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ESSAYS ON CONTRACTS AND CORPORATE GOVERNANCE STRUCTURE IN THE INFORMATION TECHNOLOGY INDUSTRY

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ESSAYS ON CONTRACTS AND CORPORATE GOVERNANCE STRUCTURE IN THE INFORMATION TECHNOLOGY INDUSTRY

by

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To my parents

ESSAYS ON CONTRACTS AND CORPORATE GOVERNANCE STRUCTURE IN THE INFORMATION TECHNOLOGY INDUSTRY

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This dissertation consists of three essays that explore contracts and corporate governance structure issues in the information technology (IT) industry. The first essay shows that when the information technology service being provided is critical to the buyer, it is optimal for the buyer and seller to sign flexible contracts that incorporate future renegotiations.

The second essay studies contracts for procuring information technology. With a game theoretic model, it shows that when uncertainty unfolds over time and contracts complete in the specification of timing are infeasible (or transaction costs of writing complete contract are prohibitively high), information asymmetry between contracting parties leads to inefficient investment decisions. In particular, premature investments will occur under certain conditions.

The third essay studies the issue of corporate governance in the technology sector. Shareholders of technology companies can only form beliefs on the financial health of technology firms and rely on the information provided by the firms to update their expectations, while the executives of these firms have access to first-hand information regarding the real potential of the new technology. A multi-period game-theoretical model with asymmetric information-updating process is developed and in equilibrium executives compensated with stocks and stock options will manipulate and untruthfully report the information, causing the public to discount strong companies with superior technologies due to expectations of possible frauds.

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Chapter 1 Introduction

The evolvement of the information technology industry has been as dramatic as the impacts it has on people's life. Most recently, following the burst of the Internet bubble, the surge of bankruptcies of dot-coms and collapses of telecommunication giants, accounting scandals of many large technology companies have caused a crisis of trust in Corporate America. This dissertation attempts to address these issues in the information technology industry by examining the economic characteristics of new technology.

The second chapter studies information technology service contracts. The technology development process is characterized as a stochastic process and when the information technology service being provided is critical to the buyer, it is optimal for the buyer and seller to sign flexible contracts that incorporate future renegotiations instead of contracts with full commitment. Assuming the seller bears the cost of accommodating flexibility, the buyer can purchase "renegotiation right" from the seller ex ante, allowing Pareto-improving contract to emerge as an outcome.

The third chapter examines the relationship between uncertainties, timing and contractual choices for information technology procurement. Proper timing in contracts, which has largely been treated as exogenous in the literature, is the key to understand parties' decisions. With a game theoretic model, it shows that when uncertainty unfolds over time and contracts complete in the specification of timing are infeasible (or transaction costs of writing complete contract are prohibitively high), information asymmetry between contracting parties leads to inefficient investment decisions. In particular, premature investments will occur under certain conditions.

The last chapter studies contracts within an information technology company rather than contracts between IT vendors and buyers and sheds light on the issue of corporate governance in the technology sector. Because of the innovative nature of new technologies and the uncertainties of their prospects, shareholders of technology companies can only form beliefs on the financial health of technology firms and rely on the information provided by the firms to update their expectations, while the executives of these firms have access to first-hand information regarding the real potential of the new technology. A multi-period game-theoretical model with asymmetric information-updating process is developed and in equilibrium executives compensated with stocks and stock options will manipulate and untruthfully report the information, causing the public to discount strong companies with superior technologies due to expectations of possible frauds. This constitutes a market failure in the high technology sector: it is highly costly for new technology companies to attract investments and in the extreme case investors completely abandon the investment opportunity on the new technology.

Chapter 2 Information Technology Service Contracts: Flexibility, Renegotiation and Value of Contracts

2.1 Introduction

The information technology (IT) industry has seen a surge in outsourcing since the last decade. Firms that perform IT functions in-house find it increasingly difficult to keep up with the technology developments, with incremental investments in the infrastructure and growing cost of IT staff. IT firms now rely heavily on an array of external service providers, such as Internet Service Providers (ISPs), Application Service Providers (ASPs), and Network Service Providers (NSPs) for various IT functions.

Besides outsourcing IT functions, firms also find that teaming up with other companies that provide value-added services to the firms' products helps to attract more customers and increase revenues and profits.

Both outsourcing and collaborating involve writing contracts with another party. Today IT management faces the tasks of designing, negotiating and monitoring a set of contracts. The primary challenge lies in the conflict between contractual commitments and the rapid changing technology and business environment. As a result, IT contracts are frequently renegotiated, adding costs to both parties involved in the contracts.

Contracts have been studied extensively in various research disciplines, especially in economics. Of these bodies of literature, incomplete contract theory, a relatively new area in economics, is the most relevant to the study of IT contracts. When the cost of specifying all possible contingencies in a contract is prohibitively high, parties will end up writing an incomplete contract. Incomplete contracts are appealing because actual contracts are usually far from being complete and contracts for information technology services make a good candidate for being analyzed in this framework. Because of the novelty of the services to be provided, the rapid technology developments and the uncertainties in related business environment, it will be almost impossible for parties to *ex ante* numerate in a contract all the possible contingencies. However, for reasons that we will see, the existing incomplete contract theory cannot be readily applied to IT contracts. We proceed to discuss the theory of incomplete contract and its applicability to IT contracts.

