})$$

$$+ \Pi(f^{CO}) \cdot E(P \mid f < f^{CO})$$

$$= (1 - \Pi(f^{CO})) \cdot \left(\frac{1}{2}(m(b) + m(\hat{b}) + \overline{\mu}(b) - \overline{\mu}(\hat{b}))\right)$$

$$+ \Pi(f^{CO}) \cdot \left(m(\hat{b}) - \overline{\mu}(\hat{b}) + \kappa\right) \tag{3.66}$$

- The unconditional variance:

$$Var_0(P) = E\left[var(P \mid f)\right] + var\left[E(P \mid f)\right] \tag{3.67}$$

$$= (1 - \Pi(f^{CO})) \cdot \frac{1}{12}(m(b) - m(\hat{b}) + \overline{\mu}(b) + \overline{\mu}(\hat{b}) - 2\kappa)^2$$

$$\frac{1}{4}\left[\Pi(f^{CO}) - \Pi^2(f^{CO})\right] \cdot \left(m(b) - m(\hat{b}) + \overline{\mu}(b) + \overline{\mu}(\hat{b}) - 2\kappa\right)^2$$

$$= \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (m(b) - m(\hat{b}) + \overline{\mu}(b) + \overline{\mu}(\hat{b}) - 2\kappa)^2$$

- The agent's certainty equivalent is:

$$CE_0 = \alpha + \beta(a - b) - e(a) - \frac{1}{2}\rho\beta^2\sigma^2 \tag{3.68}$$

$$+ \hat{u} \cdot \begin{pmatrix} (1 - \Pi(f^{CO})) \cdot \left(\frac{1}{2}(m(b) + m(\hat{b}) + \overline{\mu}(b) - \overline{\mu}(\hat{b}))\right) \\ \\ +\Pi(f^{CO}) \cdot \left(m(\hat{b}) - \overline{\mu}(\hat{b}) + \kappa\right) \end{pmatrix}$$

$$- \frac{1}{2}\rho\hat{u}^2 \cdot \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (m(b) - m(\hat{b}) + \overline{\mu}(b) + \overline{\mu}(\hat{b}) - 2\kappa)^2$$

## 3.A.2   The agent's first order condition:

I find the agent's first order condition for investment by differentiating the components of the certainty equivalent with respect to $b$.

$$\frac{\partial\Pi}{\partial b} = \frac{(-m'(b) + \tau) \cdot 2\overline{\mu}(b) - \left(m(\hat{b}) - m(b) - \overline{\mu}(\hat{b}) + \mu(b) + 2\kappa\right) \cdot 2\tau}{(2\overline{\mu}(b))^2} \tag{3.69}$$

$$= \frac{-2\overline{\mu}(b) \cdot m'(b) + \left(2\overline{\mu}(b) - 2\left(m(\hat{b}) - m(b) - \overline{\mu}(\hat{b}) + \mu(b) + 2\kappa\right)\right) \cdot \tau}{(2\overline{\mu}(b))^2}$$

$$= -\frac{m'(b)}{2\overline{\mu}(b)} - \frac{m(\hat{b}) - m(b) - \overline{\mu}(\hat{b}) + 2\kappa}{2\overline{\mu}^2(b)} \cdot \tau$$

$$\frac{\partial E_0(P)}{\partial b} = -\frac{\partial \Pi}{\partial b} \cdot \frac{1}{2} \left( m(b) + m(\hat{b}) + \overline{\mu}(b) - \overline{\mu}(\hat{b}) \right) + (1 - \Pi(f^{CO})) \cdot \frac{1}{2} \left( m'(b) + \tau \right) \quad (3.70)$$
$$+ \frac{\partial \Pi}{\partial b} \left( m(\hat{b}) + \kappa - \overline{\mu}(\hat{b}) \right)$$

$$\frac{\partial Var_0(P)}{\partial b} = \left( \frac{1}{4} \left( -\frac{\partial \Pi}{\partial b} \right) (\frac{1}{3} + \Pi(f^{CO})) + \frac{1}{4}(1 - \Pi(f^{CO})) \frac{\partial \Pi}{\partial b} \right) \cdot (m(b) - m(\hat{b}) + \overline{\mu}(\hat{b}) + \overline{\mu}(b) - 2\kappa)^2$$
$$(3.71)$$
$$+ \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot 2(m(b) - m(\hat{b}) + \overline{\mu}(\hat{b}) + \overline{\mu}(b) - 2\kappa) \left( m'(b) + \tau \right)$$

In equilibrium, with $\hat{b} = b$ these expressions simplify to:

$$\Pi(f^{CO}) = \frac{\kappa}{\overline{\mu}(b)} \quad (3.72)$$

$$\frac{\partial \Pi}{\partial b} = -\frac{m'(b)}{2\overline{\mu}(b)} - \frac{-\overline{\mu}(\hat{b}) + 2\kappa}{2\overline{\mu}(b)} \cdot \frac{\tau}{\overline{\mu}(b)} = -\left( \frac{m'(b)}{2\overline{\mu}(b)} + \left( \Pi - \frac{1}{2} \right) \cdot \frac{\tau}{\overline{\mu}(b)} \right) \quad (3.73)$$

