Reported Earnings, Auditor's Opinion, and Compensation:

Theory and Evidence

Abstract

Delegation of responsibility and use of performance measures in compensation contracts are important issues in management accounting. Unfortunately, no performance measure or compensation contract is perfect in aligning the goals of the organization with that of the agent. It is well known that an incentive motivates an agent to exert productive effort as well as unproductive effort to inflate his performance measure. Thus, a compensation contract needs to provide incentive for productive effort, and also control for unproductive effort.

This dissertation studies the effect of auditor's independence and opinion on executive compensation and executive effort allocation. Using principal agent theory, I examine a compensation contract involving two signals, one for incentive and one for control. The incentive signal is the net income reported by the executive (agent) and the control signal is the auditor's opinion. The owner (principal) can induce higher productive effort level by including the audit opinion in the compensation contract. The impact on productive effort level is higher when the auditor is more independent.

The optimal weights on earnings and audit opinion in the agent's compensation contract are obtained in a LEN framework. The weights show that the agent is rewarded for higher earnings and penalized for audit qualification. The pay-performance sensitivity increases monotonically as the auditor becomes more independent. However, the pay-opinion sensitivity does not increase monotonically as the auditor becomes more independent.

Interestingly, the pay-opinion sensitivity first increases and then decreases as the auditor becomes more independent. Intuitively, with increasing auditor independence, the need of audit opinion in the compensation contract decreases because the presence of the independent auditor itself exerts a control on the agent.

Some of these analytical results are tested empirically. Empirical evidence shows that the executive is rewarded for higher reported earnings and penalized for departures from standard unqualified opinion. The pay-performance sensitivity increases as the auditor becomes more independent. Auditor independence is measured by audit fee/(audit fee+ nonaudit fee).

The analytical model is also modified to incorporate auditor competence along with auditor independence. The modified model gives similar results to the model that only includes auditor independence.

Keywords: Executive Compensation; Auditor's Opinion; Principal Agent Theory; Performance Measure.

Reported Earnings, Auditor's Opinion, and Compensation: Theory and Evidence

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DISSERTATION

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1 Introduction

1.1 Background

Incentive compensation contract between a manager and an owner is one way to motivate managers to work to achieve the goals of the organization. In an incentive contract, the manager is compensated based on his performance measure/s. However, no performance measure or compensation contract can align the goals of the organization and that of the manager perfectly. Also, an incentive contract motivates a manager (an agent) to exert productive as well as unproductive effort. An effort is called productive if it helps in building organizational value, and an effort is called unproductive if it does not affect organizational value.

Examples of unproductive effort are widespread. For instance, when managers are evaluated by per unit average cost in absorption costing, then there is a strong incentive to spread the fixed cost of the product by producing more units (McWaters, Morse, Zimmerman 1997, page 382). Thus, the use of average cost as a performance measure provides an incentive to over-produce. Other examples include the use of transfer price as a performance measure. Suppose the transfer price is set at variable cost of the product being transferred, and the selling division is evaluated on divisional profit. If the selling divisional manager has the discretion of choosing fixed and variable cost to perform the same task, then he may choose to replace a low fixed machine cost with a high variable labor cost (McWaters, Morse, Zimmerman 1997, page 215). This way the divisional manager can increase the selling division's revenue which is based on the variable cost of the product and increase the divisional profit on which he is evaluated. However, the overall cost of the product increases and thus decreases the overall profit of the organization, keeping other things constant. This type of malfunction of performance measures applies not only to average cost or transfer price but also to almost all performance measures. Kaplan and Atkinson (1998, page 680) provide many interesting examples of earnings manipulation.

The above examples show that incentive compensation contracts can be counter productive if the actions of the manager are not properly controlled. One way to control the unproductive effort is to include a monitor's opinion in the compensation contract. In this dissertation, I analytically study a compensation contract that includes the agent's reported performance measure and a monitor's opinion about the reported performance measure. The analytical results hold for a general agent and monitor setting. Based on data availability, I consider the CEO as the agent and the external auditor as the monitor in the empirical part of this study.

1.2 Auditor Independence

The present research examines how auditor independence and auditor opinion affect executive compensation and executive effort. Auditor independence plays an important role in the perceived value of auditing. Independent auditor means an unbiased auditor who maintains a neutral viewpoint in all his actions required to perform the necessary audit and provide an opinion. It is important for an auditor to maintain an unbiased viewpoint in his/her actions regarding the audit, and it is equally important for the auditor to be perceived as independent by the users of financial statements. These two viewpoints are referred to as *independence in fact and independence in appearance.* This distinction is explained in SAS No.1 (AU section 220.3). When an auditor is acting unbiasedly in his audit related actions, then he is *independent in fact*. This is an internal condition of the auditor which is hard to assess. In contrast, an auditor is *independent in appearance* if he is considered independent by others. This is an external reputation of the auditor which can be measured (with error of course) using external characteristics of the auditor.

The AICPA Code of Professional Conduct provides general standards of conduct for the auditing profession. This code has four parts, namely, *principles, rules of conduct, interpretations of the rules, and ethical rulings.*The first issue addressed in the rules of conduct is independence as described below:

Rule 101-Independence: *A member in practice shall be independent in the performance of professional services as required by standards promulgated by bodies designated by Council.*

The interpretations of this rule prohibit direct (like stock ownership) and indirect (like a relative of the auditor owning stock) financial interests by the auditor. Any litigation (other than tax related or non audit service related) between an external audit firm and its client is considered a violation of Rule 101.

The other rules of conduct include

Rule 102 -Integrity and Objectivity: *In the performance of any professional service, a member shall maintain objectivity and integrity, shall be free of conflicts of interest, and shall not knowingly misrepresent facts or subordinate his or her judgment to others.* Even though this rule does not specifically mention independence, this rule is very relevant for the definitions of independence used in auditing research. Besides the rules 101 and 102, rules 201 (general standards), 202 (compliance with standards), and 203 (accounting principles) are relevant to auditor independence as defined in auditing research. The reader can refer to Page 90 of Arens et al. (2003) for these rules.

Along with the rules of AICPA, there are regulatory rules from the Securities and Exchange Commission (SEC). Two sets of requirements from the SEC, namely Regulation S-X and Regulation S-K are essential for financial reporting. Regulation S-X contains rules to govern financial statements and Regulation S-K contains rules to govern all disclosure notes in financial reports. The regulatory rule from the SEC on independence is *Rule 2-01(b) of Regulation S-X.* This rule has some similarities and some dissimilarities with Rule 101 of AICPA. Overall, the SEC rules are more strict than AICPA rules, mainly in the areas of bookkeeping, family relations, financial interests, and prior partnerships (Page 880 Robertson 1996). More recently, in July 2002, the Sarbanes-Oxley act was passed which puts more restrictions on external auditors for maintaining independence (Title II of the act).

As more rules come into force for practicing auditors, the academic research also responds to that. In auditing research there are several definitions of auditor independence.

Antle (1984) provides two game theory based definitions of auditor independence. Magee and Tseng (1990, page 332) define "independence as an auditor's approval of a reporting policy that he or she believes to be consistent with proper application of GAAP to the client's circumstances, without regard for the beliefs of other auditors." Alternatively, "a lack of independence can be defined as an auditor's approval of financial statements that are not in accordance with GAAP." According to DeAngelo (1981, page 116) "the level of auditor independence is defined as the conditional probability that, given a breach has been discovered, the auditor will report the breach." The auditor independence construct in the present research is closely related to both the Magee and Tseng, and DeAngelo definitions.

1.3 Auditor's Opinion

Audit reports can belong to four categories depending on the auditor's opinion. They are

(1) Standard unqualified,

(2) Unqualified with explanatory paragraph or modified wording,

(3) Qualified,

(4)Adverse or disclaimer.

As stated in Arens et al. (2003) Page 48, a standard unqualified report is issued when:

(1) all four financial statements are included in the financial report.

(2) the three general standards (Page 32, Arens et al. 2003) have been followed,

(3) sufficient evidence has been accumulated to enable the auditor to conclude that three standards of field work (page 32, Arens et al. 2003) have been met,

(4) financial statements are presented in accordance with GAAP,

(5) there are no circumstances to add an explanatory paragraph.

The second type of report, standard unqualified with explanatory paragraph or modified wording is issued when the first four conditions of unqualified report are met but the fifth condition is not met. The conditions under which an explanatory paragraph is issued are (as stated in Arens et al 2003, page 49)

1. Lack of consistent application of GAAP
2. Substantial doubt about going concern
3. Auditor agrees with a departure from promulgated accounting principles
4. Emphasis of a matter
5. Reports involving other auditors.

The first four conditions require an explanatory paragraph, where in the last condition the auditor uses a report with modified wording.

The other types of opinion are qualified opinion, adverse opinion, and disclaimer. As mentioned in Arens et al (2003), Page 49, a qualified opinion is issued when there is a scope limitation on the audit or GAAP has not been followed, however, the overall financial statements are fairly presented. An adverse opinion is issued when the financial statements are materially misstated or misleading. A disclaimer is issued when there is a severe limitation on scope or auditor independence (defined by the Code of Professional Conduct, namely, Rule 101) is violated. Thus, a qualified opinion is least severe among these three types of opinion.

Standard unqualified and unqualified with explanatory paragraph are the two most common audit opinions prevailing in practice with some rare occurrences of qualified opinions.

1.4 Motivation

In recent years, exorbitant executive compensation has become a controversial topic, mainly due to its cost free appearance. The debate over expensing stock options has been going on over more than a decade. In June 1993, FASB issued an exposure draft on stock options recommending expensing stock options (using options pricing models to value options). This triggered the debate on expensing stock options. Facing strong political opposition and no strong support from the SEC, the FASB compromised. In 1994, FASB decided to encourage, rather than require, recognition of fair value compensation cost. The related standard (Statement 123) was issued in 1995 where expanded disclosure of compensation cost was required (Kieso et al. 2001, pages 871-872). More recently, on December 17, 2004, FASB issued the final statement on accounting for stock based compensation (Statement 123R) that requires most companies to expense stock options by mid 2005.

While the debate over stock options went on, there has also been a growing concern over non-audit service fees to auditors. The issue here is whether auditor independence is impaired by the provision of non-audit services. In response to these concerns, the SEC revised its rules in November 2000 (namely, Rule S7-13-00) which requires the firm to disclose different types of fees paid to the auditor in their proxy statements filed on or after February 2001. It also prevents the independent auditor from providing certain non-audit services. Amidst these concerns over auditor independence and executive compensation, the huge corporate scandals of Enron and Worldcom took place, together with the fall of the audit firm Andersen.

In July 2002, the Sarbanes-Oxley act (www.sec.gov) was passed. This law established the Public Company Accounting Oversight Board (PCAOB) to oversee the audit of public companies. This act prohibits most non-audit services to publicly traded audit clients by the audit firms, namely, financial information systems design and implementation, internal audit, and certain other services.

All these new rules and regulations imply the importance of executive compensation and auditor independence. Since executive compensation depends on accounting information, and auditors provide assurance on accounting information, it is a natural research question to study the link between auditor assurance and executive compensation. As audit opinion and auditor independence together determine the level of assurance that the auditor provides about the quality of accounting information, this dissertation investigates the effect of audit opinion and auditor independence on CEO compensation.

Auditor competence and amount of input are also important factors for auditor's assurance. This dissertation also includes an analytical model to study the effect of audit opinion, auditor independence, and competence on manager's compensation.

It is true that an external auditor can not provide perfect monitoring, however, his/her presence does provide assurance to the owner/s of the company. This is called the monitoring (stewardship) hypothesis of the role of the auditor (Wallace 1980). The audit report usually mentions whether the financial statements are prepared in accordance with GAAP. However, it is well known that earnings (or any other performance measure) can be manipulated even when GAAP has been followed. Some of these examples are provided in Kaplan and Atkinson (1998, page 680). The empirical study in this dissertation does not address within GAAP manipulation of earnings. This is one shortcoming of this study.

1.5 Literature Review

The literature review is divided into three parts: agency theory, managerial compensation, and auditor independence related research.

Agency Theory: The analytical research in managerial compensation is primarily based on principal-agent theory (Holmstrom 1979; Grossman and Hart 1983; Holmstrom and Milgrom 1987, 1991). Holmstrom (1979) addresses the moral hazard problem where a principal delegates a single task to an agent and derives the optimal compensation plan which may be non-linear in outcome. Holmstrom and Milgrom (1987, 1991) examine a more restrictive setting where the agent has an exponential utility function, and the outcome is normally distributed. In this setting, they show that the optimal compensation is a linear function of outcome. This is the basis of the LEN (linear plan, exponential utility, normally distributed outcome) framework which has become standard in the accounting literature.

The application of principal-agent theory in accounting includes Banker and Datar (1989), Bushman and Indejikian (1993), Kim and Suh (1993), Lambert (1993), Feltham and Xie (1994), Feltham and Wu (2000), Datar et al. (2001) among others.

Banker and Datar (1989) consider the case where two signals are available about the agent's effort and characterize the joint density function under which a linear aggregation of two signals about the agent's effort is optimal for performance evaluation. As they focus on linear aggregation, relative weights placed on two signals is an important issue to address. They show that the relative weights are determined by the sensitivity, precision, and the correlation between the signals. They emphasize that the linear aggregation of the *performance measures* is the focus of the work; the compensation contract is still allowed to be a non-linear function of the aggregate performance measure (unlike LEN framework). Most of their work concerns an agent performing a single task. However, they briefly consider an extension to a *double task* case.

An extension of the Banker and Datar (1989) framework can be found in the first part of Feltham and Wu (2000) where they focus on relative weights on two signals when the agent is double-tasking. Also, Feltham and Wu (2000) use a LEN framework whereas Banker and Datar (1989) allow the compensation contract to be non-linear. The second part of Feltham and Wu (2000) focuses on capital market research. Bushman et al. (1993) and Kim and Suh (1993) both examine compensation contracts involving accounting and market based measures. A detailed discussion of these two papers can be found in Lambert (1993).

Feltham and Xie (1994) study the value of an additional signal while considering multiple signals in a multi-task setting with LEN framework. They allow the terminal value of the firm (the principal's gross payoff) as non-contractible information and the agent is compensated on performance measures which are different from the terminal value. In this setup, a measure of congruity (between expected outcome and expected performance measure) is important as it measures the alignment of the goal of the organization and that of the agent. However, the issue of congruity is not relevant in a single task setting (as in Banker and Datar 1989) as the goals of the agent and organization are already aligned in single task settings.