According to Tirole (1999), an incomplete contract "does not exhaust the contracting possibilities envisioned in the complete contracting literature" due to high transaction costs of writing complete contracts, which may include unforeseen contingencies and costs of writing, verifying and enforcing contracts.

There has been a debate over whether the indescribability of contingencies changes optimal contracts. Maskin and Tirole (1999) develop several irrelevance theorems showing that indescribability is irrelevant to optimal contracting. Hart and Moore (1999) develop a model in which the optimal contract with describable contingencies yields the first-best, while with indescribability contracting has no value, i.e. the optimal contract is the null contract.

The result that indescribability changes optimal contracts relies on the assumption that parties cannot commit not to renegotiate the contract. Hart and Moore (1988), in their seminal article, show that rational expectations of future revisions may deter parties from making relationship-specific investments. As an extreme case, renegotiation may even render contracting valueless when investments are cooperative. An investment is cooperative if it benefits the other party more than it does the investing party. Che and Hausch (1999) show that if parties making cooperative investments cannot commit not to renegotiate, the null contract is optimal, i.e., the parties should abandon contracting altogether.

Maskin and Tirole (1999) point out that when states are indescribable and contracts are incomplete, all that is required for optimality is dynamic programming and the optimality result thus obtained holds generally as long as parties can commit not to renegotiate. They also find renegotiation hard to reconcile with the assumption that parties are perfectly rational.

In sum, when contracts are incomplete, if parties can commit not to renegotiate, then the optimal contract yields the same outcome as the optimal complete contract does; if parties cannot commit not to renegotiate, that is, they are bound to renegotiate, then the anticipation of renegotiation will make contracting less valuable or even valueless. Some researchers try to solve the problem of no commitment by introducing new mechanisms into the legal system (Maskin and Tirole 1999) while other researchers suggest institutional solutions such as property rights (Hart and Moore 1999).

In a model developed in the context of IT service contracts, we endogenize the parties' ability of making commitment. We show that the gain from *ex post* renegotiation reflects the value of the right to renegotiate. When a party cannot commit not to renegotiate, it implies that the party has the right, but not the obligation to fully commit to the contract. If this right to renegotiate can be evaluated and transferred between parties, then the anticipated revisions of contracts will not damage the efficient outcome that can only be achieved through renegotiation. We illustrate in a stylized model how such a right can be priced and incorporated into the contract. In essence, we use a pricing mechanism to deal with the "commitment puzzle" under perfect rationality.

The structure of the contract in our model is designed to describe the contractual arrangement when one party is providing an IT service to the other and it differs from that studied in standard contract theory. In standard contract theory, parties pre-agree on a one-shot delivery performed by the seller to the buyer in the last stage of the game and trade may or may not happen after the uncertainty is resolved. In IT contracts, however, parties agree on a service to be provided continuously by the seller to the buyer and uncertainty resolves over time.

When a party makes full commitment to the contract, it gives up its right to revise the contract later as uncertainty resolves over time. In analyzing the IT contract and the right to renegotiate embedded in it, we find the real option theory a useful tool. The value of the right to renegotiate can be evaluated using real option analysis.

The real option theory studies firms' investment decisions under uncertainty, recognizing the value of the ability to delay, suspend and abandon a project (McDonald and Siegel 1985, 1986, Brennan and Schwartz 1985, Ingersoll and Ross 1992, Dixit and Pindyck 1994, among others). Real option analysis is particularly helpful for evaluating IT projects that usually exhibit high growth potential and high uncertainty (Kumar 1996, Panayi and Trigerogis 1998, Benaroch and Kauffman 1999, Taudes et al 2000, Schwartz and Zozaya-Gorostiza 2000). We employ the methodology of real option pricing in evaluating the right of renegotiation.

The rest of the paper is organized as follows: in Section 2 we study the reasons for IT firms to choose contracting and categorize IT contracts according to the functions being provided. Section 3 introduces a model of IT contracts for non-critical services. Section 4 discuss IT contracts for critical services. In both sections, we present a formal model and the results preceded by an illustrative example. Section 5 concludes.

2.2 The Information Technology Industry and Contracts for Two Types of Functions

In writing an IT contract, as any other contract, a buyer and a seller try to agree on the terms of trading. In the context of IT industry, the seller, often called a service provider, supplies an information technology service. The buyer, also called the client, agrees to make payments in return for the services. Both the services and payments will be carried out over a period of time.