$$\frac{\partial E_0(P)}{\partial b} = (1 - \Pi) \cdot \frac{1}{2} \left( m'(b) + \tau \right) \quad (3.74)$$
$$+ \left( \frac{m'(b)}{2\overline{\mu}(b)} + \left( \Pi - \frac{1}{2} \right) \cdot \frac{\tau}{\overline{\mu}(b)} \right) \left( \frac{1}{2} \left( m'(b) + \tau \right) \overline{\mu}(b) - \kappa \right)$$
$$= (1 - \Pi) \cdot$$
$$+ \left( \frac{m'(b)}{2\overline{\mu}(b)} + \left( \Pi - \frac{1}{2} \right) \cdot \frac{\tau}{\overline{\mu}(b)} \right) \overline{\mu}(b)(1 - \Pi)$$
$$= (1 - \Pi) \cdot \frac{1}{2} \left( m'(b) + \tau \right)$$
$$+ \left( \frac{m'(b)}{2} + \left( \Pi - \frac{1}{2} \right) \cdot \tau \right) (1 - \Pi)$$
$$= (1 - \Pi)m'(b) + (1 - \Pi)\Pi\tau$$

$$\frac{\partial Var_0(P)}{\partial b} = \frac{1}{4}\left(-\frac{\partial \Pi}{\partial b}\right)\left((\frac{1}{3}+\Pi)-(1-\Pi)\right)(2\overline{\mu}(b)-2\kappa)^2 \tag{3.75}$$

$$+ \frac{1}{2}(1-\Pi)(\frac{1}{3}+\Pi)\left(2\overline{\mu}(b)-2\kappa\right)\left(m'(b)+\tau\right)$$

$$= -\frac{\partial \Pi}{\partial b}\left(2\Pi-\frac{2}{3}\right)\overline{\mu}^2(b)(1-\Pi)^2$$

$$+ (1-\Pi)(\frac{1}{3}+\Pi)(1-\Pi)\left(m'(b)+\tau\right)\overline{\mu}(b)$$

$$= \left(\frac{m'(b)}{2\overline{\mu}(b)}+\left(\Pi-\frac{1}{2}\right)\cdot\frac{\tau}{\overline{\mu}(b)}\right)\left(2\Pi-\frac{2}{3}\right)\overline{\mu}^2(b)(1-\Pi)^2$$

$$+ (1-\Pi)(\frac{1}{3}+\Pi)(1-\Pi)\left(m'(b)+\tau\right)\overline{\mu}(b)$$

$$= m'(b)\left(\frac{1}{2\overline{\mu}(b)}2\left(\Pi-\frac{1}{3}\right)\overline{\mu}^2(b)(1-\Pi)^2+(1-\Pi)(\frac{1}{3}+\Pi)(1-\Pi)\overline{\mu}(b)\right)$$

$$+ \tau\left(\left(\Pi-\frac{1}{2}\right)\cdot\frac{1}{\overline{\mu}(b)}2\left(\Pi-\frac{1}{3}\right)\overline{\mu}^2(b)(1-\Pi)^2+(1-\Pi)(\frac{1}{3}+\Pi)(1-\Pi)\overline{\mu}(b)\right)$$

$$= m'(b)(1-\Pi)^2\overline{\mu}(b)\left(\left(\Pi-\frac{1}{3}\right)+(\frac{1}{3}+\Pi)\right)$$

$$+ \tau(1-\Pi)^2\overline{\mu}(b)\left(2\left(\Pi-\frac{1}{2}\right)\left(\Pi-\frac{1}{3}\right)+(\frac{1}{3}+\Pi)\right)$$

$$= m'(b)\overline{\mu}(b)2\Pi(1-\Pi)^2+2\tau\overline{\mu}(b)(1-\Pi)^2\left(\Pi^2-\frac{1}{3}\Pi+\frac{1}{3}\right)$$

$$= m'(b)\overline{\mu}(b)2\Pi(1-\Pi)^2+\frac{2}{3}\tau\overline{\mu}(b)\underbrace{\left((1-\Pi)^2\left(\frac{1}{3}\Pi^2-\Pi+1\right)\right)}_{\in[0,1]}$$

$$> 0$$

When $\tau > 0$, this adds a positive term to both $\frac{\partial E_0(P)}{\partial b}$ and $\frac{\partial Var_0(P)}{\partial b}$.

In sum, the derivative of the agent's certainty equivalent with respect to investment is:

$$\frac{\partial CE_0}{\partial b} = -\beta + \hat{u}\cdot\left((1-\Pi(b))m'(b)+(1-\Pi(b))\Pi(b)\tau\right) \tag{3.76}$$

$$- \frac{1}{2}\rho\hat{u}^2\left(m'(b)(1-\Pi(b))^2\overline{\mu}(b)2\Pi(b)+\tau(1-\Pi(b))^2\overline{\mu}(b)\left(2\Pi(b)^2-\frac{2}{3}\Pi(b)+\frac{2}{3}\right)\right) \tag{3.77}$$

To get the first order condition I set this equal to zero and rearrange:

$$- \beta + \hat{u} \cdot \left((1 - \Pi(b))m'(b) + (1 - \Pi(b))\Pi(b)\tau\right) \tag{3.78}$$

$$- \hat{u}^2 \cdot \rho(1 - \Pi(b))^2 \left(m'(b)\Pi(b)\overline{\mu}(b) + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right) \tag{3.79}$$

$$= 0 \tag{3.80}$$

I rearrange:

$$- \beta + \hat{u} \cdot m'(b) \left[(1 - \Pi(b)) - \hat{u} \cdot \rho(1 - \Pi(b))^2 \Pi(b)\overline{\mu}(b)\right] \tag{3.81}$$

$$+ \hat{u} \cdot \tau \left[(1 - \Pi(b))\Pi(b) - \hat{u} \cdot \rho(1 - \Pi(b))^2 \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right] \tag{3.82}$$

Rewriting gives equation (3.21).