Feltham and Xie (1994) consider a model where the agent is inflating his performance measure by providing two types of effort; one type of effort (productive) affects the terminal value of the firm and the other type (unproductive) does not affect the terminal value. This type of manipulation of performance measure is referred as "window dressing" in Feltham and Xie (1994). The model in this dissertation is an extension of this formulation.

Datar et al. (2001) also study two signals in a multi-task LEN framework. They also allow for terminal value of the firm as non-contractible information. However, they develop a measure of congruity which is different from Feltham and Xie's (1994) measure. They show that the optimal contract trades off the congruity of the overall performance measure with the risk imposed on the agent. Interestingly, unlike Banker and Datar (1989), they find that an increase in sensitivity does not necessarily increase the weight placed on that signal, even when it is perfectly congruent with the firm's terminal value.

Managerial Compensation: There is a vast empirical literature on compensation. Since this dissertation deals with window dressing, I will focus on the compensation literature dealing with earnings management.

Healy (1985) provides evidence that managers manipulate earnings upward as well as downward depending on the earnings bounds set by the annual bonus plan. Healy (1985) shows that total accruals are more negative when earnings are below the lower bound or above the upper bound of the bonus plan when compared with the total accruals when earnings are within these bounds. Holthausen, Larcker, and Sloan (1995), and Gaver, Gaver, and Austin (1995) extend Healy's work with different data sets in different time periods. Holthausen et al. (1995) find that managers manipulate earnings downwards when bonuses reach their maxima; however, there is no evidence of downward manipulation when earnings are below the lower bound specified by the bonus plan. Holthausen et al. (1995) use confidential data on executive compensation for the period 1980-1990, and thus use the actual lower and upper bounds specified by the bonus plan unlike the work of Healy (1985) where these bounds needed to be assigned. Gaver et al. (1995) show that managers manipulate earnings upward (downward) when earnings before discretionary accruals fall below (above) the lower bound. Gaver et al. (1995) use publicly available data for the period 1980-1990, and use only those firms where the information is disclosed in proxy statement to compute the lower bound of the bonus plan. Both Holthousen et al. (1995) and Gaver et al. (1995) use the modified Jones model (as suggested by Dechow, Sloan and Sweeny 1995) for discretionary accruals unlike Healy (1985) who uses total accruals as a measure of earnings manipulation. A survey of the earnings management literature can be found in Healy and Wahlen (1999).

Studies involving pay-performance sensitivity of accounting and stock based measures include Murphy (1985), Lambert and Larcker (1987), Sloan (1993), and Core et al. (2002), among others. Murphy (1985) provides evidence of a strong positive association of executive compensation and shareholder return and sales growth using time series data on individual executives. He also examines this relationship cross-sectionally and finds results very different in sign and magnitude from the time series results. Thus, he cautions researchers to be careful about individual firm specific variables while dealing with cross sectional studies.

One way to circumvent the firm specific omitted variable problem is to run cross sectional regression with differences of dependent as well as independent variables. The following authors incorporate this econometric issue in their studies. Lambert and Larcker (1987) run a cross-sectional study to examine the weights placed on accounting and market related measures in CEO cash compensation for the years 1970-1973. They identify conditions when firms place more weights on market measures when compared to accounting measures. Sloan (1993) also runs a cross-sectional study and identifies conditions when earnings shield CEO compensation from market-wide variations in equity values. Sloan's study is based on CEO cash compensation from years 1970-1988. A detailed discussion of Sloan's work can be found in Lambert (1993). Jensen and Murphy (1990) conduct an extensive study (with three samples ranging over five decades) to investigate the pay-performance relationship. They find a very weak link between executive pay and firm performance when measured by change in shareholder wealth. They measure executive pay by cash compensation as well as executive stock holdings. Most recently, Core et al. (2002) find that the relative weights placed on price and non price performance measures are increasing functions of relative variances when CEO total compensation is considered. However, the opposite is true when only cash compensation is considered.

Most of the work discussed above deals with executive cash compensation. However, as time progressed, a large portion of executive compensation became stock based, e.g., stock option, restricted stock, etc. A detail description and measurement of components of executive compensation can be found in Antle and Smith (1986). A thorough review of executive compensation is given by Lambert and Larcker (1985a, 1985b) and recently by Murphy (1999).

Auditor independence: There is no doubt about the importance of auditor independence in auditing research and practice. In the beginning of this chapter auditor independence was discussed. This section focuses on auditing research dealing with auditor independence.

Auditor independence related research often deals with fees of different categories paid to the auditor. There have been several studies which focus on different types of fees paid to the auditor to find out whether these fees impair audit independence. Simunic (1984) provides theory and evidence of positive association between audit and consulting fees. His sample, based on a survey, is composed of 263 firms from years 1976-1977. He finds a positive significant association between audit fees and consulting fees to the incumbent auditor. More specifically, he finds that incumbent audit firms earn higher audit fees when they also provide non-audit services to their clients. Using an analytical model, Simunic interprets this result as evidence of beneficial knowledge spillover between these two types of services. Palmrose (1986) finds positive association between audit and non-audit fees to incumbent as well as nonincumbent audit firms. This finding indicates that the positive correlation between audit and non-audit fees may not only occur due to knowledge spill-over as interpreted by Simunic. Davis, Ricchiute, Trompeter (1993) follow up Simunic and Palmrose to study whether providing audit as well as non-audit service to clients result in knowledge spillover. They use an audit firm's internal audit-hour and billing rate data to provide direct evidence on whether spillover exists which earlier studies did not produce. Using firm's internal billing rate data they get a direct measure of audit effort and provide evidence of positive association between non audit service and audit effort. They conclude that additional effort is needed when audit firms provide non-audit services along with audit service to the client. All these studies use single equation estimation models for audit fee.

On the contrary, Abdel-Khalik (1990) finds no relation between audit and non-audit fees and provides several explanations for the positive association between audit and non-audit fees found by other researchers. He uses Heckman's self-selection correction for the decision to purchase non-audit fees. Recently, Whisenant et al. (2003) provide evidence on the joint determination of audit and non-audit fees using a simultaneous equation model. They find no association between audit and non-audit fees and conclude that single equation models provide biased results. Thus, the empirical evidence about correlation between audit and non-audit fees remains inconclusive.

Recent research on non-audit fees and earnings management also provides mixed evidence. Frankel, Johnson and Nelson (2002) provide evidence that firms purchasing non-audit services from their auditors report higher discretionary accruals. Ashbaugh et al. (2003) find income decreasing accruals are related to non-audit service fees when they repeat Frankel et al.'s study. They also show that discretionary accruals are not higher for firms purchasing non-audit services from the same auditor. They use different measures of discretionary accruals. A discussion of Frankel et al. can be found in Kinney and Libby (2002). Recently, DeFond et al. (2002) find no significant association between non-audit service fees and propensity to issue a going concern opinion.

In a separate study, Kinney et al. (2004) examine the association of financial statement restatements and different categories of non-audit fees prior to the Sarbanes-Oxley act. They use fee data from years 1995 to 2000. They find no significant positive relation between restatements and fees for internal audit services or information system development. They find significant positive relationship between restatements and audit fees, audit related fees, and unspecified NAS (nonaudit service) fees. Interestingly, they find negative association between tax service fees and restatements. Overall, they have evidence of positive as well as negative association of restatements and NAS fees, however, the evidence does not point toward alarmingly reduced quality of reporting when NAS is purchased.

Most recently, Kornish and Levine (2004) develop an analytical model which suggests that shareholders, represented by the audit committee, can provide auditors with incentives to accept only truthful reports if auditors are offered contingent audit fees, like penalizing the auditor for inflated earnings reports. In practice, contingent fees are prohibited for auditors. Thus, this paper is relevant to regulators. Singh

(2004) addresses a problem similar to the present study with a different analytical model. Similar to Kornish and Levine (2004), he finds that shareholders are better off by increasing auditor's liability for certifying inflated earnings report than increasing penalties on managers.

Besides a very different analytical frame work and model assumptions, the present study differs from these two (Kornish and Levine 2004, and Singh 2004) articles in three ways.

- In the present study, the focus is on managerial compensation and how it depends on auditor's independence.
- Auditor's compensation or incentives are not considered. Auditor's independence captured by a parameter θ is exogenous to the present model.
- The analytical model developed in the current study is tested empirically with publicly available data, unlike Kornish et al. (2004) and Singh (2004).

1.6 Contribution

Earlier research in the area generally focused on either the determinants of executive compensation, or how audit and non-audit fees can explain earnings manipulation and other executive actions. The present work integrates these two streams of research and investigates the effect of auditor independence and audit opinion on executive (agent's) compensation. Using the principal agent theory in LEN framework, I study a compensation contract which includes audit opinion in addition to traditional accounting based performance measures.

I consider two-dimensional agent effort, one dimension represents productive effort and the other represents unproductive effort. As already mentioned, an effort is called productive if it helps in building organizational value, and an effort is called unproductive if it does not affect organizational value. The incentive of productive and unproductive effort comes directly from the use of performance measure in the compensation contract. Now, the principal can not observe the individual effort levels for productive and unproductive effort and thus needs a control mechanism built in the compensation contract. In the model proposed here, the principal uses two signals: the earnings and the auditor's opinion.

This study extends the results of "window dressing" of Feltham and Xie (1994) to study how auditor's independence and auditor's opinion influence the agent's (executive's) actions. The auditor's opinion is based on auditor's decision variable which is influenced by his/her level of independence from the client. As mentioned in DeAngelo (1981) as well as in Watts and Zimmerman (1986, page 314), an independent auditor needs to report an identified breach. Thus, the audit report has two aspects, one is *detection* which requires thorough auditing, and the other is *reporting* which requires independence. The first model developed in this dissertation mainly addresses the *reporting* aspect of auditing. Later this model is generalized to incorporate the *detection* as well as the *reporting* aspect of auditing. Appealing to practice, the auditor is assumed to be compensated with a fixed fee in this study.

Thus, I examine how including the audit opinion in the agent's compensation contract affects the pay-performance sensitivity and how this sensitivity changes with auditor independence. The effect of auditor independence on pay-opinion sensitivity is also studied. Some of the analytical results are:

- Including audit opinion in the compensation contract allows for increased pay-performance sensitivity. The impact on pay-performance sensitivity is higher when the auditor is more independent.

- The principal can induce a higher productive effort level by including audit opinion in the compensation contract. The impact on productive effort level increases as the auditor becomes more independent.
- The opposite result is true for unproductive effort level. The principal can induce the agent to reduce unproductive effort by including audit opinion in the compensation contract. Also, the more independent the auditor, the greater is the reduction in unproductive effort level.
- The agent is penalized for audit qualification. Interestingly, the pay-opinion sensitivity (the absolute value of the weight on audit opinion) does not increase monotonically as the auditor becomes more independent. All else equal, it first increases as audit independence increases and then decreases with audit independence. Intuitively, with increasing auditor independence, the need for audit opinion in the compensation contract decreases because the presence of the independent auditor itself exerts a control on the agent.

These results are of special interest due to their implication to empirical research studying auditor's independence and audit fees. Some of these above mentioned results are tested empirically with publicly available data. Empirical evidence shows that

- The executive is rewarded for higher reported earnings and penalized for departures from a standard unqualified opinion.
- The pay-performance sensitivity increases as the auditor becomes more independent. Auditor independence is measured by audit fee/(audit fee+ nonaudit fee).

The generalized model incorporates auditor independence (dealing with reporting) as well as auditor competence (dealing with detection of a breach). The analytical results are similar to the previous model showing auditor independence as well as competence help in creating proper incentives and control for the agent.

The general model is discussed in Chapter 4. Chapter 3 deals with the empirical study, and Chapter 2 focuses on the model with auditor independence.

2 Analytical Model I

This chapter deals with an agency which includes a principal (owner), an agent (manager), and a monitor (auditor). The principal hires the agent to act on his behalf and also hires the monitor to oversee the agent. The monitor is compensated with a fixed fee while the agent is compensated on his reported performance measure and the monitor's opinion about the reported performance measure. The agent is allowed to put forth productive as well as unproductive effort to inflate his performance measure. An analytical model is developed to study how a monitor's opinion can be a useful part in agent's compensation, and how it affects the agent's choice of productive as well as unproductive effort. The model also addresses different levels of monitor's independence, and how monitor's independence along with monitor's opinion affect agent's choice of productive and unproductive efforts.

2.1 Background

In agency theory, there is a principal (or owner) who hires an agent to work on his behalf. This may be due to time constraint, or geographical constraint or technological/knowlege constraint of the principal. The agent needs to put forth the effort to do the task he is responsible for. This imposes a disutility of effort on the agent as the agent is assumed to be effort averse. If the principal can observe the agent's expended effort, then he can contract based on agent's effort. This situation is known as the first best situation. However, the agent's effort is generally not observable, thus the principal may like to depend on monitoring. Complete monitoring may work for some tasks, however this is very costly as well as discouraging to the agent. Also, for certain tasks hundred percent monitoring may not be possible. This leaves the principal with one choice, that is to contract depending on a noisy indicator of agent's effort which are the performance measures of the agent.

As the principal relies on a noisy measure of effort, the principal needs to do two things. First, the principal needs to induce the best effort possible given that agent's effort is not observable. This involves factoring in the agent's preference function as well as his reservation wage. Second, the principal needs to compensate the agent with risk premium. The risk premium arises due to two reasons, (1) use of noisy performance measure which imposes risk on the agent, (2) the risk averse assumption of the agent. The situation where the principal contracts with the agent based on a noisy performance measure to induce the best effort after incorporating in the preference and risk aversion of the agent is known as the second best situation.

Depending on the responsibility of the agent, an agency theory model can be categorized as single task or multi task. A multi task framework is adopted when an agent is responsible for more than one task. For example, a professor in an academic institution is responsible for teaching as well as research. Generally, a multi task model differs from a single task model in the production function. The production function in a multi task model depends on agent's allocated effort in different tasks where as the production function in a single task model depends on a single dimensional effort. In short, multi task model is a generalization of single task model.

As already mentioned in the previous chapter, a performance based compensation provides incentive for two types of efforts. One type of effort (productive) helps to build up organization value and the other type of effort (unproductive) inflates agent's performance measure without affecting the value of the organization. This concept allows one to break a single task problem as double task, one dimension of effort builds up the organizational value and the other dimension does not affect the value, however, affects the agent's performance measure. This type of formulation was first considered by Feltham and Xie (1994, henceforth FX) and they call this "window dressing".

Due to this type of malfunction of performance based compensation, care needs to be taken to provide incentive for productive effort and control for unproductive effort at the same time. One way to address this problem is to include a monitor's signal in the compensation contract along with the performance measure reported by the agent. Note that the compensation contract does not necessarily have to explicitly incorporate the auditor's opinion, as long as the auditor's signal affects the agent's compensation. This dissertation provides an analysis of this type of compensation contract.