From the buyer's point of view, the reasons for choosing to contract on a service over doing it in-house may be multifaceted. The main reason is that acquiring a service on a contractual base allows the company to concentrate on its core business and avoids using up its scarce IT resources for operations not central to its strategic objective. The company may clearly define its core business from the outset and choose its contractual partner for certain IT functions. For example, an Internet content-provider may choose an ISP to provide Internet access services. Firms may also originally perform the function in-house, but then decide to outsource it as the function becomes more of routine work or less related to the core business. For example, a bank may outsource its loan processing function to an ASP.

Another important reason for outsourcing, which is often used by the purchaser to justify the decision and also by the seller as the selling point, is cost reduction. As the demand for IT services within the firm increases, it becomes more and more expensive to own the infrastructure and support the IT staff and outsourcing becomes a better alternative financially.

Firms seeking external solutions also find it attractive to receive innovative and cutting edge services without the internal investment. By building business partnerships, the firm can move fast to markets and gain competitive advantage.

When examining the various contracts in the IT industry, we categorize them into two groups according to the indispensability of the services to the buyer: contracts for critical IT functions and contracts for non-critical functions. We find this distinction necessary to understand the choices that the buyer has and the subsequent decisions it makes.

First, if the function is critical for the buyer, then the buyer has to ensure continuous subscription to the service. The buyer does not have the choice to temporarily suspend the service as long as it is in business. Although the firm may change its service provider, renegotiate the terms of the contract, it has to maintain continuous access to the service and cannot operate without it. A critical service may still be down occasionally, but it occurs only as a failure, never by the decision of the firm. Such a failure is often disastrous and involves tremendous explicit and implicit costs.

A function is non-critical to the buyer if it is not essential to the buyer's business. The buyer can either sign a long-term contract with a provider to gain access to the service, or would like to buy the service only when needed, if there is a market for such a service. A contract may offer some convenience to the buyer, but the service by nature is not indispensable for the buyer and can be acquired opportunistically.

Of course, such a distinction between contracts for critical and non-critical functions is an abstract of the real world and actual contracts may fall anywhere between these two extremes. A good example of contracts for critical service will be a dedicated Internet access contract between an ISP and an online company, such as eBay, Amazon.com. Obviously, if the Internet access is down, the business operations will be paralyzed.

Application services such as email, some database applications are usually less critical than services such as web server, security and network access, but may become critical at certain times. So it is only proper to consider such services as mid-way between critical and non-critical services. In practice we see that most firms sign contracts for these services rather than buying them on a market from time to time.

Some functions, such as web services that offer personalized online experience, can be non-critical. Buyers do not rely on these services to carry out businesses but such services may add value to their products and help to attract customers. In such a case, the buyer and seller may sign a contract to form a strategic alliance. For example, in July 2001, America Online entered into an agreement with Amazon.com to provide its subscribers a more personalized online shopping experience (Amazon.com 2001). As an alternative, markets can be developed for such services so that firms can choose when to buy such services and how much to buy, thus have more flexibility than using bilateral contracts.

In the following sections we develop models for both types of contracts and show: when the functions are non-critical, buyers and seller will choose to use markets instead of contracts, provided that such a market exists; and if the functions are critical, the buyer and seller will choose to sign flexible contracts.

2.3 Contract for Non-critical Functions

2.3.1 The Model

First we examine the contract for a non-critical IT service. Suppose at t=0, the buyer and the seller sign a contract for a service to be delivered continuously from time 0 to T. The buyer receives an instantaneous utility u_t from the service at time t and the seller incurs an instantaneous cost of c_t providing the service. The buyer and the seller should then decide on the rate of payment w, which for simplicity is set to be constant. We assume both the buyer and the seller are risk-neutral.

Since the function is non-critical and it is unnecessary for the buyer to keep the access to the service all the time, the buyer will consider buying the service from a market, if possible. For the seller, obviously it is not constrained to supply the service continuously and can provide the service either through contract or through market.

As an illustrative example, consider an online travel agent, say Expedia.com. Customers can make their entire vacation plans at Expedia.com, including booking a flight, renting a car, making reservations for a hotel room, etc. If Expedia.com can offer a service to automatically notify the customer about a flight delay or cancellation through his/her cell phone, then the company can attractive more customers and thus earn higher revenue. Because it doe not own cell phone companies, it may sign bilateral contracts with these companies to provide this service. Because the demand for such a service is uncertain, the benefits that Expedia.com gains from such a contract, which is represented by u_t in the model, is also fluctuating. Intuitively, there will be redundancy in a contractual relationship.

We next examine what the buyer and seller will choose if a market for the service exists. First, the buyer is choosing between two alternatives: to get the service continuously at a constant price of w for the duration of the contract T, or buy instant service at any time from any supplier at the prevailing price of that moment, if it is beneficial to do so.

The seller also has two alternatives to choose from. The seller can sign the contract and provide the service for a constant price of *w* from *t*=0 to *T*, or sell the service at any time at the market prevailing price of that moment whenever profitable.