- The marginal effect on the probability of disclosure:

$$\frac{\partial(1 - \Pi)}{\partial b} = \frac{m'(b)}{2\overline{\mu}(b)} + \left(\Pi - \frac{1}{2}\right) \cdot \frac{\tau}{\overline{\mu}(b)} \tag{3.83}$$

This is positive when

$$\frac{m'(b)}{2\overline{\mu}(b)} + \left(\Pi - \frac{1}{2}\right) \cdot \frac{\tau}{\overline{\mu}(b)} > 0 \tag{3.84}$$

$$\left(\Pi - \frac{1}{2}\right) \cdot \frac{\tau}{\overline{\mu}(b)} > -\frac{m'(b)}{2\overline{\mu}(b)}$$

$$\Pi \cdot \frac{\tau}{\overline{\mu}(b)} > \frac{1}{2} \cdot \frac{\tau}{\overline{\mu}(b)} - \frac{m'(b)}{2\overline{\mu}(b)}$$

$$\Pi > \frac{1}{2}\left(1 - \frac{m'(b)}{\tau}\right)$$

or

$$\frac{m'(b)}{\tau} > 1 - 2\Pi \tag{3.85}$$

## 3.A.3   The stock bonus

I rearrange (3.78) .

$$-\beta + \hat{u} \cdot (1 - \Pi(b)) \left( m'(b) + \Pi(b)\tau \right) - \hat{u}^2 \cdot \rho (1 - \Pi(b))^2 \left( m'(b)\Pi(b)\tau + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) = 0$$

(3.86)

- I solve this as a quadratic equation wrt $u$:

$$\hat{u}^V = \frac{1 - \sqrt{1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2}}}{\frac{2\rho (1 - \Pi(b)) \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}{(m'(b) + \Pi\tau)}}$$

(3.87)

$$= \frac{\left( 1 - \left( 1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)}{\frac{2\rho (1 - \Pi(b)) \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}{(m'(b) + \Pi\tau)}} \cdot \frac{\left( 1 + \left( 1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)}{\left( 1 + \left( 1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)}$$

$$= \left( 1 - \left( 1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2} \right) \right)$$

$$\cdot \left( \frac{1}{\frac{2\rho (1 - \Pi(b)) \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}{(m'(b) + \Pi\tau)}} \right)$$

$$\cdot \left( 1 + \left( 1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)^{-1}$$

$$= 4\rho\beta \frac{\left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}{(m'(b) + \Pi\tau)}$$

$$\cdot \frac{1}{2\rho (1 - \Pi(b)) \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}$$

$$\cdot \left( 1 + \left( 1 - \frac{4\rho \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right) \beta}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)^{-1}$$

$$= \frac{\beta}{(m'(b) + \Pi\tau)} \frac{2}{(1 - \Pi)} \cdot \left( 1 + \left( 1 - 4\beta\rho \frac{\left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)^{-1}$$

(3.88)

- $b^{\max}$ is the value of $b$ where the square root above is equal to zero:

$$\sqrt{1 - \frac{4\rho\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)\beta}{(m'(b) + \Pi\tau)^2}} = 0 \tag{3.89}$$

I use the numerical values from the example:

$$\sqrt{1 - \frac{4 \cdot 0.2\left((2-b)0.25 + 1.75\left(\left(\frac{0.25}{(1+1.75\cdot b)}\right)^2 - \frac{1}{3}\cdot\frac{0.25}{(1+1.75\cdot b)} + \frac{1}{3}\right)(1+1.75\cdot b)\right)0.67729}{\left((2-b) + \frac{0.25}{(1+1.75\cdot b)}\cdot 1.75\right)^2}} = 0$$

$$\tag{3.90}$$

$$1 - \frac{4 \cdot 0.2\left((2-b)0.25 + 1.75\left(\left(\frac{0.25}{(1+1.75\cdot b)}\right)^2 - \frac{1}{3}\cdot\frac{0.25}{(1+1.75\cdot b)} + \frac{1}{3}\right)(1+1.75\cdot b)\right)0.67729}{\left((2-b) + \frac{0.25}{(1+1.75\cdot b)}\cdot 1.75\right)^2} = 0$$