2.2 Model and Assumptions

I consider a single period principal agent model where an owner (principal) hires a manager (agent) to act on his behalf, and also employs an auditor to monitor the agent. The monitor is compensated with a fixed fee while the agent's compensation is based on his reported performance measure and the monitor's opinion about the reported performance measure. The firm's output x is not observed by the principal at the time the agent is paid, but is assumed to depend on the agent's productive effort level a. The time-line of the model is shown below.

Principal hires manager and monitor	Manager chooses effort levels	Manager reports his performance to the principal. Monitor provides his opinion to the principal	Manager and monitor get compensated	Firm's terminal value realized

The principal relies on a bivariate signal $y = (y_1, y_2)$ to compensate the agent where y_1 is the performance measure reported by the agent and y_2 is the auditor's estimate of agent's performance measure. I use the LEN (linear- exponential-normal) framework where x, y_1, and y_2 are assumed to follow normal distributions, the agent has negative exponential utility, and the risk neutral principal compensates the agent using a linear contract based on y_1, and y_2. Thus,

$$x = a + \epsilon_x$$

$$y_1 = \lambda a + b + \epsilon_1$$

$$y_2 = y_1 - \theta b + \epsilon_2$$

$$\Delta = y_1 - y_2 = \theta b - \epsilon_2$$

where:

y_1 is the agent's signal (net income or sales, depending on the type of responsibility of the agent), it depends on productive effort a as well as unproductive effort b.

y_2 is the auditor's estimate of the agent's signal; The audit opinion is based on the decision variable Δ which equals $y_1 - y_2$.

Δ is the decision variable used by the auditor for his opinion. This is a continuous version of audit opinion used here to develop the theory. A large (material) Δ is assumed to lead to qualified opinion. Throughout this paper Δ is referred to as "audit signal."

a is the productive effort and b is the unproductive effort.

ϵ_x, ϵ_1 and ϵ_2 are normally distributed with mean 0 and variance σ_x^2, σ_1^2, and σ_2^2 respectively. For technical simplicity, I assume ϵ_1 and ϵ_2 are independent.

The parameter λ is the sensitivity of the signal to the agent's productive effort level a; the sensitivity of the agent's signal to the unproductive effort level b is assumed to be one. This assumption can be relaxed with a more general sensitivity of b but the result does not change. Also, the mathematical expressions are simpler with sensitivity of b equal to one. Later, the model in Chapter 4 incorporates a more general sensitivity of b.

The parameter θ represents the level of independence of the auditor. It varies between 0 and 1. An auditor with θ equal to 0 represents a totally dependent auditor and θ equal to 1 represents a totally independent auditor. In the present model, θ is exogenously determined.

The present model incorporates all types of auditors, ranging from *totally dependent* ($\theta = 0$) to *totally independent* ($\theta = 1$). The best possible scenario for the principal is to hire an independent auditor with $\theta = 1$ and $\epsilon_2 = 0$. In that case, the auditor's report is based on the exact manipulated amount reported by the agent and Δ becomes b. However, this is an extreme situation. As DeAngelo (1981, page 117, footnote 8) mentions that "It is important to note that perfect independence is a Nirvana-type construct useful only as a benchmark". Watts and Zimmerman (1986, page 315, footnote 3) says "Note that we do not expect auditors to be totally independent (i.e., report discovered breaches with probability one)". Thus, realistically, $\theta < 1$, however, the analytical model does not require θ to be strictly less than one.

The worst possible scenario is to hire a totally dependent auditor with $\theta = 0$ and in that case, Δ equals $-\epsilon_2$ and no manipulation is reported even if b is large (with $-\epsilon_2$ small). The model requires θ to be positive in order to identify manipulation. This assumption can be linked to DeAngelo (1981, page 116). She writes " If the capital market expected the auditor never to deviate from management's position, then it would assess the value of the auditor's opinion as zero." This situation is discussed later again in Remark 2.3.

In the present model, the principal is assumed to be risk neutral and the agent is assumed to be risk averse with negative exponential utility $U(t) = -e^{-r(t-k(a,b))}$ with constant risk aversion r and cost of effort $k(a,b) = \dfrac{a^2}{2} + \dfrac{b^2}{2}$. The agent also has a reservation wage w_R. The agent's compensation is a linear function of y_1, and Δ. Here y_1 is the performance measure reported by the agent, and Δ the monitor's signal regarding the agent's reported measure. This framework with linear compensation, negative exponential utility, and normal errors is known as LEN framework. In a restrictive setting, Holmstrom and Milgrom (1987, 1991) show that the optimal compensation is a linear function of the outcome. Since then it has become standard in accounting literature. This framework allows closed form solutions which are good to examine the directional impact of certain incentives.

The present formulation represents "window dressing" or earnings management by the agent. The window dressing is captured by the fact that the output x is not affected by the unproductive effort b, and the agent's report y_1 involves a as well as b. More importantly, auditor's signal Δ depends on b, and auditor's assurance goes down as b increases, keeping θ constant. The auditor's assurance also depends on the independence parameter θ. For given b positive, the chance of providing clean opinion goes down as the auditor becomes more independent (θ increases).

This formulation is a generalization of FX's window dressing formulation. With $\theta = 1$, the present formulation reduces to the following:

$$x = a + \epsilon_x$$

$$y_1 = \lambda a + b + \epsilon_1$$

$$y_2 = y_1 - b + \epsilon_2$$

$$\Delta = y_1 - y_2 = b - \epsilon_2$$

This coincides with the window dressing case described in FX (page 442). FX focus on the value of additional signal like Δ in this case. They show that an additional signal has no value when it is just a noisy presentation of the other signal. This result is consistent with the Holmstrom (1979) sufficient statistics condition for value adding signal. Another contribution of FX's work is to allow the separation of firm's value x, and agent's performance measure y_1. This separation allows them to incorporate window dressing and myopic performance measure which frequently arise in practice.

The analytical results derived in the present work will hold for any valid performance measure accompanied with monitor's assuring signal. However, for empirical study, reported income is taken as y_1 and auditor's opinion is considered as monitor's signal. In this dissertation, the generalization of window dressing is applied to explain how auditor independence and opinion affect executive action and compensation.

Before considering the bivariate signal, I state the following proposition with one signal y_1.

Proposition 2.1: If the principal's problem is the following:

Problem P2.1

$$MaxE(x - A_0 - B_0 y_1)$$

s.t.

$$\int - e^{-r(A_0+B_0y_1-k(a,b))} f(y_1|a,b)dy_1 \geq -e^{-rw_R}$$

and

$$(a,b) \ \in \ argmax \ E(U(A_0 + B_0 y_1)|\hat{a}, \hat{b}),$$

then the optimal linear compensation plan is given by

$$a_0 = \frac{\lambda^2}{1 + \lambda^2 + r\sigma_1^2}$$

$$b_0 = \frac{\lambda}{1 + \lambda^2 + r\sigma_1^2}$$

$$A_0 = w_R - B_0^2(1 + \lambda^2 - r\sigma_1^2)/2$$

$$B_0 = a_0/\lambda = b_0$$

The proof of this proposition is simple and hence omitted. I state it here for comparing the compensation plans considered in this dissertation.

In the next section, I consider the case where the auditor's decision variable Δ is available. This case would be helpful for hypotheses development for empirical study.

2.3 Optimal Linear Compensation with Earnings and Auditor's Signal Δ

This section focuses on agent's compensation which is a linear function of y_1 and Δ. The principal pays the agent based on agent's report y_1 and monitor's report Δ before the firm's value x is realized. The principal keeps the residual after paying the agent and the monitor. However, the monitor is paid with a fixed fee, which allows the model to be free from monitoring fee. Thus, the compensation can be expressed as:

$$s(y_1, \Delta) \quad = \quad A_1 + By_1 - C_1\Delta$$

The principal's problem can be summarized as:

Problem P2.2.

$$MaxE(x - A_1 - B_1y_1 + C_1\Delta)$$

s.t.

$$\int\int - e^{-r(A_1+B_1y_1-C_1\Delta-k(a,b))}f(y_1, \Delta|a, b)dy_1d\Delta \geq -e^{-rw_R}$$

and

$$(a, b) \in argmaxE(U(A_1 + B_1y_1 - C_1\Delta)|\hat{a}, \hat{b})$$

Note that the weight on accounting earnings is given by B_1 and the weight on audit decision variable Δ is given by $-C_1$ implying a large positive Δ will penalize the agent if $C_1 > 0$. The following proposition gives the optimal weights of the signals y_1 and Δ. The proof is given in the Appendix.

Proposition 2.2: The optimal effort levels and weights for the principal-agent problem P2 are given by:

$$a_1 = \frac{\lambda^2(\theta^2 + r\sigma_2^2)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + r\sigma_2^2}$$

$$b_1 = \frac{\lambda r\sigma_2^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + r\sigma_2^2}$$

$$A_1 = w_R - B_1^2(1 + \lambda^2 - r\sigma_1^2)/2 - C_1^2(\theta^2 - r\sigma_2^2)/2 + B_1 C_1 \theta$$

$$B_1 = a_1/\lambda = \frac{\lambda(\theta^2 + r\sigma_2^2)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + r\sigma_2^2}$$

$$C_1 = \frac{\lambda\theta}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + r\sigma_2^2}$$

Remark 2.1: Note that $C_1 > 0$ if θ is positive. Thus, to penalize the agent for unjustified income inflation, the auditor needs to be independent to some extent. The optimal compensation plan penalizes the agent if Δ is positive. A positive Δ implies y_1 is higher than y_2, i.e., the agent's reported income is higher than the auditor's estimated income. In practice, an independent auditor demands adjustment if there is a material difference between his estimate y_2 and the agent's report y_1. If the agent fails to do that the auditor would provide a qualified opinion. There are other reasons for a departure from unqualified opinion in practice, but in this study I focus on Δ as the only decision variable of the auditor for technical simplicity. Appealing to conservatism, a positive Δ is referred as audit qualification in this study.

Proposition 2.2 and Remark 2.1 implies the following corollary.

Corollary 2.1: It is optimal to penalize the manager for audit qualifications, i.e., a positive C_1 and a positive Δ penalizes the agent.

Remark 2.2: One can also compute the value to the principal of the new signal Δ following FX. The value is defined as the difference in principal's surpluses $W - W_0$

where $W(W_0)$ is the principal's surplus when Δ is (not) used in the compensation contract. The following corollary expresses the value of the signal Δ.

Corollary 2.2: The value of the audit signal Δ is given by

$$W - W_0 = \frac{\lambda^2\theta^2}{2(\lambda^2 + r\sigma_1^2 + 1)((\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + r\sigma_2^2)}$$
$$= C_1 \frac{\lambda\theta}{2(\lambda^2 + r\sigma_1^2 + 1)}$$

The proof of corollary 2.2 follows from the proof of corollary 4.2 which is provided in the appendix.

Remark 2.3: It is clear from the above corollary 2 that the signal Δ has no value if θ is zero. Intuitively, if the auditor is totally dependent ($\theta = 0$) the audit signal should have no value. Technically, in this case, $\Delta = -\epsilon_2$, and following Holmstrom (1979, Section 5) y_1 is then sufficient for (y_1, Δ) which further implies that Δ is not informative. This concept is also considered in DeAngelo (1981, page 116) as mentioned earlier in the chapter.

The effect of including audit signal, Δ, in the compensation contract, is further explored in terms of effort levels and incentives placed on y_1. The following corollary expresses that the audit signal Δ plays the desired roles in the compensation contract, namely, inducing productive effort and discouraging unproductive effort.

Corollary 2.3: Compensating the agent using accounting earnings as well as audit signal allows for :

1. Higher pay-performance sensitivity (i.e., $B_1 > B_0$).
2. Higher level of productive effort (i.e., $a_1 > a_0$).
3. Lower level of unproductive effort (i.e., $b_1 < b_0$).

The proof of Corollary 2.3 is similar to that of Corollary 4.3 which is provided in the Appendix. Besides the above corollaries, the role of Δ and the effect of the exogenous parameters can be summarized in the following table. The proofs of the results summarized in TABLE 1 are similar to those of TABLE 6 which are provided in the Appendix.

TABLE 1

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
σ_1	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	No Change	$\downarrow$	$\downarrow\uparrow$	$\downarrow$
σ_2	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$
λ	$\uparrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	No Change	$\uparrow\downarrow$	?	$\uparrow\downarrow$
θ	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow\downarrow$	$\downarrow\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$

Intuitive reasoning for the comparative statics reported in the above table 1 is as follows:

As σ_1 increases, the signal y_1 becomes less precise which drives B_1 down. As B_1 goes down, the incentive on y_1 goes down which drags down the productive effort level a_1 as well as the level of unproductive level b_1. Also, as b_1 goes down with B_1, there is less need of monitoring (represented by audit opinion) which drags C_1 down. This reduced need of control is also reflected in the reduced value of the audit report, $W - W_0$ and reduced impact $B_1 - B_0$.

As σ_2 increases, the signal Δ gets less precise. This drives C_1 down which in turn drives b_1 up due to lack of control. To reduce this problem of increased unproductive effort, the incentive B_1 decreases. The decrease in B_1 reduces the level of productive effort a_1. The reduced precision of signal Δ is reflected in the reduced value $W - W_0$, reduced impact $B_1 - B_0$.

As λ increases, the sensitivity of y_1 with respect to a increases. This boosts B_1

up for small λ. However, for large λ, the high sensitivity itself works as an incentive causing B_1 to decrease. This property of B_1 leads to similar increasing/decreasing property of C_1 as well as b_1. All these combined drive similar increasing/decreasing behavior of audit signal's value, namely, $W - W_0$ as well as $B_1 - B_0$.

As θ increases, the audit report becomes more sensitive with respect to unproductive effort b which drives C_1 up for small θ. However, for large θ, C_1 goes down as the presence of independent auditor itself works as a control mechanism. This control mechanism brings b_1 down, first by audit penalty when θ is small, and then by the presence of independent auditor itself when θ is large. Thus, b_1 decreases monotonically when θ increases. This property of b_1 allows the firm to put more incentive on net income ($B_1 \uparrow$) as in this case the harmful side effect of more incentive is under control. This monotonic increase in B_1 leads to increased productive effort level a_1. Also, increased auditor independence provides (1) more value of the audit report which is reflected in increased $W - W_0$, (2) more impact on unproductive effort reflected in increased $b_0 - b_1$, (3) more impact on productive effort reflected in increased $B_1 - B_0$ $(=(a_1 - a_0)/\lambda)$.