To analyze the decisions of the buyer and the seller, we first make the following assumptions concerning the processes followed by the payoff to the buyer, the price and the cost to the seller:

Assumption 1. Suppose that the buyer's utility u_t, the market price of the service p_t, and the seller's cost c_t all follow geometric Brownian motions governed by

(1) $$du = \alpha_u u dt + \sigma_u u dz_u$$

(2) $$dp = \alpha_p p dt + \sigma_p p dz_p$$

(3) $$dc = \alpha_c c dt + \sigma_c c dz_c$$

where z_u, z_p and z_c are standard Wiener processes that may be correlated with one another, with correlation coefficients ρ_{up}, ρ_{uc}, and ρ_{pc}, the subscripts representing the two correlated processes. α_i, and σ_i (i=u, p, c) are constants.

Assumption 2. The initial values, i.e. the values at t=0, are:

$u(t=0)=u_0$, $p(t=0)=p_0$, $c(t=0)=c_0$.

The above stochastic processes imply that it is impossible to describe all the future states of nature *ex ante*. Thus the contract that the buyer and the seller sign is incomplete. But as long as they know the future payoffs probabilistically, the optimal contracts can be designed using dynamic programming.

The processes followed by the u_t and c_t in (1) and (3) show the stochastic nature of technology developments in IT. The price process in (2) depends on the competition structure of the market.

2.3.2 Buyer's problem

At t=0, the buyer's expected total payoff from contracting is given by:

(4) $$V_c^B = \int_0^T \left[E_0(u_t) - w\right] e^{-rt} dt$$

where r is the interest rate. E_0 means that the expectation is taken at t=0.

To evaluate V_c^B, by Assumption 1 and 2, we have

(5)

$$\int_0^T \left[E_0(u_t) - w\right] e^{-rt} dt = \int_0^T \left[u_0 e^{\alpha_u t} - w\right] e^{-rt} dt = \frac{u_0}{r - \alpha_u}\left(1 - e^{-(r-\alpha_u)T}\right) - \frac{w}{r}\left(1 - e^{-rT}\right)$$

Define $\delta = r - \alpha_u$, rewrite (5) as

(6) $V_c^B = \frac{u_0}{\delta}\left(1 - e^{-\delta T}\right) - \frac{w}{r}\left(1 - e^{-rT}\right)$

The buyer's expected payoff without the contract is given by:

(7) $$V_m^B = \int_0^T E_0\left[\max\left(0, u_t - p_t\right)\right]e^{-rt}dt$$

We use subscripts *c* and *m* to represent "contract" and "market" respectively.

To evaluate V_m^B, we define

(8) $v_0^B(t) = e^{-rt}E_0\left[\max\left(0, u_t - p_t\right)\right]$

A formula for (8) is available (see McDonald and Siegel 1985). However, it is not necessary for our result presented in Proposition 1.

Thus the buyer will choose to contract when $V_c^B > V_m^B$, or

(9) $\frac{u_0}{\delta}\left(1 - e^{-\delta T}\right) - \frac{w}{r}\left(1 - e^{-rT}\right) > \int_0^T v_0^B(t)dt$

2.3.3 Seller's decision

The seller's expected total profit with the contract is:

(10) $V_c^S = \int_0^T \left[w - E_0\left(c_t\right)\right]e^{-rt}dt$

To evaluate V_c^S in (10), by Assumption 1 and 2, we have

(11)

$$\int_0^T \left[w - E_0(c_t)\right]e^{-rt}dt = \int_0^T \left[w - c_0 e^{\alpha_c t}\right]e^{-rt}dt = \frac{w}{r}\left(1 - e^{-rT}\right) - \frac{c_0}{r - \alpha_c}\left(1 - e^{-(r-\alpha_c)T}\right)$$

Define $\eta = r\text{-}\alpha_c$, rewrite (11) as

(12) $$V_c^S = \frac{w}{r}\left(1 - e^{-rT}\right) - \frac{c_0}{\eta}\left(1 - e^{-\eta T}\right)$$

Without the contract the seller can get:

$$V_m^S = \int_0^T E_0\left[\max\left(0,\ p_t - c_t\right)\right]e^{-rt}dt$$

Similarly we define

$$v_0^S(t) = e^{-rt}E_0\left[\max\left(0,\ p_t - c_t\right)\right]$$

Thus the seller will sign the contract if $V_c^S > V_m^S$, or

(13) $$\frac{w}{r}\left(1 - e^{-rT}\right) - \frac{c_0}{\eta}\left(1 - e^{-\eta T}\right) > \int_0^T v_0^S(t)dt$$

2.3.4 Optimal Contracting

In the optimal contract, the payment rate *w* should satisfy both (9) and (13), i.e.

$$(14)\ \frac{c_0}{\eta}\left(1-e^{-\gamma T}\right)+\int_0^T v_0^S(t)dt<\frac{w}{r}\left(1-e^{-rT}\right)<\frac{u_0}{\delta}\left(1-e^{-\delta T}\right)-\int_0^T v_0^B(t)dt$$