I use this value of $b$ in the expression for $\hat{u}^V$ and find the necessary stock bonus:

$$\hat{u}^V = \frac{1 - \sqrt{1 - \frac{4\cdot0.2\left((2-b)0.25+1.75\left(\left(\frac{0.25}{(1+1.75\cdot b)}\right)^2 - \frac{1}{3}\cdot\frac{0.25}{(1+1.75\cdot b)} + \frac{1}{3}\right)(1+1.75\cdot b)\right)0.67729}{\left((2-b)+\frac{0.25}{(1+1.75\cdot b)}\cdot1.75\right)^2}}}{\frac{2\cdot0.2(1-\left(\frac{0.25}{(1+1.75\cdot b)}\right))\left((2-b)0.25+1.75\left(\left(\frac{0.25}{(1+1.75\cdot b)}\right)^2 - \frac{1}{3}\left(\frac{0.25}{(1+1.75\cdot b)}\right) + \frac{1}{3}\right)(1+1.75\cdot b)\right)}{\left((2-b)+\left(\frac{0.25}{(1+1.75\cdot b)}\right)1.75\right)}} \tag{3.91}$$

$$b^{\max} = 1.1432$$

$$\hat{u}^V = 1.4401$$

### 3.A.4   The effect of $\rho$

To find $\rho^{\max}$ I note that the term $\left(1 - \frac{4\rho\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)\beta}{(m'(b)+\Pi\tau)^2}\right)$ in (3.25) must be $\geq 0$, since this is in a square root:

$$1 - \frac{4\rho\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)\beta}{(m'(b) + \Pi\tau)^2} > 0 \tag{3.92}$$

$$\frac{4\rho\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)\beta}{(m'(b) + \Pi\tau)^2} < 1$$

$$4\rho\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)\beta < \left(m'(b) + \Pi\tau\right)^2$$

$$\rho < \frac{\left(m'(b) + \Pi\tau\right)^2}{4\beta\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)}$$

This defines $\rho^{\max}$ :

$$\rho^{\max} = \frac{\left(m'(b) + \Pi\tau\right)^2}{4\beta\left(m'(b)\kappa + \tau\left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right)\overline{\mu}(b)\right)} \tag{3.93}$$

I differentiate $\hat{u}^V$ with respect to $\rho$:

$$\frac{\partial \hat{u}^V}{\partial \rho} = \frac{2\beta}{(m'(b) + \Pi\tau)} \frac{1}{(1 - \Pi)} \tag{3.94}$$

$$\cdot (-1) \left( 1 + \left( 1 - 4\beta\rho \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)^{-2}$$

$$\cdot \frac{1}{2} \left( 1 - 4\beta\rho \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)^2} \right)^{-\frac{1}{2}}$$

$$\cdot (-4)\beta \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)^2}$$

$$= \hat{u}^V 2\beta \frac{1}{(m'(b) + \Pi\tau)^2} \left( m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) \right)$$

$$\cdot \left( 1 + \left( 1 - 4\beta\rho \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)^2} \right)^{\frac{1}{2}} \right)^{-1}$$

$$\cdot \left( 1 - 4\beta\rho \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)^2} \right)^{-\frac{1}{2}}$$

$$= \left(\hat{u}^V\right)^2 (1 - \Pi) \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)}$$

$$\cdot \left( 1 - 4\beta\rho \frac{\left(m'(b)\kappa + \tau \left(\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}\right) \overline{\mu}(b)\right)}{(m'(b) + \Pi\tau)^2} \right)^{-\frac{1}{2}}$$

This is positive when:

$$\frac{\partial \hat{u}^V}{\partial \rho} > 0 \tag{3.95}$$

when

$$m'(b)\kappa + \tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) > 0 \tag{3.96}$$

$$\tau \left( \Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} \right) \overline{\mu}(b) > -m'(b)\kappa$$

$$\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} > -\frac{m'(b)\kappa}{\tau \overline{\mu}(b)}$$

$$\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3} > -\frac{m'(b)}{\tau}\Pi$$

$$\frac{\Pi^2 - \frac{1}{3}\Pi + \frac{1}{3}}{\Pi} > -\frac{m'(b)}{\tau}$$

This always holds, since the RHS is negative,and the LHS is positive.

## 3.A.5  Full disclosure bonus

- The agent's first order condition:

$$\frac{\partial CE_0}{\partial b} = -\beta + \hat{u}^F m'(b) - \frac{1}{3}\rho \left( \hat{u}^F \right)^2 \overline{\mu}(b)\overline{\mu}'(b) = 0 \tag{3.97}$$

I solve this with respect to $\hat{u}^F$:

$$\hat{u}^F = \frac{-m'(b) \pm \sqrt{(m'(b))^2 - 4\frac{1}{3}\rho\overline{\mu}(b)\tau\beta}}{2 \left( -\frac{1}{3}\rho\overline{\mu}(b)\tau \right)} \tag{3.98}$$

$$\hat{u}^F = \frac{1 - \sqrt{1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}}}{\frac{2}{3}\frac{\rho\overline{\mu}(b)\tau}{m'(b)}}$$

- I rewrite:

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$$\hat{u}^F = \frac{1 - \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}}{\frac{2}{3}\frac{\rho\overline{\mu}(b)\tau}{m'(b)}} \cdot \frac{1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}}{1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}} \tag{3.99}$$

$$= \frac{1 - \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)}{\frac{2}{3}\frac{\rho\overline{\mu}(b)\tau}{m'(b)}} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1}$$

$$= \frac{\frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}}{\frac{2}{3}\frac{\rho\overline{\mu}(b)\tau}{m'(b)}} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1}$$

$$= 2 \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1} \tag{3.100}$$

- The stock price variance with full disclosure

$$var(P^F) \equiv \sigma_\mu^2 = \frac{1}{12}(2\overline{\mu}(b))^2 = \frac{1}{3}\overline{\mu}(b)^2 = \frac{1}{3}(\lambda + \tau b)^2 \tag{3.101}$$

- The derivative of $Var_0(P^F)$ with respect to $b$ is:

$$\frac{\partial Var_0(P^F)}{\partial b} = \frac{2}{3}(\lambda + \tau b)\tau \tag{3.102}$$

$$= \frac{2}{3}\overline{\mu}(b)\tau > 0$$

When $\tau > 0$, $\frac{\partial Var_0(P^F)}{\partial b}$ is positive, but when $\tau = 0$, it is zero.