In brief, the optimal linear compensation involving reported earnings and auditor's signal have been derived in this chapter. The optimal weights on earnings and auditor's signal show that the agent is rewarded for higher earnings and penalized for audit qualification. The induced efforts (both productive and unproductive) and the optimal weights have many interesting properties which are summarized in TABLE 1. To name a few properties,

- Including auditor's signal in the compensation contract allows for increased pay-performance sensitivity ($B_1 > B_0$). The pay-performance sensitivity is higher when the auditor is more independent ($B_1 \uparrow$ as $\theta \uparrow$).

- The principal can induce a higher productive effort level by including auditor's signal in the compensation contract ($a_1 > a_0$). The induced productive effort level increases as the auditor becomes more independent ($a_1 \uparrow$ as $\theta \uparrow$).

- The opposite result is true for unproductive effort level. The principal can induce the agent to reduce unproductive effort by including auditor's signal in the compensation contract ($b_1 < b_0$). Also, the more independent the auditor, the greater is the reduction in unproductive effort level ($b_1 \downarrow$ as $\theta \uparrow$).

- The agent is penalized for audit qualification. Interestingly, the pay-opinion sensitivity (the absolute value of the weight on audit opinion) does not increase monotonically as the auditor becomes more independent. All else equal, it first increases as audit independence increases and then decreases with audit independence. Intuitively, with increasing auditor independence, the need for audit opinion in the compensation contract decreases because the presence of the independent auditor itself exerts a control on the agent.

In the next chapter, some of these analytical properties are tested empirically with publicly available data.

3 Empirical Study

This chapter empirically examines the effect of auditor independence and auditor opinion on executive compensation. Before getting into the detail of the empirical study, I would like to discuss the general composition of executive compensation. Executive compensation is composed of different components, namely, salary, bonus, total value of options granted, total value of restricted stock granted, long term incentive payouts, and all other compensation.

Salary is the fixed component of compensation, and is generally set at the beginning of the period, and does not depend on CEO performance. However, a change in salary from one period to another may depend on performance (Lynch and Perry 2003, page 46, footnote 4). In recent years salaries make a small fraction of total executive compensation, however, base salaries typically play an important role in determining the other components of compensation, namely, target bonuses, option grants, pension and other severance packages (Murphy 1999, page 9-10).

Bonus is a performance dependent award which can be set by board of directors or can be based on a strict formula. It can be based on either individual or divisional or corporate performance level. Murphy (1999, page 10) categorized bonus plans in terms of three basic components, namely, performance measures, performance standards, and the pay-performance relationship. Usually, there are two thresholds defining a bonus plan, one lower and one upper, depending on the performance standard. A minimum bonus is paid when the lower threshold is achieved, and the maximum or target bonus is paid when the upper threshold is achieved. The zone in between the lower and upper thresholds is called the "incentive zone" where bonus increases with performance.

Long term incentive plans (LTIP) are performance based awards depending on three to five year cumulative performance of the employee. The structure of LTIP is generally similar to that of an annual bonus plan.

All other compensation includes contribution to employee pension funds, life insurance premiums, accidental death premiums, payment for unused vacation, etc.

Restricted stocks are company stocks granted to award an employee when certain restrictions are met. The restriction generally is related to employee longevity. The cost of a restricted stock award is measured by the grant date market value of the number of shares in the award and it is expensed over the employee service period which is often the vesting period (Lynch and Perry 2003, page 49, footnote 10)

Stock options granted to an employee give rights to purchase a specific number of shares at a given price for a given period. The given price, known as exercise price, is generally set at the stock price of the day it is granted. The given period is called the option period or life of the option. Life of an option generally lasts for five to ten years and there is also a restrictive (vesting) period before which it can not be exercised. Stock options can be fixed as well as variable options. In fixed options, the exercise price and number of shares are fixed at the grant date. In variable options, the exercise price as well as the number of shares can vary over the life of the option. Fixed options are more common than variable options in most industries.

Valuation of stock options is an important issue. Previously, the cost of granted stock options were measured by the "intrinsic value method" under APB Opinion 25. Under this method, the option value is measured by the difference of exercise price and grant date market price multiplied by the number of shares in the option granted. For most options, the exercise price is equal to the grant date market price. Thus, under the intrinsic value method, the cost of granting stock option is calculated to be zero. After a long debate over more than a decade, in December 2004 FASB issued SFAS

123R which requires companies to expense stock option values calculated by the fair value method. The most widely used method for valuing options under fair value is the Black-Scholes method. The Black-Scholes method depends on many assumptions which may not always be valid. Thus, Black-Scholes values are not free from biases. Murphy (1999, page 17) explains the reasons for upward as well as downward biases in Black-Scholes values. The executive compensation database uses Black-Scholes methodology for determining option value.

Thus, executive compensation has many different components. In this chapter, I empirically examine how auditor independence and opinion affect executive compensation. The empirical study focuses on some of the analytical results related to audit independence (θ) as summarized in table 1 in chapter 2 and also on Proposition 2.2 and Corollary 2.1. I mainly study empirically how executive compensation relates to accounting earnings and audit opinion and how the weights B_1 and C_1 in the compensation contract vary with θ. Considering the comparative statics reported in table 1, I have the following three hypotheses stated in alternate form:

Hypothesis 1: Compensation is positively related to earnings and negatively related to audit opinion, all else remaining the same.

Hypothesis 2: The pay-performance sensitivity increases ($B_1 \uparrow$) as the auditor becomes more independent ($\theta \uparrow$), assuming all else remain the same.

Hypothesis 3: The audit-opinion sensitivity (C_1)

(1) increases as the auditor becomes more independent ($\theta \uparrow$), for small values of θ, assuming all else remain the same.

(2) decreases as the auditor becomes more independent ($\theta \uparrow$), for large values of θ, assuming all else remain the same.

The first hypothesis directly follows from Proposition 2.2 and Corollary 2.1. As a reminder, the assumed linear compensation is $s(y_1, \Delta) = A_1 + By_1 - C_1\Delta$ where the coefficient on y_1 is positive (by Proposition 2.2) and that of Δ is negative (by Corollary 2.1). The first part of Hypothesis 1 has already been established by a number of researchers (e.g., Murphy, Lambert and Larker). The second part of hypothesis 1 is new and is of particular interest.

The hypotheses 2 and 3 follow directly from table 1. The intuition behind these hypotheses is that as θ increases, the audit signal becomes more valuable which drives C_1 up for small θ. However, for large θ, C_1 goes down as the presence of an independent auditor itself works as a control mechanism. This control mechanism brings b_1 down, first due to inclusion of audit opinion in compensation when θ is small, and then by the presence of independent auditor itself when θ is large. Thus, b_1 decreases monotonically when θ increases. This property of b_1 allows the firm to put more incentive on net income ($B_1 \uparrow$) as in this case the harmful side effect of more incentive on net income is under control.

Some of the results in Table 1 have already been established empirically. Results in Frankel et al. (2002) show a significant positive association between non-audit fees and earnings management. They show that firms with higher FEERATIO (non-audit fee/total fee) have significantly higher absolute discretionary accruals on the average (Frankel et al. 2002, table 4, page 86). This result is comparable to the findings in Table 1 in chapter 2 that $b_1 \downarrow$ as $\theta \uparrow$. If absolute discretionary accrual can be taken as a proxy for unproductive effort and FEERATIO as a proxy for $1 - \theta$, then the chapter 2 findings are in the same line as Frankel et al. (2002). However, other studies (e.g., Ashbaugh et al. 2003) question these results.

3.1 Sample Selection and Regression Model:

The model developed in Chapter 2 applies to a single firm (or agency). Thus, for empirical verification it would have been better if we had enough firm specific observations. However, due to data restrictions, specifically for compensation and audit fees, we do not have enough firm specific observations to run firm specific regression. As a result the models are estimated cross-sectionally.

The sample consists of 3004 firm years from 2001 to 2003 covering all industries. The firm fundamentals are collected from the Compustat Industrial, the audit fee data are collected from the Audit fee of the Compustat data file and compensation data are collected from the Execucomp of the Compustat data file.

The regression model developed here depends very much on the linear compensation structure assumed in the paper, namely, $s(y_1, \Delta) = A_1 + B_1 y_1 - C_1 \Delta$. The measure of CEO compensation considered in this paper is the total compensation including salary, bonus, total value of options granted, total value of restricted stock granted, and long term incentive pay outs (CEOPAY). Due to high skewness of compensation data, I work with log of ceo compensation.

For accounting earnings y_1 the variable considered is ROA, to control for wide variation in accounting earnings in the cross-sectional sample.

For a proxy for Δ, I use a dummy variable $OPINION$ which is based on auditor's opinion. Audit opinion takes the values 0, 1, 2, 3, 4, 5 in Compustat data file. In the sample, I mainly have 1's and 4's. These are defined later in the chapter.

For a proxy for auditor's independence parameter, θ, I consider the ratio audit fee/total fee, where total fee is the sum of audit related fees, tax fees, fees paid for other services and fees for auditing financial statements. Audit fee is the fee for auditing financial statements. This measure of independence is in accordance with the view that nonaudit fees impair auditor independence. A similar measure nonaudit fee/total fee has been used by Frankel et al. (2002) where they provide evidence that firms purchasing nonaudit services from their auditors report higher discretionary accruals. Their measure of nonaudit fees include financial information system and other fees whereas the nonaudit fee in this dissertation does not include financial information system fees paid to the auditor. One reason for not including financial information system fees is that the financial information system development does not happen every year and the sample considered here ranges from 2000 to 2003. Frankel et al. (2002) collect the audit and nonaudit fee data from proxy statements filed between February 5, 2001 to June 15, 2001.

For controlling other parameters in the regression model I include log of total assets in the regression model. Logarithm of audit fee is included for controlling the level of monitoring apart from the ratio. Thus, I run the following two regression models:

$$logcomp = \beta_0 + \beta_1 ROA + \beta_2 OPINION + \beta_3 RATIO + \beta_4 logasset + \beta_5 logaudit + \epsilon_1$$

$$logcomp = \beta_0 + \beta_1 ROA + \beta_2 OPINION + \beta_3 RATIO + \beta_4 ROA * RATIO$$
$$+ \beta_5 logasset + \beta_6 logaudit + \epsilon_2$$

where logcomp = log(CEOPAY) = log of ceo compensation including salary, bonus, granted stock options, restricted stock, and long term incentive pay outs.

ROA = data178/average total assets, where data178 stands for operating income after depreciation in Compustat Annual Industrial.

OPINION = It is a dummy variable to represent audit opinion. Audit opinion takes values 0 (financial statements not audited), 1 (unqualified opinion), 2 (qualified opinion), 3 (disclaimer or no opinion), 4 (unqualified with explanatory language) and 5 (adverse opinion). Firms with audit opinion 0 have been deleted from the sample. With this, the sample has audit opinion 1 (with frequency 1088), 2 (with frequency 3) and 4 (with frequency 1913). Variable $OPINION$ is a dummy variable which is 0 if audit opinion is 1, and 1 otherwise. Therefore, $OPINION$ distinguishes standard unqualified opinions from all other opinions. Although, explanatory paragraphs do not represent a qualification of the financial statements, they do represent a less clear signal and were considered qualifications in earlier time periods.

RATIO = audit fee/total fee where total fee is the sum of audit related fees, tax related fees, fees paid for other services and fees for auditing financial statements. Audit fee is the fee for auditing financial statements.

logasset = log(total asset); total asset is data6 in the compustat data file.

logaudit = log(audit fee) where audit fee is the fee for auditing financial statements.

The proxy OPINION is particularly noisy, as the opinion category 1 may not always imply a detected breach.

3.2 Results:

The results in TABLE 2 gives the means of all the independent and the dependent variables. The total assets are measured in millions of US dollars whereas the audit fees and ceo compensations are measured in thousands of US dollars.

TABLE 2

Descriptive Statistics

Variables	N	Mean	Std Dev	Minimum	Maximum
LOGCOMP	3004	7.8043	1.2909	−6.9077	11.4955
LOGASSET	3004	7.4787	1.6739	2.2283	14.0498
LOGAUDIT	3004	6.7435	1.1705	0.4694	11.2896
ROA	3004	0.0771	0.1104	−1.2007	0.642
OPINION	3004	0.6378	0.4807	0	1
RATIO	3004	0.5959	0.1933	0.0071	0.9964
ROA∗RATIO	3004	0.0448	0.0717	−1.057	0.5725

The TABLE 3 shows Pearson correlations and the p-values for significance test. The number at the top of each box represents the correlation and the number below represents the p-value. The Pearson correlations in TABLE 3 shows that most of the correlations are significant except in four cases. However, most of the correlations do not pose serious multi-collinearity problem in regression as the regression shows significant results. The highest correlation is observed between ROA and ROA*RATIO which is 0.9225. This high correlation poses a problem in multiple regression which is addressed later in this section.

TABLE 3

PEARSON CORRELATION

	LOGASSET	LOGAUDIT	ROA	OPINION	RATIO	ROA∗RATIO
LOGCOMP	0.5038 < .0001	0.4363 < .0001	0.1564 < .0001	0.0838 < .0001	−0.0949 < .0001	0.1335 < .0001
LOGASSET		0.7678 < .0001	0.0914 < .0001	0.2122 < .0001	−0.0449 0.0138	0.0762 < .0001
LOGAUDIT			0.0059 0.7457	0.2608 < .0001	0.0487 0.0076	0.0084 0.6446
ROA				−0.0188 0.3025	−0.0533 0.0035	0.9225 < .0001
OPINION					0.0654 0.0003	0.0063 0.7291
RATIO						0.1689 < .0001

The results in the first part of TABLE 4 shows that both ROA and OPINION are significant with the predicted signs. This supports Hypothesis 1. The second part of Table 4 shows a positive significant coefficient on ROA*RATIO, however, the significance of ROA vanishes when the interaction term ROA*RATIO is added in the model. This happens due to high correlation between ROA and $ROA * RATIO$.