For *w* to exist, the necessary condition is

$$(15)\ \frac{c_0}{\eta}\left(1-e^{-\eta T}\right)+\int_0^T v_0^S(t)dt<\frac{u_0}{\delta}\left(1-e^{-\delta T}\right)-\int_0^T v_0^B(t)dt$$

Rearranging terms, we get

$$(16)\ \int_0^T v_0^S(t)dt+\int_0^T v_0^B(t)dt<\frac{u_0}{\delta}\left(1-e^{-\delta T}\right)-\frac{c_0}{\eta}\left(1-e^{-\eta T}\right)\ \text{or}$$

$$\int_0^T\left[v_0^S(t)+v_0^B(t)\right]dt<\frac{u_0}{\delta}\left(1-e^{-\delta T}\right)-\frac{c_0}{\eta}\left(1-e^{-\eta T}\right)$$

However, we prove in Proposition 1 that (16) can never be true.

Proposition 1. If both the buyer and the seller have the outside opportunities to trade on the market for functions that are non-critical for the buyer, under Assumption 1 and 2, both the buyer and the seller will trade on the market, i.e. the optimal contract is the null contract.

Proof: To prove Proposition 1, we only need to prove that (16) does not hold.

On the left-hand side, first recall that $v_0^B(t) = e^{-rt} E_0[\max(0, u_t - p_t)]$, thus

At any *t*, $E_0[\max(0, u_t - p_t)] > E_0(u_t - p_t)$ because

$$E_0[\max(0, u_t - p_t)] = \int_0^\infty \int_{p_t}^\infty (u_t - p_t) f(u_t, p_t) du_t dp_t$$

while $E_0(u_t - p_t) = \int_0^\infty \left\{ \int_0^{p_t} (u_t - p_t) f(u_t, p_t) du_t + \int_{p_t}^\infty (u_t - p_t) f(u_t, p_t) du_t \right\} dp_t$

and $\int_0^{p_t} (u_t - p_t) f(u_t, p_t) du_t < 0$ by Assumption 1.

By Assumption 1 and 2, we have

$$(17) \quad \begin{aligned} v_0^B(t) &= e^{-rt} E_0[\max(0, u_t - p_t)] > e^{-rt} E(u_t - p_t) \\ &= e^{-rt}\left(u_0 e^{-\alpha_u t} - p_0 e^{-\alpha_p t}\right) = u_0 e^{-\delta t} - p_0 e^{-(r-\alpha_p)t} \end{aligned}$$

Similarly, at any *t*, we have

$$E_0[\max(0,\ p_t - c_t)] > E_0(p_t - c_t)$$

Thus

$$(18) \quad \begin{aligned} v_0^S(t) &= e^{-rt} E_0[\max(0,\ p_t - c_t)] > e^{-rt} E(p_t - c_t) \\ &= e^{-rt}\left(p_0 e^{-\alpha_p t} - c_0 e^{-\alpha_c t}\right) = p_0 e^{-(r-\alpha_p)t} - c_0 e^{-\eta t} \end{aligned}$$

Integrating the over the sum of (17) and (18), we get

$$\int_0^T \left[v_0^S(t) + v_0^B(t)\right]dt > \int_0^T \left[u_0 e^{-\delta t} - p_0 e^{-(r-\alpha_p)t} + p_0 e^{-(r-\alpha_p)t} - c_0 e^{-\gamma t}\right]dt = \frac{u_0}{\delta}\left(1 - e^{-\delta T}\right) - \frac{c_0}{\gamma}\left(1 - e^{-\gamma T}\right) \tag{19}$$

We see that (19) contradicts (16).

So there is no payment rate that the buyer and the seller can agree on. Thus the optimal contracting is to write no contract.

Q.E.D.

The intuition for Proposition 1 is quite clear: because buying and selling are not mandatory for either party, the cost of tying up in a contract in adverse conditions outweighs the benefits. If a contract is in place, there will be times when the buyer does not gain from the service (in the travel agent example, when there is no demand for the automatic notification service) but still pays for it. Similarly for the seller the contract may prevent it from selling the service on the market to realize higher profit.

From the above analysis, we see that the existence of markets will benefit both the buyer and the seller. Actually, the IT industry has started to realize this commercial opportunity. For example, Microsoft has introduced .Net My Services that integrates web service components and is open to customers and other service providers (Geng et al 2001). Though .Net My Services may not match exactly the market we describe here, it does show that such smart marketplaces add value to service providers and buyers (for more detailed discussion on this topic, see Geng et al 2001).

2.4 Contract for Critical Functions

When the buyer is contracting on a critical function, as we said, the firm has to ensure that it has continuous access to the service and the cost of any service interruption is prohibitively high. If there is any friction in the market (if exists) and the buyer may not get the service from time to time, then the buyer will rule out the use of the market completely. Besides, in the case of critical function outsourcing, the service usually requires specific investments, making the choice of using the market infeasible. The total transaction costs of buying on the market may also be much larger than that incurred for negotiating a contract.