- I find $b^{F\,\max}$ by setting the square root in $\hat{u}^F$ above equal to zero.

$$\sqrt{1 - \frac{4}{3}\frac{\rho\overline{\mu}(b^{F\,\max})\tau\beta}{(m'(b^{F\,\max}))^2}} = 0 \tag{3.103}$$

When I use this in the example, I find:

$$\sqrt{1 - \frac{4}{3}\frac{0.2 \cdot (1 + 1.75 \cdot b^{F\max}) \cdot 1.75 \cdot 0.67729}{((2 - b^{F\max}))^2}} = 0 \qquad (3.104)$$

$$b^{F\max} = 1.052 \qquad (3.105)$$

The corresponding value of $\hat{u}^F$ is $\hat{u}^F = 1.3887$.

- The derivative of $\hat{u}^F$ with respect to $\tau$.

$$\frac{\partial \hat{u}^F}{\partial \tau} = 2 \cdot \frac{\beta}{m'(b)} \cdot (-1) \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-2} \cdot \frac{1}{2}\left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{-\frac{1}{2}} \cdot \left(-\frac{4}{3}\frac{\rho\overline{\mu}(b)\beta}{(m'(b))^2}\right)$$

$$(3.106)$$

$$= 2 \cdot \frac{\beta}{m'(b)} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1} \cdot \left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1}$$

$$\cdot \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{-\frac{1}{2}} \cdot \frac{2}{3}\frac{\rho\overline{\mu}(b)\beta}{(m'(b))^2}$$

$$= \hat{u}^F \cdot 2\frac{\beta}{m'(b)}\left(1 + \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{\frac{1}{2}}\right)^{-1} \cdot \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{-\frac{1}{2}} \cdot \frac{1}{3}\frac{\rho\overline{\mu}(b)}{m'(b)}$$

$$= (\hat{u}^F)^2 \cdot \left(1 - \frac{4}{3}\frac{\rho\overline{\mu}(b)\tau\beta}{(m'(b))^2}\right)^{-\frac{1}{2}} \cdot \frac{1}{3}\frac{\rho\overline{\mu}(b)}{m'(b)} > 0 \qquad (3.107)$$

### 3.A.6 Voluntary versus full disclosure in equilbrium:

- Stock price variance: When $\hat{b} = b$ in equilibrium, I can simplify the expression for the stock price variance in (3.67) to:

$$Var_0(P) \qquad (3.108)$$

$$= \frac{1}{4}(1 - \Pi(f^{CO}))(\frac{1}{3} + \Pi(f^{CO})) \cdot (2\overline{\mu}(b) - 2\kappa)^2$$

$$= \underbrace{(1 - \Pi(f^{CO}))^3(\frac{1}{3} + \Pi(f^{CO}))}_{\in[0,\frac{1}{3}]} \cdot \overline{\mu}(b)^2 \qquad (3.109)$$

$$var(P^F) = \frac{1}{3}\overline{\mu}(b)^2 \tag{3.110}$$

The stock price variance is lower with voluntary disclosure than with full disclosure.

$$var(P^F) = \frac{1}{3}\overline{\mu}(b)^2 \tag{3.110}$$

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# Chapter 4

# Discussion and conclusion

## 4.1   Summary and main contributions

### 4.1.1   Setting

In this thesis, I analyze a setting where a manager makes a short-term operating decision, a long-term investment decision, and a reporting decision. I study how the reporting decision might influence the manager's investment choice. The reporting decision is voluntary: the manager can choose whether to disclose his information, but the manager must report truthfully if he chooses to disclose. I analyze how the manager's investment incentives and the owners' expected payoff differ when the manager can control the disclosure decision (voluntary disclosure) compared to the base case of mandatory (or full) disclosure.

### 4.1.2   Model

The model I use to study these issues is based on Dutta and Reichelstein (2005), with some modifications, and adding a voluntary disclosure decision. The model in my thesis has two periods. The manager is hired at time zero, for one period, but the payoffs from investment are not realized until period 2, after the manager has left the company. The manager initially makes two decisions; effort (describing short term operating decisions) and how much to invest (how much money to spend on a long term investment project). At the end of the first period, cash flows from effort are realized. Both investment cost and cash flow from effort appear in

period one. I assume that the accounting system cannot distinguish between the two. This means that the owners and the manager cannot contract on the specific parts of the first-period cash flows. This creates an interaction between effort and investment incentives.

At the end of period one, the agent privately observes a signal about future investment payoffs. I assume that this signal is a perfect prediction of future investment payoffs. The agent can choose whether to disclose this signal to the owners of the company and to the outside stock market. This is the manager's voluntary disclosure decision. If he does disclose, the company incurs a disclosure cost. The stock market incorporates all available information, including the agent's disclosure or no disclosure, into the stock price. The agent is then compensated based on two performance measures; this stock price and total cash flows (from the investment cost and effort payoffs) in period 1. Compensation is assumed to be linear in these two performance measures. In the last period, the cash flows from investment are realized and paid to owners.