TABLE 4

OLS regression results with dependent variable logcomp

Variables	Predicted Signs	Coefficient	p value	Coefficient	p value
Intercept		4.71324	$< .00005$	4.79246	$< .00005$
ROA	+	1.36549	$< .00005$	.34693	.2684
OPINION	−	−.08061	.0309	−.08367	.0264
RATIO	−	−.51995	$< .00005$	−.65690	$< .00005$
ROA∗RATIO	+			1.68113	.0277
logasset	+	.28676	$< .00005$	.28561	$< .00005$
logaudit	+	.17831	$< .00005$	.18071	$< .00005$
Adjusted R^2			.2798		.2804

To avoid this problem, I run the following regression model. I first divide the sample in two groups using the variable RATIO. First we find the median of the variable RATIO, which is approximately equal to 0.6. Group 1 has RATIO 0.6 or lower, and Group 2 has RATIO higher than 0.6. Then I run the following regression model

$$logcomp = \beta_0 + \beta_1 ROA + \beta_2 OPINION + \beta_3 logasset + \beta_4 logaudit + \epsilon$$

separately for two groups. Table 5 gives the results. The results show that ROA is significant in both groups and the coefficient of ROA is (significantly) higher for high ratio group which supports hypothesis 2. To test whether the pay-performance sensitivity is significantly higher in the high ratio group, I use the statistic

$$\frac{(1.6525 - 1.1329)}{\sqrt{(0.2214^2 + 0.2906^2)}}$$

$$= 1.4227$$

which is significant at 10% level with p-value= 0.0774. The denominator of the above statistic represents the standard errors of the coefficients of ROA in low and high ratio groups respectively.

TABLE 5

OLS regression results with dependent variable logcomp run separately in low and high RATIO groups

		RATIO Low		RATIO High	
Variables	Predicted Signs	Coefficient	p value	Coefficient	p value
Intercept		4.67609	$< .00005$	4.08938	$< .00005$
ROA	+	1.13295	$< .00005$	1.65254	$< .00005$
OPINION	−	−.05679	.1285	−.12823	.0361
logasset	+	.31788	$< .00005$	.26023	$< .00005$
logaudit	+	.11578	.0001	.24312	$< .00005$
Adjusted R^2			.3392		.2354

TABLE 5 shows that the coefficient of OPINION is lower in the high RATIO group. The coefficient of OPINION is not significant in the low ratio group but significant in the high ratio group. More detailed studies using less noisy opinion data are necessary to further test hypothesis 3. One such potential measure is the report on internal control required by Section 404 of the Sarbanes -Oxley Act.

I also use a few other measures of independence different from RATIO. These measures depend on client specific audit (nonaudit or total)fees compared to total audit fees (nonaudit or total) coming to the audit firm in a given year. However, I do not get significant results with these measures of independence.

The overall implications of the empirical study are:

- on the average for higher ROA the ceo compensation is higher when other variables are controlled at the same level. Also, for higher OPINION, the ceo compensation is lower on the average when all other variables are kept constant. This result supports hypothesis 1.

- the coefficient of ROA is higher for the high ratio group. This result indicates that the pay-performance increases as ratio increases supporting hypothesis 2.

- the coefficient of OPINION is lower in high ratio group. However, the coefficient is not significant in the low ratio group. This result provides weak support to hypothesis 3. A more refined division of ratio groups as well as more refined proxy for audit signal are needed to provide evidence for hypothesis 3 which I leave for future research due to data limitations.

In the next chapter, I shall discuss a more general analytical model which involves auditor competence as well as independence.

4 Analytical Model II with Auditor Competence and Independence

This chapter studies an analytical model which incorporates auditor competence as well as auditor independence. This is a generalization of the model discussed in chapter 2. Similar to chapter 2, optimal linear compensation contract is derived for an agent who is hired by the owner of a firm to act on his behalf. The owner also hires a monitor to oversee the agent and compensates him with a fixed fee. The agent is allowed to inflate his performance measure by expending productive as well as unproductive effort. As in chapter 2, the agent's compensation depends on his reported performance measure and the monitor's opinion about his performance measure. The closed form solution of the optimal linear compensation allows one to study the effect of monitor's signal and monitor's independence/competence level on agent's compensation and agent's choice of efforts.

4.1 Model Assumptions

The previous model in Chapter 2 deals with auditor independence, and auditor competence level is assumed to be constant. As Watts and Zimmerman (1986, page 314) write:

" The probability an auditor reports a breach, conditional on a breach occurring, depends on

1. The probability that the auditor *discovers* a breach.

2. The probability that the auditor *reports* the discovered breach.

The first probability (discovery) depends on the auditor's competence and the quantity of inputs devoted to audit. The second probability (reporting) refers to auditor's independence from the client."

In Chapter 2, the probability of discovering a breach is assumed to be constant. In this chapter, I relax this assumption and introduce a new parameter ν to represent the level of competence of the auditor to discover a breach. This parameter ν can be thought as the probability of discovering a breach which depends on auditor competence as well as input. However, I refer to ν as auditor's competence parameter to mean competence and input both, for simplicity.

The other modification deals with the sensitivity of unproductive effort. This sensitivity is assumed to be one in chapter 2. I now allow it to be different from one and use a new parameter μ to represent this sensitivity. Thus, the generalized model is similar to the previous model with these modifications.

Similar to the previous case, the firm's output x is not observed by the principal at the time the agent is paid, but is assumed to depend on the agent's productive effort level a. The principal relies on a bivariate signal $y = (y_1, y_2)$ to compensate the agent. The LEN framework is used where x, y_1 and y_2 are assumed to follow normal distributions, the agent has negative exponential utility, and the risk neutral principal compensates the agent using a linear contract based on y_1, and y_2. Thus,

$$x = a + \epsilon_x$$

$$y_1 = \lambda a + \mu b + \epsilon_1$$

$$y_2 = y_1 - \theta \nu \mu b + \epsilon_2$$

$$\Delta = y_1 - y_2 = \theta \nu \mu b - \epsilon_2$$

where:

y_1 is the agent's signal (net income or sales, depending on the type of responsibility of the agent);

y_2 is the auditor's estimate of the agent's signal;

Δ is the decision variable used by the auditor for his opinion. A large (material) Δ is assumed to lead to qualified opinion. Throughout this paper Δ is referred as audit signal.

ϵ_x, ϵ_1 and ϵ_2 are normally distributed with mean 0 and variance σ_x^2, σ_1^2 and $\sigma_2^2(1-\nu)$ respectively. Also, ϵ_1 and ϵ_2 are assumed to be independent. The change in the variance assumption of ϵ_2 is to incorporate the auditor competence. The idea is that the probability of breach discovery becomes higher as ν increases to one. With $\nu = 1$ the auditor signal Δ becomes noise free as the variance of ϵ_2 becomes zero.

The parameter λ is the sensitivity of the signal to the agent's productive effort level a and μ is the sensitivity of the agent's signal to the unproductive effort level b. This formulation represents "window dressing" or earnings management by the agent. The fact that the performance measure is affected by the unproductive effort b but the output is not affected by b is considered as manipulation by the agent. The parameters θ and ν represent the level of independence and the level of competence of the auditor, respectively. They both vary between 0 and 1. An auditor with θ equal to 0 represents a totally dependent auditor and θ equal to 1 represents a totally independent auditor. An auditor with ν equal to 0 represents an auditor with no competence, and ν equal to 1 represents an auditor with highest level of competence.

y_2 is the auditor's estimate, and the audit report is based on the decision variable Δ which equals $y_1 - y_2$.

The present model incorporates all combinations of dependent, independent, competent, incompetent auditors. The best possible scenario for the principal is to hire an independent, competent auditor with $\theta = 1$ and $\nu = 1$. In that case, the auditor can figure out exactly the manipulated amount reported by the agent, namely, μb and Δ becomes free of noise. However, this is an extreme situation, and represents a limiting case. The worst possible scenario is to hire an incompetent and dependent auditor with $\theta = 0$ and $\nu = 0$. In that case, Δ equals ϵ_2 and no manipulation is reported if ϵ_2 is small. The model requires both θ and ν to be positive in order to identify manipulation. With one of the parameters θ or ν equal to zero, the auditor's report Δ becomes uninformative.

As before, the principal is assumed to be risk neutral and the agent is assumed to be risk averse with negative exponential utility $U(t) = -e^{-r(t-k(a,b))}$ with constant risk aversion r and cost of effort $k(a,b) = a^2/2 + b^2/2$. The agent also has a reservation wage w_R.

Before considering the bivariate signal, I would like to state the following proposition with one signal y_1.

Proposition 4.1: If the principal's problem is the following:

Problem P4.1

$$MaxE(x - A_0 - B_0 y_1)$$

s.t.

$$\int -e^{-r(A_0 + B_0 y_1 - k(a,b))} f(y_1|a,b)dy_1 \geq -e^{-rw_R}$$

and

$$(a,b) \; \in \; argmax \; E(U(A_0 + B_0 y_1)|\hat{a}, \hat{b}),$$

then the optimal compensation plan is given by

$$a_0 = \frac{\lambda^2}{\mu^2 + \lambda^2 + r\sigma_1^2}$$

$$b_0 = \frac{\lambda\mu}{\mu^2 + \lambda^2 + r\sigma_1^2}$$

$$A_0 = w_R - B_0^2(\lambda^2 + \mu^2)/2 + r\sigma_1^2 B_0^2/2$$

$$B_0 = a_0/\lambda = b_0/\mu$$

The proof of this proposition is simple and hence omitted. I state it here for comparing the compensation plans considered in this paper.

4.2 Optimal Linear Compensation with Earnings and Auditor's Signal Δ

This section focuses on agent's compensation

$$s(y_1, \Delta) = A_1 + By_1 - C_1\Delta$$

The principal's problem can be summarized as:

Problem P4.2

$$MaxE(x - A_1 - B_1y_1 + C_1\Delta)$$

s.t.

$$\int\int - e^{-r(A_1+B_1y_1-C_1\Delta-k(a,b))} f(y_1, y_2|a, b)dy_1dy_2 \geq -e^{-rw_R}$$

and

$$(a, b) \in argmaxE(U(A_1 + B_1y_1 - C_1\Delta)|\hat{a}, \hat{b})$$

Note that the weight on accounting earnings is given by B_1 and the weight on audit report Δ is given by $-C_1$ implying a large positive Δ will penalize the agent. The following proposition gives the optimal weights of the signals y_1 and Δ. The proof is given in the Appendix.

Proposition 4.2: The optimal effort levels and weights for the principal-agent problem P4.2 are given by:

$$a_1 = \frac{\lambda(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$b_1 = \frac{\lambda\mu r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$A_1 = w_R - B_1^2(\lambda^2 + \mu^2 - r\sigma_1^2)/2 - C_1^2(\theta^2\nu^2\mu^2 - r\sigma_2^2(1-\nu))/2 + B_1 C_1\theta\nu\mu^2$$

$$B_1 = a_1/\lambda = \frac{\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$C_1 = \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

Remark 4.1: Note that $C_1 > 0$ if θ and ν are both positive. Thus, to penalize the agent for unjustified income inflation, the auditor needs to be independent and competent, to some extent. The optimal compensation plan penalizes the agent if Δ is positive. A positive Δ implies y_1 is higher than y_2, i.e., the agent's reported income is higher than the auditor's estimated income. In practice, an independent auditor demands adjustment if there is a material difference between his estimate y_2 and the agent's report y_1. If the agent fails to do that, the auditor would provide a qualified opinion. There are other reasons for a departure from unqualified opinion in practice, but in this dissertation I focus on Δ as the only decision variable of the auditor for technical simplicity. Appealing to conservatism, a positive Δ is referred as audit qualification in this paper.

Corollary 4.1: It is optimal to penalize the manager for audit qualifications, i.e., a positive C_1 and a positive Δ penalizes the agent.

One can also compute the value to the principal of the new signal Δ following Feltham and Xie (1994). The value is defined as the difference in principal's surpluses $W - W_0$ where $W(W_0)$ is the principal's surplus when Δ is(not) used in the compensation contract. The following corollary expressed the value of the signal Δ.

Corollary 4.2: The value of the audit signal Δ is given by

$$W - W_0 = \frac{\lambda^2\theta^2\nu^2\mu^4}{2(\lambda^2 + r\sigma_1^2 + \mu^2)((\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2)}$$

$$= C_1 \frac{\lambda\theta\nu\mu^2}{2(\lambda^2 + r\sigma_1^2 + \mu^2)}$$

The proof of the above corollary is provided in the appendix.

It is clear from the above corollary that the signal Δ has no value if any of θ or ν is zero. Intuitively, if the auditor is totally dependent ($\theta = 0$) or totally incompetent ($\nu = 0$) the audit signal should have no value. Technically, in this case, $\Delta = \epsilon_2$, and following Holmstrom (1979) y_1 is then sufficient for (y_1, Δ).

The effect of including audit signal Δ in the compensation contract is further explored in terms of effort levels and incentives placed on y_1. The following corollary expresses that the audit signal Δ plays the desired roles in the compensation contract, namely, inducing productive effort and discouraging unproductive effort.

Corollary 4.3: Compensating the agent using accounting earnings as well as audit signal allows for:

1. Higher pay-performance sensitivity (i.e., $B_1 > B_0$).
2. Higher level of productive effort (i.e., $a_1 > a_0$).
3. Lower level of unproductive effort (i.e., $b_1 < b_0$).

The proof of Corollary 4.3 is given in the Appendix.

Besides the above corollaries, the role of Δ and the role of the parameters can be summarized in the following table. The proofs of the results summarized in TABLE 6 are provided in the Appendix.

TABLE 6

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
σ_1	↓	↓	↓	↓	No Change	↓	↓↑	↓
σ_2	↓	↑	↓	↓	↑	↓	↓	↓
λ	↑	↑↓	↑↓	↑↓	No Change	↑↓	?	↑↓
μ	↓	↑↓	↓	↑	↓	↑	?	↑
θ	↑	↓	↑	↑↓	↓↑	↑	↑	↑
ν	↑	↓	↑	↑↓	↓↑	↑	↑	↑

The intuitive reasoning for the comparative statics reported in the above table is as follows:

As σ_1 increases, the signal y_1 becomes less precise which drives B_1 down. As B_1 goes down, the incentive on y_1 goes down which drags down the productive effort level a_1 as well as the level of unproductive effort b_1. Also, as b_1 goes down with B_1, there is less need of audit penalty which drags C_1 down. This reduced need of control is also reflected in the reduced value of the audit report, $W - W_0$ and reduced $B_1 - B_0$.

As σ_2 increases, the signal Δ gets less precise. This drives C_1 down which in turn drives b_1 up due to lack of control. To reduce this problem of increased unproductive effort, the incentive B_1 decreases. The decrease in B_1 reduces the level of productive effort a_1. The reduced precision of signal Δ is reflected in the reduced value $W - W_0$, $B_1 - B_0$.

As λ increases, the sensitivity of y_1 with respect to productive effort a increases. This boosts B_1 up for small λ. However, for large λ, the high sensitivity itself works as an incentive causing B_1 to decrease. This property of B_1 leads similar increasing/decreasing property of C_1 as well as b_1. All these combined drive similar increasing/decreasing behavior of audit report's value, namely, $W - W_0$ as well as

$B_1 - B_0$.