Thus the buyer’s goal is to buy continuous service at lowest possible prices. In absence of technology developments, the buyer can achieve this goal with one contract that lasts forever and it only has to carefully negotiate the payment rate with the seller to share the total gain from the trade, which is the integral of buyer’s benefit net of the seller’s cost.

However, when there are competing technologies and new technologies keep being introduced, the buyer is concerned with being tied up in obsolete technology. In the IT industry, such concerns often lead to short-term contracts and frequent renegotiations.

In practice, the buyer and the seller of a critical IT service often engage in negotiating a detailed contract called Service Level Agreement (SLA) to specify various aspects of the service. In the rest of this section, we first provide an overview of the business practice of SLA and discuss the challenges of evaluating flexible contracts. We then present a model in which the buyer chooses the optimal duration of the contract in two regimes: with and without commitment. We also discuss the implications of our results to incomplete contract theory.

2.4.1 Contracts for Critical Services: Service Level Agreements (SLAs)

Service Level Agreements (SLAs) have caught a lot of attention and are now "widely considered to be the foundation of the relationship between a service provider and end-user organizations" (Steve Steinke, editor-in-chief of Network Magazine).[1] The service level agreement describes the services to be provided and guarantees the service levels. If the service provider fails to deliver the specified service level, it will pay penalties to the client. Key elements of an SLA include service levels and performance metrics, price, penalty, security, customer care and support, backup and disaster recovery, and tracking and reporting measures.

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[1] PR Newswire, financial news section, "Network Magazine Hosts Service Level Agreements Panel Discussion at SUPERCOMM 2001; Enterprise Networkers, Service Providers, and Industry Analysts Join Magazine Editors in Discussing Critical Issues in SLAs", June 12, 2001

One problem with the SLA is that the IT services that the two parties agreed on are actually a moving target. In the IT industry rapid change is the norm rather than the exception. Because of technology developments, the SLA carefully negotiated today may become obsolete tomorrow. IT professionals and researchers have realized the conflict between guaranteed services and changing technologies, and started to promote and practice more flexible SLAs. However, the value of flexible contract to the two parties is not clear, providing no economic basis for the parties' decisions on writing contracts.

First, with the wide spread of information technology, the client of the IT services, which is often an end-user organization, may have a growing user base and the users may have increasing demand for faster and better services. It is often suggested that enterprises negotiating an SLA keep in mind their future growth, but it is not clear how such a potential for growth should be translated into terms of the SLA and how much value these terms will add to the SLA.

Second, the advance in information technology is constantly driving down the costs of providing IT services, improving the quality of services, and making new types services available. IT enterprises are eager to take advantages of technology development and do not want to be locked up into obsolete technology, inferior quality or higher prices by signing any soon-to-be-out-of-date contract.

The reality in the IT industry manifests this inherent conflict between the guarantees on IT services and the changing technology. One of the characteristics of the so-called "second wave of outsourcing" is the renegotiation of SLAs because the original SLAs signed a couple of years ago no longer meet organization's needs or reflect the market value of the services.

Because in renegotiation buyers may threat to terminate the contract with their current service providers to take advantage of newer, better contract terms offered by other providers, sellers often modify their SLAs in order to keep their clients. The most remarkable example is the announcements by the Internet Service Providers to enhance their SLAs. As summarized by Denise Pappalardo, "Every three months or so an ISP comes out with an upgrade that trumps the last best SLA", which is described by Joanna Makris, a program director at the Yankee Group as "a game of one-upmanship" (Pappalardo 2000). In July 2000, Genuity was the first ISP to offer customers a minimum round-trip latency guarantee of 65 milliseconds. Then three months later UUNET, WorldCom's ISP subsidiary, enhanced its SLA by improving its guarantee from no great than 85-millisecond delay to 65-millisecond. It also promised 99% of packets will be delivered. In Febrary 2001, Cable & Wireless guaranteed that dedicated Internet access customers would not experience more than 55 milliseconds of round-trip latency over its network, trumping the AT&T's SLA enhancement in Jan, which guarantees latency not to exceed 60 milliseconds. Cable & Wireless also guaranteed no more than 1% packet loss. In April Genuity reduced its packet loss measurement from 1% to 0.5% and its latency measurement from 65 milliseconds to 55 milliseconds, backing up these enhancements by expanding its Tier 1 network.

To avoid being locked up into obsolete technology, some experts advise IT enterprises entering into SLAs with their service providers to contract for a shorter period of time. But as we know, since the function is critical thus once the old one expires the buyer will have to negotiate a new SLA, which is again costly, it will not be beneficial if the contracts are too short. Another approach is to build more flexibility into the SLA. For example, ITAA's ASP Service Level Agreement Guidelines[2] includes a section for upgrades and suggests an SLA to address upgrade expectation and procedures. Ideally, an SLA should accommodate upgrades and changes in the scale and scope of services and have flexible pricing schemes. (Gray 2000)

It is also desirable to describe expectation and procedures for upgrade and enhancement in the SLA. Under certain circumstances clients may require the service provider to use the most up-to-date technology, which usually leads to an escalating SLA. Large financial services companies usually write escalating SLAs such that the supplier will introduce enhancements to services within a certain period of time following the expansion or upgrade of its network (Samuels 2001).