### 4.1.3   Analysis

The "unraveling" result ((Grossman and Hart (1980), Grossman (1981), Milgrom (1981)) states that under certain conditions the company (or its manager) will always disclose all their private information to the stock market. If the firm does not disclose, the market will interpret this as low firm value (bad news). With no disclosure, the market will revise their valuation downwards, eventually down to the lowest possible firm value. Every firm with value higher than the lowest possible will then have an incentive to reveal their information, to separate themselves from the lowest-value type, and there will be full disclosure (except for the firms with lowest possible value). One of the conditions for this unraveling to occur (see for instance Beyer et al. (2010)), is that disclosure is not costly[1]. In Verrecchia (1983) there is costly disclosure, and in equilibrium in this model the company will disclose only good news. The same is the case in my model, which also has costly disclosure. When the manager chooses not to disclose bad news, the stock price will not reveal the exact value of the news (the signal) since the market only observes non-disclosure. However, non-disclosure in itself is bad news, so the stock price will be revised downwards and will reflect a general low value.

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[1] Other reasons are: It is public knowledge that the company has private information; all market participants interpret the firm's disclosure in the same way; the firm's disclosure is credible; it is not possible to commit ex ante to a certain disclosure policy (Beyer et al. (2010)).

I analyze how voluntary disclosure influences the manager's investment incentives for the two cases where risk is constant in investment (Chapter 2) and when risk is increasing in investment (Chapter 3). I show that for a given stock bonus, the manager's incentives for investing can be lower or higher with voluntary disclosure than with full disclosure, depending on the disclosure setting and the parameters of the model. The reason that incentives are different with voluntary disclosure is that the manager can choose not to disclose, and in this case his compensation will be constant relative to the stock price, since the stock price in these cases does not contain information about the investment. With linear compensation, as I assume, the compensation will then be flat (constant) for low payoffs which the manager will not disclose, and increasing in stock price for higher outcomes (as shown in Figure 2.2). This protects the manager from the downside risk of investing, but the resulting piecewise linear compensation in payoffs alters the manager's investment incentives.

In the models I assume that the investment level that the manager chooses is not observable or contractible. Only the aggregate cash flow from operations and the investment expenditure is contractible. There may be many cases where it is difficult to separate operating from investment cash flows. Examples include R&D investment and human resources investment. For R&D, the capitalization vs expensing of R&D expenditures depends on how the company views the future prospects of the R&D project[2]. These are to a certain extent based on subjective factors and the manager's discretion. This can also make it difficult to separate the operating and investment cash flows. If, on the other hand, the investment expenditure is perfectly observable and contractible, there would be a full separation of operating and investment cash flows, and this would solve the investment incentive problem.

In my model, where investment expenditures are not separately observable, the stock price is used to create investment incentives. The stock price, however, contains uncertainty and consequently imposes risk on the manager. As a result of this, the stock price is an imperfect tool in the matching process, but it is nevertheless useful in contracting.

The aggregation assumption creates a trade-off between effort and investment incentives.

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[2]Literature on R&D accounting that has focused on the arguments for and against expensing vs capitalization include Chambers, Jennings and Thompson (2003) and Lev, Nissim and Thomas (2005). Others have tried to explain empirically why some firms choose one strategy over the other if there is accounting flexibility (Landry and Callimaci (2003), Oswald (2008), and Cazavan-Jeny, Jeanjean and Joos (2010)). Accounting standards that deal with R&D include SFAS No. 2 and IAS No 38.

Effort is personally costly to the manager, but investment is not. In order to create effort incentives, the principal has to make the manager's compensation depend on the aggregate period-1 cash flow, since this is the only performance measure that can be used to induce effort. This, however, creates disincentives for the manager to invest, since investment reduces period-1 cash flow. The result is an induced incentive problem which is an underinvestment problem.

### 4.1.4 Results

In Chapters 2 and 3 I compare the voluntary and full disclosure settings. I find that the principal in some cases are better off letting the manager control the disclosure decision instead of having full disclosure. First, the principal saves on the expected disclosure cost with voluntary disclosure. Second, the risk imposed on the agent is smaller with voluntary disclosure, holding everything else constant. This is because the manager can choose not to disclose his information, and in these cases the stock price will not depend on the pay-off from the risky investment. This reduces the overall variance of both the stock price and the manager's compensation. The manager will choose not to disclose when payoffs are low. This protects him from the downside risk of investing. However, this also makes the manager invest less for a given linear contract, when the risk is independent of investment (Chapter 2). On the other hand, when risk increases with investment (Chapter 3), this convexity in the manager's payoff may increase investment incentives with voluntary disclosure compared to full disclosure.

The difference in the incentive effect of stock price with voluntary and full disclosure suggests that the disclosure setting must be taken into account by the principal when deciding on the contract that she will offer the agent. I show that the principal can strictly prefer to let the manager decide whether to disclose or not (voluntary disclosure), compared to full (or mandatory) disclosure. The policy implication of this is that it may be socially optimal to have voluntary disclosure instead of full, mandatory disclosure, and that managerial discretion in reporting decisions may be the optimal policy. The models also illustrate the interaction between reporting and real decisions; between disclosure and investment.