As μ increases, the sensitivity of the audit report Δ with respect to unproductive effort b increases. This drives C_1 up, monotonically. Also, as μ increases, it creates more incentive for unproductive effort which drives b_1 up for small μ. However, for large μ, a high audit penalty pulls b_1 down. Thus, with μ increasing, the audit report becomes more useful which increases the value $W - W_0$ as well as $B_1 - B_0$. As μ increases the control mechanism is more important than the incentive mechanism. This drives B_1 down which drags down the productive effort level a_1 due to lack of incentives. It is interesting to note that C_1 increases monotonically when μ increases, where as B_1 first increases and then decreases when λ increases.

As θ increases, the audit report becomes more precise which drives C_1 up for small θ. However, for large θ, C_1 goes down as the presence of independent auditor itself works as a control mechanism. This control mechanism brings b_1 down, first by audit penalty when θ is small, and then by the presence of independent auditor itself when θ is large. Thus, b_1 decreases monotonically when θ increases. This property of b_1 allows the firm to put more incentive on net income ($B_1 \uparrow$) as in this case the harmful side effect of more incentive is under control. This monotonic increase in B_1 leads to increased productive effort level a_1. Also, increased auditor independence provides (1) more value of the audit report which is reflected in increased $W - W_0$, (2) more impact on unproductive effort reflected in increased $b_0 - b_1$, (3) more impact on productive effort reflected in increased $B_1 - B_0$ $(=(a_1 - a_0)/\lambda)$.

Increased audit competence ν has similar effects as increased θ. Thus, audit independence and audit competence both have similar effect on the incentives, effort levels, and principal's surplus, provided ν and θ are both positive.

Before I finish this chapter, I would like to emphasize a few points about the present model. The model in this chapter differs from the model in chapter 2 in the following ways:

- This model incorporates auditor competence as well as auditor independence while the previous model in chapter 2 only deals with auditor independence.
- The model in this chapter incorporates a sensitivity μ of the unproductive effort which was assumed to be one in the model considered in chapter 2.
- The most important feature in the present model is the assumption of the variance of ϵ_2 which is assumed to be $\sigma_2^2(1-\nu)$. Thus, the higher the competence of the auditor the lower is the noise level in audit signal Δ. In case of perfect competence, i.e. $\nu = 1$ the audit signal becomes noise free. This is a feature which was not captured in the model of chapter 2 where the variance of ϵ_2 was σ_2^2 a constant.

In brief, the optimal linear compensation involving reported earnings and auditor's signal have been derived in this chapter. The optimal weights on earnings and auditor's signal show that the agent is rewarded for higher earnings and penalized for audit qualification. The induced efforts (both productive and unproductive) and the optimal weights have many interesting properties which are summarized in TABLE 6. To name a few properties,

- Including auditor's signal in the compensation contract allows for increased pay-performance sensitivity ($B_1 > B_0$). The pay-performance sensitivity is higher when the auditor is more independent or more competent ($B_1 \uparrow$ as $\theta \uparrow$ also $B_1 \uparrow$ as $\nu \uparrow$).

- The principal can induce a higher productive effort level by including auditor's signal in the compensation contract ($a_1 > a_0$). The induced productive effort level increases as the auditor becomes more independent or more competent ($a_1 \uparrow$ as $\theta \uparrow$ and $a_1 \uparrow$ as $\nu \uparrow$).

- The opposite result is true for unproductive effort level. The principal can induce the agent to reduce unproductive effort by including auditor's signal in the compensation contract ($b_1 < b_0$). Also, the more independent/competent the auditor, the greater is the reduction in unproductive effort level ($b_1 \downarrow$ as $\theta \uparrow$ and $b_1 \downarrow$ as $\nu \uparrow$).

- The agent is penalized for audit qualification. Interestingly, the pay-opinion sensitivity (the absolute value of the weight on audit opinion) does not increase monotonically as the auditor becomes more independent (or more competent). All else equal, it first increases as audit independence (competence) increases and then decreases with audit independence (competence). Intuitively, with increasing auditor independence/competence, the need for audit opinion in the compensation contract decreases because the presence of the independent/competent auditor itself exerts a control on the agent.

Thus, the model involving auditor competence as well as auditor independence give similar results as the previous model with only auditor independence. I do not have a proper proxy for auditor competence, presently, which does not allow me to test empirically the results with auditor competence. An easy competence proxy can be audit firm size, which is a popular measure of audit quality. However, in my sample 97% are Big 4 firms, thus this proxy does not work well for my sample. Future studies may use a better proxy for competence (which also includes audit input) such as a firm's internal audit hour and billing rate data as used by Davis, Ricchiute, Trompeter (1993) in their audit, nonaudit service related study. However, this type of internal data is difficult to obtain.

5 Conclusion

5.1 Summary of Findings

This dissertation studies the effect of an auditor's signal on an agent's compensation. Analytical results show that the principal is better off when the auditor's signal is included in the agent's compensation plan. The principal can induce a higher level of productive effort and a lower level of unproductive effort by including the audit signal in the compensation contract. The more independent the auditor, the greater the effect on effort levels. The results also show that the pay-performance sensitivity is higher when the auditor is more independent, however the pay-opinion sensitivity varies in a different way when the auditor is more independent. Some of these analytical results are tested empirically with publicly available data. Empirical evidence shows that the executive is rewarded for higher reported earnings and penalized for audit reports other than standard unqualified. The empirical results also show that the pay-performance sensitivity increases as the auditor becomes more independent.

An analytical model incorporating auditor independence as well as competence is also developed. Similar to the earlier model, the analytical results show that the auditor competence has similar effect on effort levels and principal's surplus as auditor independence.

5.2 Limitations and Directions for Future Research

- In practice, the principal may not have access to the auditor's decision variable (Δ). Instead, the principal has access to auditor's opinion which is based on auditor's decision variable. The financial statements of public firms come with auditor's opinion, which can be broadly categorized in five categories. For modelling purpose, I assume here that auditor's opinion is of two types, namely, qualified and unqualified, and the agent's compensation is

$$s(y_1, \delta) = A_2 + B_2 y_1 - C_2 \delta$$

where

$$\delta = 1_{y_1 - y_2 > \alpha} = 1_{\Delta > \alpha}$$

Here, $\delta = 1$ stands for qualified opinion and $\delta = 0$ represents unqualified opinion. Unfortunately, this problem does not have a closed form solution and I plan to study it numerically. Numerical study for the audit opinion case is under investigation. This way one can compare the numerical results with the analytical results when auditor's decision variable Δ is available.

- A better proxy for Δ is highly desirable. Due to unavailability of refined data, auditor's opinion is used as a proxy for Δ in this dissertation.

- A suitable proxy for auditor competence will be very useful to test empirically the analytical results related to auditor competence in chapter 4.

- Incorporate stock price in the compensation plan in addition to earnings and audit opinion. Preliminary results show that the incentive weight on earnings increases with inclusion of audit opinion, whereas the incentive weight on stock price decreases with the inclusion of audit opinion. The more independent the auditor, the greater is the impact on these weights.

  The results remain similar to what has been described in this dissertation: By including audit opinion in addition to earnings and stock price, the principal can induce higher level of productive effort and control the unproductive effort at a lower level. This impact on effort levels is more pronounced when the auditor is more independent.

6 Appendix

Proof of Proposition 2.2: I start with the constraint,

$$(a, b) \in argmax_{\hat{a},\hat{b}}\, E(U(A_1 + B_1 y_1 - C_1\Delta|\hat{a}, \hat{b})$$

$$E(U(s(y_1, y_2)|a, b) \;=\; \int\int -e^{-r(A_1+B_1y_1-C_1\Delta-k(a,b))} f(y_1, \Delta|a, b)dy_1 d\Delta$$

Now,

$$B_1 y_1 - C_1\Delta \;\sim N(B_1(\lambda a + b) - C_1\theta b,\; B_1^2\sigma_1^2 + C_1^2\sigma_2^2)$$

Thus

$$E(U(s(y_1, \Delta)|a, b) = -e^{rk(a,b)-rA_1-rB_1(\lambda a+b)+rC_1\theta b+r^2(B_1^2\sigma_1^2+C_1^2\sigma_2^2)/2}$$

Let

$$\sigma^2 = \; B_1^2\sigma_1^2 + C_1^2\sigma_2^2$$

The F.O.C. implies

$$\frac{\partial(rk(a, b) - rA_1 - rB_1(\lambda a + b) + rC_1\theta b + r^2\sigma^2/2)}{\partial a} = 0$$

$$\frac{\partial(rk(a, b) - rA_1 - rB_1(\lambda a + b) + rC_1\theta b + r^2\sigma^2/2)}{\partial b} = 0$$

These imply

$$rk'(a, b) - rB_1\lambda = 0$$

$$rk'(a, b) - rB_1 + rC_1\theta = 0$$

Solving these two equations using $k(a, b) = a^2/2 + b^2/2$ we get

(1) $$a = B_1\lambda$$

(2) $$b = B_1 - C_1\theta$$

To determine A_1, we appeal to the constraint

$$-e^{-rA_1+rk(a,b)-rB_1(\lambda a+b)+rC_1\theta b+r^2\sigma^2/2} \geq -\ e^{-rw_R}$$

where w_R is the agents reservation wage. Now, assuming equality,

$$-rA_1 + rk(a,b) - rB_1(\lambda a + b) + C_1\theta b + r^2\sigma^2/2 \ = -rw_R$$

$$\Rightarrow A_1 = w_R + k(a,b) - B_1(\lambda a + b) + C_1\theta b + r\sigma^2/2$$

Thus using $k(a,b) = a^2/2 + b^2/2$ and $a = B_1\lambda$, $b = B_1 - C_1\theta$ we have

(3) $$A_1 = w_R - (a^2 + b^2)/2 + r\sigma^2/2$$

Now the principal's objective function,

$$E(x - A_1 - B_1 y_1 + C_1\Delta)$$

$$= a - (w_R - (a^2 + b^2)/2 + r\sigma^2/2) - B_1(\lambda a + b) + C_1\theta b$$

$$= a - w_R - (a^2 + b^2)/2 - r\sigma^2/2$$

$$= B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta)^2/2 - w_R - r\sigma^2/2$$

Thus F.O.C. implies

$$\frac{\partial B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta)^2/2 - w_R - r\sigma^2/2}{\partial B_1} = 0$$

$$\frac{\partial B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta)^2/2 - w_R - r\sigma^2/2}{\partial C_1} = 0$$

This implies

(4) $$\lambda - B_1\lambda^2 - (B_1 - C_1\theta) + rB_1\sigma_1^2 = 0$$

$$(B_1 - C_1\theta)\theta - rC_1\sigma_2^2 = 0 \tag{5}$$

These equations can be written as

$$\lambda - B_1(1 + \lambda^2 + r\sigma_1^2) - C_1\theta = 0 \tag{6}$$

$$B_1 = C_1(\theta^2 + r\sigma_2^2)/\theta \tag{7}$$

Solving these equations give

$$B_1 = \frac{\lambda(\theta^2 + r\sigma_2^2)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + (r\sigma_2^2)} \tag{8}$$

$$C_1 = \frac{\lambda\theta}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + (r\sigma_2^2)} \tag{9}$$

Now

$$a = B_1\lambda = \frac{\lambda^2(\theta^2 + r\sigma_2^2)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + (r\sigma_2^2)} \tag{10}$$

and

$$b = B_1 - C_1\theta = \frac{\lambda r\sigma_2^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2 + \theta^2) + (r\sigma_2^2)} \tag{11}$$

Using equations 3, 10, and 11 one gets

$$A_1 = w_R - B_1^2(1 + \lambda^2 - r\sigma_1^2)/2 - C_1^2(\theta^2 - r\sigma_2^2)/2 + B_1C_1\theta$$

This proves Proposition 2.2.⋈⋈

Proof of Proposition 4.2: I start with the constraint,

$$(a, b) \in argmax_{\hat{a},\hat{b}}\, E(U(A_1 + B_1y_1 - C_1\Delta|\hat{a}, \hat{b})$$

$$E(U(s(y_1, y_2)|a, b) \;=\; \int\!\!\int -e^{-r(A_1+B_1y_1-C_1\Delta-k(a,b))} f(y_1, \Delta|a, b)dy_1d\Delta$$

Now,

$$B_1y_1 - C_1\Delta \;\sim N(B_1(\lambda a + \mu b) - C_1\theta\nu\mu b,\; B_1^2\sigma_1^2 + C_1^2\sigma_2^2(1 - \nu))$$

Thus

$$E(U(s(y_1,\Delta)|a,b) = -e^{rk(a,b)-rA_1-rB_1(\lambda a+\mu b)+rC_1\theta\nu\mu b+r^2(B_1^2\sigma_1^2+C_1^2\sigma_2^2(1-\nu))/2}$$

Let

$$\sigma^2 = \; B_1^2\sigma_1^2 + C_1^2\sigma_2^2(1-\nu)$$

The F.O.C. implies

$$\frac{\partial(rk(a,b) - rA_1 - rB_1(\lambda a + \mu b) + rC_1\theta\nu\mu b + r^2\sigma^2/2)}{\partial a} = 0$$

$$\frac{\partial(rk(a,b) - rA_1 - rB_1(\lambda a + \mu b) + rC_1\theta\nu\mu b + r^2\sigma^2/2)}{\partial b} = 0$$

These imply

$$rk'(a,b) - rB_1\lambda = 0$$

$$rk'(a,b) - rB_1\mu + rC_1\theta\nu\mu = 0$$

Solving these two equations using $k(a,b) = a^2/2 + b^2/2$ we get

$$a = B_1\lambda \tag{12}$$

$$b = B_1\mu - C_1\theta\nu\mu \tag{13}$$

To determine A_1, I appeal to the constraint

$$-e^{-rA_1+rk(a,b)-rB_1(\lambda a+\mu b)+rC_1\theta\nu\mu b+r^2\sigma^2/2} \geq -\; e^{-rw_R}$$

where w_R is the agents reservation wage. Now, assuming equality,

$$-rA_1 + rk(a,b) - rB_1(\lambda a + \mu b) - C_1\theta\nu\mu b + r^2\sigma^2/2 \; = -rw_R$$

$$\Rightarrow A_1 = w_R + k(a,b) - B_1(\lambda a + \mu b) + C_1\theta\nu\mu b + r\sigma^2/2$$