[2] ITAA ASP SLA Guidelines: http://www.itaa.org/asp/itaasla.pdf

Although the industry has realized the dynamic nature of SLAs and started to address this problem, it is not clear how much the flexibilities are worth. In a stylized model presented below, we obtain the optimal duration for an IT contract and quantify the value of flexible contracts.

2.4.2 Dynamic choice of technologies for critical function contracting

Suppose that a buyer and a seller are negotiating a contract for a critical function. If the technology is the only choice that the buyer has and is ever going to have, they will choose to contract for an infinite time. However, the buyer will not do so because it wants to take advantage of future technology development.

To simplify the reality, suppose there are two technologies available. One technology is mature, bringing more profit now but does not have much growth potential while the other is still in infancy and but has larger growth potential. By intuition, the buyer will contract on the mature technology first for a finite period of time and once this contract ends the buyer can choose between the two technologies. The buyer would like it even better if it has the freedom to switch to the new technology at the “best” time.

Though in reality there may be more than two technologies to choose from, the opportunity cost of choosing one technology is always the highest payoff that can be obtained from the rest of the alternatives. So the trade-off between two alternative technologies is general. Another issue is that new technologies will keep emerging. However, if we have no prior information on future technologies, then the optimal decision of the firm would not change; if we do have the information, in probabilistic sense, then it should have been included in the evaluation of opportunity costs. Thus our model of choice between two technologies is general for choosing the optimal duration of contracts.

Because we want to focus on the choice of the length of contract both with commitment and without and the gain purely from flexibility in duration, we do not model how the buyer and seller determine the payment terms. Thus we evaluate the value of the contract in the sense of total surplus. It is equivalent to assuming that the buyer and seller have symmetric information and the buyer has all the bargaining power, so that the payment will equal cost. We evaluate the contract with commitment, where the length of the first contract is fixed and not renegotiated, and the contract with flexibility, where the buyer gets to choose when to end the current contract and start a new one

First we make the following formal assumption on the two technologies.

Assumption 3. Technologies A and B generate instantaneous profit flow (benefits minus cost) x_t *and* y_t *at t respectively.* x_t *and* y_t *follow geometric Brownian motions governed by*

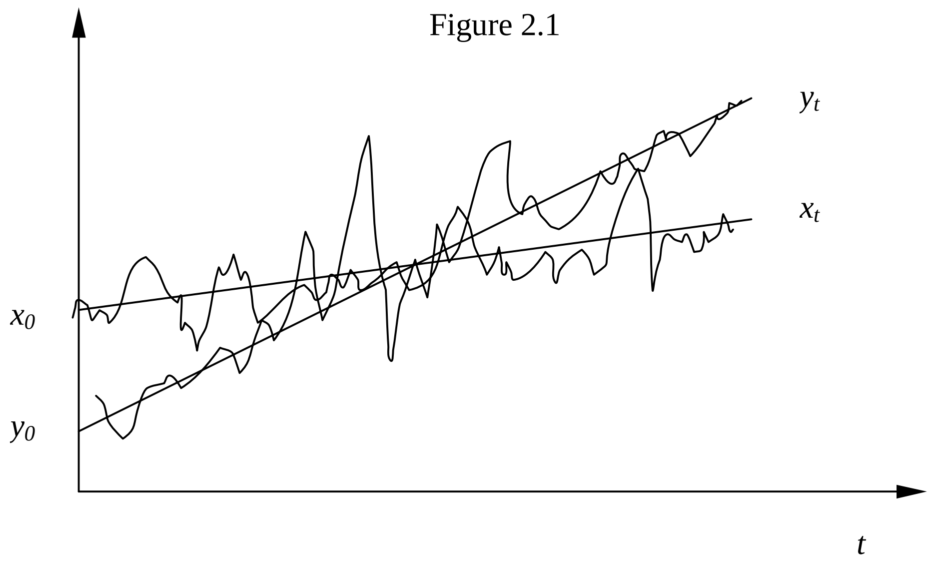
$$(20)\ dx = \alpha_x x dt + \sigma_x x dz_x$$

$$(21)\ dy = \alpha_y y dt + \sigma_y y dz_y$$

where z_x and z_y are standard Wiener processes that are correlated with each another and the correlation coefficient is ρ_{xy}. α_i, and σ_i ($i=x, y$) are constants. The initial values of x and y are x_0 and y_0 respectively.

Without loss of generality, we assume that $x_0 > y_0$ and $\alpha_x < \alpha_y$. That is, A is the mature technology and B is the new one. Figure 2.1 shows a sketch of possible paths of x_t and y_t.

Figure 2.1



2.4.3 With Commitment to the Duration of the Contract

First we examine the case where the buyer makes full commitment to the duration of the contract. That is, the buyer commits not to switch to the new technology before the contract ends. Denote the optimal duration of the contract by T^*. We give the formula for T^* in Theorem 1, followed by the proof.