The models extend the voluntary disclosure literature by including real investment decisions into the model. Verrecchia (1983) and other voluntary disclosure models describe pure exchange economies. By including real production decisions, I can study the interaction between reporting

decisions and real decisions.

The models contribute to the literature on incentives and performance evaluation by extending the model in Dutta and Reichelstein (2005) to include a reporting decision by the manager. When the manager controls the information that the stock market receives, he can hide information about bad news. This reduces the downside risk for the agent, but it also changes the effectiveness of the stock bonus in incentive contracting.

### 4.1.5 Limitations

One limitation of my study is that I assume that the compensation contract is linear in the two performance measures. I do not claim that this linear contract is optimal. I study the optimal contract, under the restriction that it is linear. I do this to make the model tractable and to be able to study how the exogenous factors influence the optimal contract. Holmström and Milgrom (1987), Christensen and Feltham (2005, Chapter 19) and Edmans and Gabaix (2011) all study settings where the optimal contract is linear. The contract is optimally linear only under very certain conditions in these models, conditions for instance on preferences, production uncertainty, and information. I do not claim that these restrictions are met in my model, and the linearity assumption is therefore an exogenous assumption restricting the applicability of the model. My aim, however, is to study what insight a model with linear compensation and voluntary disclosure provides.

In Chapter 3, I show that voluntary disclosure can be more efficient for the principal than full disclosure (this also holds for the model in Chapter 2, but here the result is driven by the savings in expected disclosure cost. In Chapter 3 the result holds more generally). Voluntary disclosure implies that the manager's compensation becomes piece-wise linear and convex in the signal, while full disclosure compensation is linear. Others have studied how piece-wise linear contracts can be optimal compared to linear contracts, for instance the optimality of stock options versus stock compensation (Feltham and Wu (2001), Kadan and Swinkels (2008), Flor, Frimor and Munk (2011), and Wu (2011)). With options or my model's voluntary disclosure setting, the manager is protected from downside risk but rewarded for high outcomes. Both situations can reduce the risk premium the principal has to pay, and it can give the manager incentives to invest in risky projects. I have shown that voluntary disclosure can be more

efficient in incentives than full disclosure. However, it is likely that the same result that I prove for voluntary disclosure can be achieved by giving the manager a piece-wise linear compensation directly.

Another assumption I use in the model is that the investment uncertainty is uniformly distributed. This means that the noise has a finite support, and that each outcome within the support has equal probability. It also means that the distribution is completely characterized by its mean and variance (no third moment). The normal distribution is a relevant alternative. However, the uniform distribution has the advantage of simplicity and tractability in my model. Also, the manager's preferences are defined in terms of mean and variance, so that higher moments are not part of the agent's preferences.

## 4.2 Accruals, voluntary disclosure and earnings management

The models in chapters 2 and 3 showed how the manager could withhold information to the stock market, and how this voluntary disclosure decision influenced the manager's investment incentives. In chapter 1 I discussed the role of accruals in financial accounting, and how the manager could use accruals to manage earnings. I also discussed how the models in Chapter 2 and 3 are closely related to accrual accounting.

The signal that the manager receives in the model is a perfect prediction of future cash flow from the investment. This signal can be used to induce investment, and in the model it is the only way to give the manager investment incentives. The manager is in the company only in period 1, and the cash flows from investment are not realized until period 2. The signal about future cash flows can be used to create investment incentives by rewarding the manager in period 1 for cash flows that do not occur until period 2. I can relate this to the discussion about accruals in Chapter 1. Using the signal in incentives in period 1 works like a fair value accrual. A fair value accrual would in this case match the revenue received in period 2 to the cost in period 1 when the cost occurs. Other models of accruals, such as in Reichelstein (1997) and Rogerson (1997), instead match costs to the relevant revenue in the period the revenue occurs.

In Chapter 1 I also discussed how the manager can have some discretion over accruals

reporting, and that this discretion can be used for signalling or opportunistic purposes. In my model, the manager's reporting discretion lies in his disclosure decision. The manager can withhold information by not disclosing, and this is his way of managing information. This is closely related to the earnings management decisions that the manager can take with regard to accruals. In both cases the manager controls the information that the market receives.

## 4.3 Possible extensions and suggestions for further research

### 4.3.1 Alternative signals

**Investment cost**

In the original model, the signal is a perfect prediction of future cash flows from investment. I have discussed how this resembles a fair value accrual. A possible extension to the model, could be to consider alternative signals. For instance, an interesting case is when the signal is a perfect or noisy measure of the investment cost. Consider first a perfect signal about investment cost. For each possible choice of investment level, the manager knows with certainty what the disclosure stock price will be (the expected value of the investment, given the observed investment level). For the principal, first best investment can be achieved by setting the stock bonus equal to the cash flow bonus; the two will then cancel each other out in the manager's compensation. The manager will then be indifferent with respect to investment level and will (by assumption) invest the first best level. The cash bonus could be set to solve the effort problem separately[3].

This type of accrual would create a perfect separation of the effort and investment problems. It is interesting to note that a perfect signal about investment cost in this model creates perfect disaggregation and consequently first best investment, while a perfect signal about future cash flows from investment does not.