Thus using $k(a,b) = a^2/2 + b^2/2$ and $a = B_1\lambda$, $b = B_1\mu - C_1\theta\nu\mu$ I have

$$A_1 = w_R - (a^2 + b^2)/2 + r\sigma^2/2 \tag{14}$$

Now the principal's objective function,

$$E(x - A_1 - B_1 y_1 + C_1\Delta)$$

$$= a - (w_R - (a^2 + b^2)/2 + r\sigma^2/2) - B_1(\lambda a + \mu b) + C_1\theta\nu\mu b$$

$$= a - (w_R - (a^2 + b^2)/2 + r\sigma^2/2) - (a^2 + b^2)$$

$$= a - w_R - (a^2 + b^2)/2 - r\sigma^2/2$$

$$= B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta\nu)^2\mu^2/2 - w_R - r\sigma^2/2$$

Thus F.O.C. implies

$$\frac{\partial B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta\nu)^2\mu^2/2 - w_R - r\sigma^2/2}{\partial B_1} = 0$$

$$\frac{\partial B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta\nu)^2\mu^2/2 - w_R - r\sigma^2/2}{\partial C_1} = 0$$

This implies

$$\lambda - B_1\lambda^2 - (B_1 - C_1\theta\nu)\mu^2 + rB_1\sigma_1^2 = 0 \tag{15}$$

$$(B_1 - C_1\theta\nu)\mu^2\theta\nu - rC_1\sigma_2^2(1-\nu) = 0 \tag{16}$$

These equations can be written as

$$\lambda - B_1(\mu^2 + \lambda^2 + r\sigma_1^2) + C_1\theta\nu\mu^2 = 0 \tag{17}$$

$$B_1 = C_1(\theta^2\nu^2\mu^2 + r\sigma_2^2(1-\nu))/\theta\nu\mu^2 \tag{18}$$

Solving these equations give

$$B_1 = \frac{\lambda(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} \tag{19}$$

$$C_1 = \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} \tag{20}$$

From equations 12, 13, and 14 one gets

$$A_1 = w_R - B_1^2(\mu^2 + \lambda^2 - r\sigma_1^2)/2 \tag{21}$$

$$-C_1^2(\theta^2\nu^2\mu^2 - r\sigma_2^2(1-\nu))/2 + B_1C_1\theta\nu\mu^2$$

From equations 12 and 19 one gets

$$a_1 = \frac{\lambda(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} \tag{22}$$

From equations 13 and 20 one gets

$$b_1 = \frac{\lambda\mu r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} \tag{23}$$

This proves Proposition 4.2.⋈⋈

Proof of Corollary 4.2:

I start with the principal's surplus

$$W = E(x - A - B_1y_1 + C_1\Delta)$$

$$= a - (w_R - (a^2+b^2)/2 + r\sigma^2/2) - B_1(\lambda a + \mu b) + C_1\theta\nu\mu b$$

$$= a - (w_R - (a^2+b^2)/2 + r\sigma^2/2) - (a^2+b^2)$$

$$= a - w_R - (a^2+b^2)/2 - r\sigma^2/2$$

$$= B_1\lambda - B_1^2\lambda^2/2 - (B_1 - C_1\theta\nu)^2\mu^2/2 - r/2(B_1^2\sigma_1^2 + C_1^2\sigma_2^2(1-\nu)) - w_R$$

$$= \frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{D} - \frac{\lambda^4(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))^2}{2D^2} - \frac{(\lambda\mu r\sigma_2^2(1-\nu))^2}{2D^2}$$
$$-r\frac{\lambda^2(\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))^2\sigma_1^2}{2D^2} - r\,\frac{\lambda^2\theta^2\nu^2\mu^4\sigma_2^2(1-\nu)}{2D^2} - w_R$$

where

$$D = (\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2$$

Thus,

$$W = \frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{D} - \frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))^2}{2D^2}(\lambda^2 + r\sigma_1^2)$$
$$-\frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{2D^2}(\mu^2 r\sigma_2^2(1-\nu)) - w_R$$
$$= \frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{D}(1 - \frac{(\lambda^2 + r\sigma_1^2)(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{2D} - \frac{\mu^2 r\sigma_2^2(1-\nu))}{2D}) - w_R$$
$$= \frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{D}(1 - \frac{D}{2D}) - w_R$$
$$= \frac{\lambda^2(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{2D} - w_R$$

Thus, from Proposition 4.2,

$$2W = a_1 - w_R \tag{24}$$

Now, the principal's surplus W_0 with y_1 alone is

$$W_0 = \lim_{\sigma_2\to\infty} W$$

$$2W_0 = \lim_{\sigma_2\to\infty} \frac{\lambda(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} - w_R$$
$$= \lim_{\sigma_2\to\infty} \frac{\lambda^2(\frac{\mu^2\theta^2\nu^2}{r\sigma_2^2(1-\nu)} + 1)}{(\lambda^2 + r\sigma_1^2)(\frac{\mu^2\theta^2\nu^2}{r\sigma_2^2(1-\nu)} + 1)} - w_R$$

$$= \frac{\lambda^2}{\lambda^2 + r\sigma_1^2 + \mu^2} - w_R$$

Thus, from Proposition 4.1,

$$2W_0 = a_0 - w_R \tag{25}$$

Thus, the difference of principal's surpluses is $W - W_0$. For mathematical simplicity I work with $2(W - W_0)$.

$$2(W - W_0) = \frac{\lambda(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} - \frac{\lambda^2}{\lambda^2 + r\sigma_1^2 + \mu^2}$$

$$= \lambda^2 \frac{(\lambda^2 + r\sigma_1^2 + \mu^2)(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu)) - (\lambda^2 + r\sigma_1^2 + \mu^2)r\sigma_2^2(1-\nu) - (\lambda^2 + r\sigma_1^2)(\mu^2\theta^2\nu^2)}{(\lambda^2 + r\sigma_1^2 + \mu^2)D}$$

$$= \frac{\lambda^2\theta^2\nu^2\mu^4}{(\lambda^2 + r\sigma_1^2 + \mu^2)D}$$

$$= C_1 \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2 + \mu^2)}$$

This proves Corollary 4.2. ⋈⋈

Proof of Corollary 4.3:

Proof of $B_1 > B_0$:

From Proposition 4.2

$$B_1 = \frac{\lambda(\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

From Proposition 4.1

$$B_0 = \frac{\lambda}{\mu^2 + \lambda^2 + r\sigma_1^2}$$

After simplification,

$$B_1 - B_0 = \frac{\lambda\theta^2\nu^2\mu^4}{(\lambda^2 + r\sigma_1^2 + \mu^2)D}$$

where

$$D = (\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2$$

Thus,

$$B_1 - B_0 > 0$$

which proves part(1) of Corollary 4.3.

Proof of $a_1 > a_0$ follows from $B_1 > B_0$ as $a_1 = B_1\lambda$ and $a_0 = B_0\lambda$.

Proof of $b_1 < b_0$: Once again propositions 4.1 and 4.2 give

$$b_1 = \frac{\lambda\mu r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$b_0 = \frac{\lambda\mu}{\mu^2 + \lambda^2 + r\sigma_1^2}$$

After simplification

$$b_1 - b_0 = \frac{-\lambda\mu^3\theta^2\nu^2(\lambda^2 + r\sigma_1^2)}{(\lambda^2 + r\sigma_1^2 + \mu^2)((\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2)}$$

This implies $b_1 < b_0$ and this completes the proof of corollary 4.3.$\bowtie\bowtie$

Lemma 1: Consider a function

$$f(x) = Lx + Mx^{-1}$$

for $x > 0$ and L, M both positive. This function is decreasing in x if $x^2 < M/L$ and increasing if $x^2 > M/L$. The function attains minimum at $x = M/L$.

Proof of Lemma 1: The proof follows immediately by noting that

$$f'(x) = L - Mx^{-2}$$

which implies the required functional behavior of $f(x)$ described in Lemma 1.

Proofs of the results summarized in TABLE 6: The proofs are categorized row wise.

Proof of the results summarized in first row of TABLE 6:

The first row is given by

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
σ_1	↓	↓	↓	↓	No Change	↓	↓↑	↓

From proposition 4.2 one notes that σ_1 appears only in the denominator of a_1, b_1, B_1, C_1 and all these quantities are positive. These immediately imply that all of a_1, b_1, B_1, C_1 decrease as σ_1 increases. Also, the ratio B_1/C_1 is independent of σ_1 which indicates B_1/C_1 is not affected by σ_1. Corollary 4.2 indicates that $W - W_0$ involves σ_1 only in the denominator. Also, $W - W_0 > 0$ which implies that $W - W_0$ decreases as σ_1 increases. The proof of corollary 4.3 indicates $B_1 - B_0$ involves σ_1 only in the denominator. Also, $B_1 - B_0 > 0$ which imply $B_1 - B_0$ decreases with σ_1. Finally, for $b_0 - b_1$ note from the proof of corollary 4.3 that

$$\begin{aligned} b_0 - b_1 &= \frac{\lambda\mu^3\theta^2\nu^2(\lambda^2 + r\sigma_1^2)}{(\lambda^2 + r\sigma_1^2 + \mu^2)((\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2)} \\ &= \frac{\lambda\mu^3\theta^2\nu^2}{(\lambda^2 + r\sigma_1^2 + \mu^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + \dfrac{r\sigma_2^2(1-\nu)\mu^2}{\lambda^2 + r\sigma_1^2}} \end{aligned}$$

I define

$$f(\lambda^2 + r\sigma_1^2) \;=\; (\lambda^2 + r\sigma_1^2)(\theta^2\nu^2\mu^2 + r\sigma_2^2(1-\nu)) \;+\; \frac{\mu^4 r\sigma_2^2(1-\nu)}{\lambda^2 + r\sigma_1^2}$$

Using Lemma 1 with $L = \theta^2\nu^2\mu^2 + r\sigma_2^2(1-\nu)$ and $M = \mu^4 r\sigma_2^2(1-\nu)$ one gets $f(\lambda^2 + r\sigma_1^2)$ decreasing in $(\lambda^2 + r\sigma_1^2)$ if $(\lambda^2 + r\sigma_1^2)^2 < M/L$ and increasing if $(\lambda^2 + r\sigma_1^2)^2 > M/L$.

Also, note that

$$b_0 - b_1 = \frac{\lambda\mu^3\theta^2\nu^2}{f(\lambda^2 + r\sigma_1^2) + \textit{terms independent of } \sigma_1}$$

As the denominator decreases for $(\lambda^2 + r\sigma_1^2)^2 < M/L$ and increases for $(\lambda^2 + r\sigma_1^2)^2 > M/L$, the reverse is true for $b_0 - b_1$. This completes the proof of $b_0 - b_1$ increasing as σ_1 increases for small σ_1^2 and decreasing as σ_1 increases for large σ_1. This completes the proof of the first row of TABLE 6.

The proof of the second row of TABLE 6:

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
σ_2	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$

To show $a_1 \downarrow as\ \sigma_2 \uparrow$: Note that a_1 can be expressed as

$$a_1 = \frac{\lambda^2}{(\lambda^2 + r\sigma_1^2) + \cfrac{\mu^2}{1 + \cfrac{\theta^2\nu^2}{r\sigma_2^2(1-\nu)}}}$$

This shows $a_1 \downarrow$ as $\sigma_2 \uparrow$.

Also, $B_1 = a_1/\lambda$ which immediately implies that $B_1 \downarrow$ as $\sigma_2 \uparrow$. For $B_1 - B_0$, note that B_0 does not depend on σ_2 which implies $B_1 - B_0$ behaves in the same way as B_1 with respect to σ_2.

It is easy to see that C_1 decreases as σ_2 increases as C_1 involves σ_2 only in the denominator, and C_1 is positive.

To show $W - W_0$ decreases as σ_2 increases, note that it involves σ_2 only through C_1 (Corollary 4.2). Thus, the behavior of $W - W_0$ with respect to σ_2 would be exactly the similar to that of C_1 which implies $W - W_0 \downarrow$ as $\sigma_2 \uparrow$.

To show $b_1 \uparrow as\ \sigma_2 \uparrow$: The expression for b_1 given in Proposition 4.2 can be expressed as

$$b_1 = \frac{\lambda\mu}{(\lambda^2 + r\sigma_1^2) + \mu^2 + \dfrac{\mu^2\theta^2\nu^2(\lambda^2 + r\sigma_1^2)}{r\sigma_2^2(1-\nu)}}$$

This shows $b_1 \uparrow$ as $\sigma_2 \uparrow$.

For $b_0 - b_1$, note that b_0 does not involve σ_2. This further implies that $b_0 - b_1$ behaves like $-b_1$ with respect to σ_2 which is $b_0 - b_1 \downarrow$ as $\sigma_2 \uparrow$. This completes the proof of second row of TABLE 6.

The proof of third row of TABLE 6.

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
λ	$\uparrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	No Change	$\uparrow\downarrow$	?	$\uparrow\downarrow$

From proposition 4.2

$$a_1 = \frac{\lambda(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

By dividing the numerator and denominator by λ^2 one gets

$$a_1 = \frac{\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu)}{(1 + r\sigma_1^2/\lambda^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2/\lambda^2}$$

Thus, the denominator is a decreasing function of λ, which proves $a_1 \uparrow$ as $\lambda \uparrow$.

Proposition 4.2 gives

$$b_1 = \frac{\lambda\mu r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$= \frac{\mu r\sigma_2^2(1-\nu)}{(\lambda + r\sigma_1^2/\lambda)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2/\lambda}$$

Thus, the denominator can be expressed as

$$f(\lambda) = L\lambda + M\lambda^{-1}$$

where

$$L = (r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2)$$

and

$$M = (r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2)r\sigma_1^2 + r\sigma_2^2(1-\nu)\mu^2$$

Using Lemma 1, the denominator of b_1 is decreasing if $\lambda^2 < M/L$ and increasing if $\lambda^2 > M/L$. Thus, b_1 is increasing for $\lambda^2 < M/L$ and decreasing for $\lambda^2 > M/L$.

From proposition 4.2

$$\begin{aligned} B_1 &= \frac{(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} \\ &= \frac{\mu^2\theta^2\nu^2 + r\sigma_2^2(1-\nu)}{(\lambda + r\sigma_1^2/\lambda)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2/\lambda} \end{aligned}$$

Thus, the denominator can be expressed as

$$f(\lambda) = L\lambda + M\lambda^{-1}$$

where

$$L = (r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2)$$

and

$$M = (r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2)r\sigma_1^2 + r\sigma_2^2(1-\nu)\mu^2$$

Using Lemma 1, the denominator of B_1 is decreasing if $\lambda^2 < M/L$ and increasing if $\lambda > M/L$. Thus, B_1 is increasing for $\lambda^2 < M/L$ and decreasing for $\lambda > M/L$. The proof of C_1 increasing (decreasing) for small (large)λ follows in similar way. Also, B_1/C_1 remains unchanged when λ changes as B_1/C_1 is independent of λ.

For C_1 the result is again non-monotonous. To prove that note from Proposition 4.2 that

$$C_1 = \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$= \frac{\theta\nu\mu^2}{(\lambda + r\sigma_1^2/\lambda)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2/\lambda}$$

Thus, the denominator of C_1 can be expressed as

$$f(\lambda) = L\lambda + M\lambda^{-1}$$

$$L = (r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2)$$

and

$$M = (r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2)r\sigma_1^2 + r\sigma_2^2(1-\nu)\mu^2$$

Using Lemma 1, the denominator of C_1 is decreasing if $\lambda^2 < M/L$ and increasing if $\lambda^2 > M/L$. Thus, C_1 is increasing for $\lambda^2 < M/L$ and decreasing for $\lambda^2 > M/L$.

From the proof of Corollary 4.2, I have the following

$$2(W - W_0) = \frac{\lambda(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} - \frac{\lambda^2}{\lambda^2 + r\sigma_1^2 + \mu^2}$$

$$= \frac{1}{1 + L_1 t} - \frac{1}{1 + L_2 t}$$

where

$$L_1 = r\sigma_1^2 + \frac{r\sigma_2^2(1-\nu)\mu^2}{r\sigma_2^2(1-\nu) + \theta^2\nu^2\mu^2}$$

$$L_2 = r\sigma_1^2 + \mu^2$$

and

$$t = \lambda^{-2}$$

Thus

$$2(W - W_0) = \frac{(L_2 - L_1)t}{(1 + L_1 t)(1 + L_2 t)}$$

$$= \frac{(L_2 - L_1)}{(1/t + L_1)(1 + L_2 t)}$$

$$= \frac{(L_2 - L_1)}{L_1 L_2 t + 1/t + (L_1 + L_2)}$$

Let $f(t) = L_1 L_2 t + 1/t$. By Lemma 1, $f(t)$ is increasing if $t^2 > 1/L_1 L_2$ and decreasing if $t^2 < 1/L_1 L_2$. Also, it is easy to see that $L_1 < L_2$. Thus, the denominator of $W - W_0$ is decreasing for $t^2 < 1/(L_1 L_2)$ and increasing for $t^2 > 1/(L_1 L_2)$. This implies $W - W_0$ is increasing in t for $t^2 < 1/(L_1 L_2)$ and decreasing in t for $t^2 > 1/(L_1 L_2)$. Noting that $t = 1/\lambda^2$, one can see that $W - W_0$ is increasing in λ for $1/\lambda^4 < 1/(L_1 L_2)$ and decreasing in λ for $1/\lambda^4 > 1/(L_1 L_2)$. This implies the required result.

Lastly, to establish the result for $B_1 - B_0$. From equations 24 and 25, and the fact that $B_1 = a_1/\lambda$ and $B_0 = a_0/\lambda$ imply that

$$2(B_1 - B_0) = 2(W - W_0)/\lambda = \frac{(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2} - \frac{\lambda}{\lambda^2 + r\sigma_1^2 + \mu^2}$$

$$= \frac{1}{\lambda + L_1/\lambda} - \frac{1}{\lambda + L_2/\lambda}$$

where

$$L_1 = r\sigma_1^2 + \frac{r\sigma_2^2(1-\nu)\mu^2}{r\sigma_2^2(1-\nu) + \theta^2\nu^2\mu^2}$$

and

$$L_2 = r\sigma_1^2 + \mu^2$$

Thus,

$$2(B_1 - B_0) = \frac{(L_2 - L_1)/\lambda}{(\lambda + L_1/\lambda)(\lambda + L_2/\lambda)}$$

$$= \frac{(L_2 - L_1)}{(\lambda^2 + L_1)(\lambda + L_2/\lambda)}$$

$$= \frac{(L_2 - L_1)}{(\lambda^3 + (L_1 + L_2)\lambda + L_1 L_2/\lambda)}$$

Let

$$g(\lambda) = \lambda^3 + (L_1 + L_2)\lambda + L_1 L_2/\lambda$$

This implies

$$g'(\lambda) = 3\lambda^2 + (L_1 + L_2) - L_1L_2/\lambda^2$$

Thus to have

$$g'(\lambda) > 0$$

one needs

$$3\lambda^2 + (L_1 + L_2) - L_1L_2/\lambda^2 > 0$$

$$3\lambda^4 + (L_1 + L_2)\lambda^2 - L_1L_2 > 0$$

$$\lambda^4 + (L_1 + L_2)\lambda^2/3 - L_1L_2/3 > 0$$

$$\lambda^4 + (L_1 + L_2)\lambda^2/3 + (L_1 + L_2)^2/36 - (L_1 + L_2)^2/36 - L_1L_2/3 > 0$$

$$(\lambda^2 + \frac{L_1 + L_2}{6})^2 > (L_1 + L_2)^2/36 + L_1L_2/3$$

$$(\lambda^2 + \frac{L_1 + L_2}{6}) > ((L_1 + L_2)^2/36 + L_1L_2/3)^{1/2}$$

$$\lambda^2 > ((L_1 + L_2)^2/36 + L_1L_2/3)^{1/2} - (L_1 + L_2)/6 = L_3(say)$$

Thus, the denominator of $B_1 - B_0$ is increasing in λ if $\lambda^2 > L_3$ and decreasing if $\lambda^2 < L_3$. This proves that $B_1 - B_0$ is increasing in λ if $\lambda^2 < L_3$ and decreasing if $\lambda^2 > L_3$. This completes the proof of third row TABLE 6.

Proof of fourth row of TABLE 6

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
μ	$\downarrow$	$\uparrow\downarrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\uparrow$	?	$\uparrow$

To show $a_1 \downarrow as\ \mu \uparrow$: Note that a_1 can be expressed as

$$a_1 = \cfrac{\lambda^2}{(\lambda^2 + r\sigma_1^2) + \cfrac{\mu^2}{1 + \cfrac{\theta^2\nu^2}{r\sigma_2^2(1-\nu)}}}$$

This shows $a_1 \downarrow$ as $\mu \uparrow$.

Also, $B_1 = a_1/\lambda$ which immediately implies that $B_1 \downarrow$ as $\mu \uparrow$.

To show $C_1 \uparrow$ as $\mu \uparrow$, note from Proposition 4.2 that

$$C_1 = \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$
$$= \frac{\lambda\theta\nu}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu)/\mu^2 + \theta^2\nu^2) + r\sigma_2^2(1-\nu)}$$

Thus the denominator of C_1 decreases as μ increases which further implies $C_1 \uparrow$ as $\mu \uparrow$. This result together with the result $B_1 \downarrow$ as $\mu \uparrow$ implies that B_1/C_1 decreases as μ increases.

To show $(W - W_0) \uparrow$ as $\mu \uparrow$, note from Corollary 4.2 that

$$W - W_0 = C_1 \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2 + \mu^2)}$$

As C_1 increases in μ, it is enough to show that $\frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2 + \mu^2)}$ increases in μ. Now

$$\frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2 + \mu^2)}$$
$$= \frac{\lambda\theta\nu}{(\lambda^2/\mu^2 + r\sigma_1^2/\mu^2 + 1)}$$

This is an increasing function of μ which immediately implies that $(W - W_0) \uparrow$ as $\mu \uparrow$.

To prove $B_1 - B_0$ increases with μ, it is easy to use that

$B_1 - B_0 = (W - W_0)/\lambda$. To prove $b_1 \uparrow\downarrow$ as μ increases, note from Proposition 4.2 that

$$b_1 = \frac{\lambda\mu r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$
$$= \frac{\lambda r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu)/\mu + \mu\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu}$$

Thus, the denominator of b_1 can be expressed as

$$f(\mu) = L\mu + M\mu^{-1}$$

where $L = (\lambda^2 + r\sigma_1^2)(\theta^2\nu^2) + r\sigma_2^2(1-\nu)$ and $M = (\lambda^2 + r\sigma_1^2)r\sigma_2^2(1-\nu)$. By Lemma 1, $f(\mu)$ increases if $\mu^2 > M/L$ and decreases if $\mu^2 < M/L$. This implies b_1 increases if

$\mu^2 < M/L$ and decreases if $\mu^2 > M/L$. This completes the proof of fourth row of TABLE 6.

Proof of the fifth row of TABLE 6:

The fifth row of TABLE 6 is

	a_1	b_1	B_1	C_1	B_1/C_1	$W-W_0$	b_0-b_1	B_1-B_0
θ	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow\downarrow$	$\downarrow\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$

To show $a_1 \uparrow as\ \theta \uparrow$: Note that a_1 can be expressed as

$$a_1 = \frac{\lambda^2}{(\lambda^2 + r\sigma_1^2) + \dfrac{r\sigma_2^2(1-\nu)\mu^2}{r\sigma_2^2(1-\nu) + \theta^2\nu^2\mu^2}}$$

This shows $a_1 \uparrow$ as $\theta \uparrow$.

Also, $B_1 = a_1/\lambda$ which immediately implies that $B_1 \uparrow$ as $\theta \uparrow$.

For $B_1 - B_0$, note that B_0 does not involve θwhich implies that $B_1 - B_0$ behaves in the same way as does B_1 with respect to θ.

From equations 24 and 25, it is immediate that

$$2(W - W_0) = a_1 - a_0$$

. Also, a_0 does not involve θ which implies that $W - W_0$ behaves in the same way as does a_1 with respect to θ.

For b_1, note that θ appears only in the denominator which implies b_1 is inversely related to θ. Also, $b_1 - b_0$ behaves in the same way with respect to θ as b_1 as b_0 does not involve θ.

However, for C_1 the result is non-monotonous. To prove that note from Proposition 4.2 that

$$C_1 = \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$

$$= \frac{\lambda\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu)/\theta + \mu^2\theta\nu^2) + r\sigma_2^2(1-\nu)\mu^2/\theta}$$

Thus, the denominator of C_1 can be expressed as

$$f(\theta) = L\theta + M\theta^{-1}$$

where $L = (\lambda^2 + r\sigma_1^2)(\mu^2\nu^2)$ and $M = (\lambda^2 + r\sigma_1^2 + \mu^2)r\sigma_2^2(1-\nu)$. By Lemma 1, $f(\theta)$ increases if $\theta^2 > M/L$ and decreases if $\theta^2 < M/L$. This implies C_1 increases if $\theta^2 < M/L$ and decreases if $\theta^2 > M/L$.

For B_1/C_1, note that

$$\begin{aligned} B_1/C_1 &= \frac{(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{\lambda\theta\nu\mu^2} \\ &= L\theta + M\theta^{-1} \end{aligned}$$

where $L = \nu$ and $M = r\sigma_2^2(1-\nu)/\nu\mu^2$. Once again, by Lemma 1, B_1/C_1 decreases if $\theta^2 < M/L$ and increases if $\theta^2 > M/L$.

This completes the proof of fifth row of TABLE 6.

Proof of the sixth (last) row of TABLE 6:

The last row of TABLE 6 is

	a_1	b_1	B_1	C_1	B_1/C_1	$W - W_0$	$b_0 - b_1$	$B_1 - B_0$
ν	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow\downarrow$	$\downarrow\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$

To show $a_1 \uparrow as \nu \uparrow$: Note that a_1 can be expressed as

$$a_1 = \frac{\lambda^2}{(\lambda^2 + r\sigma_1^2) + \cfrac{\mu^2}{1 + \cfrac{\theta^2\nu^2}{r\sigma_2^2(1-\nu)}}}$$

As $\nu^2/(1-\nu)$ is an increasing function of ν,this implies that the denominator of a_1 is a decreasing function of ν. Thus, $a_1 \uparrow$ as $\nu \uparrow$.

Also, $B_1 = a_1/\lambda$ which immediately implies that $B_1 \uparrow$ as $\nu \uparrow$.

For $B_1 - B_0$, note that B_0 does not involve ν which implies that $B_1 - B_0$ behaves in the same way as does B_1 with respect to ν.

From equations 24 and 25, in this Appendix it is immediate that

$$2(W - W_0) = a_1 - a_0.$$

Also, a_0 does not involve ν which implies that $W - W_0$ behaves in the same way as does a_1 with respect to ν.

For b_1, note from Proposition 4.2 that b_1 can be written as

$$b_1 = \frac{\lambda\mu r\sigma_2^2(1-\nu)}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$
$$= \frac{\lambda\mu}{(\lambda^2 + r\sigma_1^2) + \mu^2 + \dfrac{\mu^2\theta^2\nu^2(\lambda^2 + r\sigma_1^2)}{r\sigma_2^2(1-\nu)}}$$

As already mentioned that $\nu^2/(1-\nu)$ is an increasing function of ν, this implies that the denominator of b_1 is an increasing function of ν. Thus, $b_1 \downarrow$ as $\nu \uparrow$.

Also, $b_1 - b_0$ behaves in the same way with respect to ν as b_1 as b_0 does not involve ν.

The non-monotonic behavior of C_1 with respect to ν can be established by expressing C_1 as

$$C_1 = \frac{\lambda\theta\nu\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1-\nu) + \mu^2\theta^2\nu^2) + r\sigma_2^2(1-\nu)\mu^2}$$
$$= \frac{\lambda\theta\mu^2}{(\lambda^2 + r\sigma_1^2)(r\sigma_2^2(1/\nu - 1) + \mu^2\theta^2\nu) + r\sigma_2^2(1/\nu - 1)\mu^2}$$
$$= \frac{\lambda\theta\mu^2}{f(\nu) + \textit{terms independent of } \nu}$$

where

$$f(\nu) = L\nu + M\nu^{-1}$$

where $L = (\lambda^2 + r\sigma_1^2)(\mu^2\theta^2)$ and $M = (\lambda^2 + r\sigma_1^2 + \mu^2)r\sigma_2^2$. By Lemma 1, $f(\nu)$ increases if $\nu^2 > M/L$ and decreases if $\nu^2 < M/L$. This implies C_1 increases if $\nu^2 < M/L$ and decreases if $\nu^2 > M/L$.

For B_1/C_1, note that

$$B_1/C_1 = \frac{(\lambda\mu^2\theta^2\nu^2 + \lambda r\sigma_2^2(1-\nu))}{\lambda\theta\nu\mu^2}$$

$$= L\nu + M\nu^{-1} + terms\ independent\ of\ \nu$$

where $L = \theta$ and $M = r\sigma_2^2/\theta\mu^2$. Once again, by lemma 1, B_1/C_1 decreases if $\nu^2 < M/L$ and increases if $\nu^2 > M/L$. This completes the proof of the last row of TABLE 6.

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