However, the model would be more complicated if the signal contains noise; when the signal

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[3]This holds as long as the benefit of going from the lowest possible investment level $\underline{b}$, to the first best investment $b^{FB}$, is sufficiently high to cover the disclosure cost. The choice is then between $\underline{b}$ and no disclosure and $b^{FB}$ and disclosure. Assuming the disclosure cost is relatively low compared to the difference in payoff between investing $\underline{b}$ and investing $b^{FB}$, first best investment and disclosure will be the result.

is a noisy measure of investment cost. The market would not use the signal for valuation but base the stock price on its own conjectures about investment. The stock price will in turn not reflect the actual investment level. Consequently, the stock price is not valuable for incentive purposes. The agent will not have any investment incentives and will only invest the lowest possible amount. However, consider a third scenario, where the incentive contract can be written directly on the noisy signal of investment cost, and not on the stock price. A simple preliminary analysis suggests that the signal is valuable for incentives. Investment can be induced by having a positive incentive weight on the signal. In this case, the signal creates a separation, though imperfect, between investment and effort cash flows. This creates investment incentives. This scenario is related to accruals as described in Paton and Littleton (1940), where (most) accruals are based on transactions and historical cost, and investment costs are distributed to the asset's operating periods.

The noisy signal of investment cost is not valuable for valuation but it is valuable for incentives. The result that information has different value for valuation and incentives is not new and is consistent with for instance Gjesdal (1981) and Paul (1992). It would be interesting to study these issues in more detail and analyze the results in relation to the current model.

**Other signals**

Another possibility is to see what changes if the signal is an imperfect measure of future cash flows. In Chapters 2 and 3 I looked at a setting where the signal is a perfect measure of cash flows. There could also be different signals, as described in the section above, and different signals could have different disclosure costs.

**Accounting choices**

There is a considerable empirical literature that tries to explain how and why firms choose the accounting methods that they do (see Fields et al. (2001) for an overview of the empirical accounting choice literature, and Quagli and Avallone (2010) for a recent empirical study). Watts and Zimmerman's (1986, 1990) positive accounting theory emphasizes the manager's self interest as one determinant of accounting choice; the manager will have incentive to choose the accounting method that for instance maximizes his earnings-based compensation. From

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the earnings management literature, there is some evidence that managers do manage earnings (see Chapter 1 for a further discussion). But these studies mostly take the manager's incentive contract as given. A manager's incentive contract can influence both real decisions such as investment and accounting method choices. However, the accounting method in place can also influence the manager's real decisions. For instance, Rogerson (1997) and Reichelstein (1997) show in theoretical models how depreciation rules influence the manager's investment incentives, and Baldenius and Reichelstein (2005) study the accounting method's influence on the manager's production and inventory decisions. Jackson et al (2010), Jackson (2008) and Seybert (2010) provide empirical and experimental studies on how accounting methods influence the firm's investment decisions. It would be interesting to study in more detail how accounting choices and real decisions influence each other, and what the role of the manager's incentives is in these decisions.

The model I present in this thesis, deals with the manager's choice of whether to disclose his information or not. It could possibly be extended (or changed) to deal with accounting choice. For instance, what happens if the manager has the discretion whether to choose fair value or historical cost to report on an investment project? Would this influence his incentives to invest in the first place? Another accounting choice could be between expensing and capitalization (which would be closely related to the current model in this thesis). Holthausen (1990) suggests three motivations for accounting choice: opportunistic behavior, efficient contracting, and information perspectives (signalling). It could also be interesting to see whether and how other aspects than opportunism, such as signalling, could be included in such a model.

### 4.3.2 Other extensions

The model is a one-shot-model with two periods. A possible extension is to include more periods. Discounting could be introduced in the model, as well as the possibility that the manager and owners have different discount rates. This would create investment incentive problems as in the models by Dutta and Reichelstein discussed in Chapter 1. An interesting question is then how voluntary disclosure (in each period) would influence investment incentives.

In the model I have developed, the manager can withhold information, but he has to report truthfully, if he makes a disclosure. Another interesting extension could be to allow the manager

to misreport the signals. Einhorn and Ziv (2011) analyze misreporting in voluntary disclosures, and Wu (2011) analyze misreporting in connection with stock option compensation. This would move the model even closer to the earnings management literature.

In the current model, the manager's investment incentives are deteremined by the explicit incentive contract and the disclosure setting. Other incentives that could influence the manager could come from career concerns (as in Holmstrom (1982), Demers and Wang (2010)). This is not covered in my model and would require a multi-period model. A topic for future research could be to explore this issue further and see how career concerns would influence the voluntary disclosure decision and investment incentives.

The manager's reputation for disclosure might also be included in such a model. Recent research has shown that a manager's individual or manager-specific characteristics and reputation influence his disclosure decisions and the market's response to his disclosures (Bamber et al. (2010), Brochet et al. (2011), Baik et al. (2011), Yang (2011)). What are the manager's incentives for building a reporting reputation?

The stock market plays a passive role in the model; it only creates a stock price at time 1, based on available information. There are several ways to make this setting more realistic, for instance by having trade in the stock at time 1, where some owners have to sell at this time. This could create preferences for the principal at time 0 with regard to disclosure at time 1. I could also introduce risk aversion for stock market participants, and see how this would change the role of disclosure.

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