Theorem 1. If the buyer commits not to renegotiate the adoption of new technology, under Assumption3, the optimal contract duration is given by

$$T^* = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}, \qquad \textit{where } \eta = r\text{-}\alpha_x,\ \delta = r\text{-}\alpha_y.$$

and the maximum payoff for the buyer is

$$F_0 = \frac{x_0}{\eta} + M\left(\frac{1}{\delta} - \frac{1}{\eta}\right), \text{ where } M = x_0 e^{-\eta T^*} = y_0 e^{-\delta T^*} = y_0^{\frac{\eta}{\eta-\delta}} x_0^{-\frac{\delta}{\eta-\delta}}.$$

Proof: We solve the buyer's problem backwardly.

At time T, the buyer will choose between technology A and B, comparing the two sums of future discounted profits. Thus,

$$(22)\ F_T = \max\left\{\int_T^\infty x_t e^{\alpha_x t} e^{-rt} dt,\ \int_T^\infty y_t e^{\alpha_y t} e^{-rt} dt\right\}$$

At t=0, the firm's problem is:

$$(23)\ F_0 = \max\left\{\max\left\{\int_0^T x_t e^{\alpha_x t} e^{-rt} dt,\ \int_0^T y_t e^{\alpha_y t} e^{-rt} dt\right\} + F_T\right\}$$

Further analysis of (23) shows that the firm has four types of strategies: 1) choose A at both t=0 and t=*T*; 2) choose A at t=0 and switch to B at t=*T*; 3) choose B at t=0 and switch to A at t=*T*; 4) choose B at both t=0 and t=*T*. And F_0 represents the maximum of the payoffs from these four choices. That is,

$$(24)\ \begin{aligned} F_0 = \max\Big\{ & \int_0^\infty x_t e^{\alpha_x t} e^{-rt} dt,\ \int_0^T x_t e^{\alpha_x t} e^{-rt} dt + \int_T^\infty y_t e^{\alpha_y t} e^{-rt} dt, \\ & \int_0^T y_t e^{\alpha_y t} e^{-rt} dt + \int_T^\infty x_t e^{\alpha_x t} e^{-rt} dt,\ \int_0^\infty y_t e^{\alpha_y t} e^{-rt} dt \Big\} \end{aligned}$$

We define $\eta = r\text{-}\alpha_x$, $\delta = r\text{-}\alpha_y$. Under Assumption 3, (24) becomes

$$(25)\ F_0 = \max\left\{\frac{x_0}{\eta},\ \frac{x_0}{\eta}\left(1-e^{-\eta T}\right) + \frac{y_0}{\delta} e^{-\delta T},\ \frac{x_0}{\eta} e^{-\eta T} + \frac{y_0}{\delta}\left(1-e^{-\delta T}\right),\ \frac{y_0}{\delta}\right\}$$

We denote the above payoffs by f_i, *i*=1, 2, 3, 4, in the order of that in (25).

The payoffs for choosing the same technology both at t=0 and t=*T* are fixed. That is, $f_1 \equiv \frac{x_0}{\eta}$ and $f_4 \equiv \frac{y_0}{\delta}$ respectively.

To maximize f_2, we obtain the first order condition:

(26) $\frac{\partial f_2}{\partial T} = x_0 e^{-\eta T} - y_0 e^{-\delta T} = 0$

The unique solution to (26) is $T^* = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}$. And $\frac{\partial f_2}{\partial T} > 0$ for all $T<T^*$, $\frac{\partial f_2}{\partial T} < 0$ for all $T>T^*$.

Note that we assume $x_0 > y_0$, and $\alpha_x < \alpha_y$, so $\eta > \delta$, thus $T^*>0$. So f_2 has interior solution and is globally maximized at T^*: $T^* = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}$.

(27) $T^* = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}$ and

(28) $f_2^* = \frac{x_0}{\eta} + y_0^{\frac{\eta}{\eta-\delta}} x_0^{-\frac{\delta}{\eta-\delta}} \left(\frac{1}{\delta} - \frac{1}{\eta} \right)$

Taking the derivative of f_3 with respect to T, we find that $\frac{\partial f_3}{\partial T} = 0$ also at $T = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}$. However, second-order condition shows that this is the minimum. Thus f_3 has corner solutions at T=0 or $T=\infty$. If T=0, then $f_3 = \frac{x_0}{\eta}$. If $T=\infty$, then $f_3 = \frac{y_0}{\delta}$. Thus the problem is reduced to the optimal choice between f_1, f_2^*, and f_4.

Notice that if T=∞, then $f_2 = \frac{x_0}{\eta}$ and if T=0, then $f_2 = \frac{y_0}{\delta}$. And we have shown that f_2 is globally maximized at $T = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}$, thus f_2 is not maximized at either T=0 or T=∞.

Thus the solution to (25), i.e. optimal duration T^*, is given by

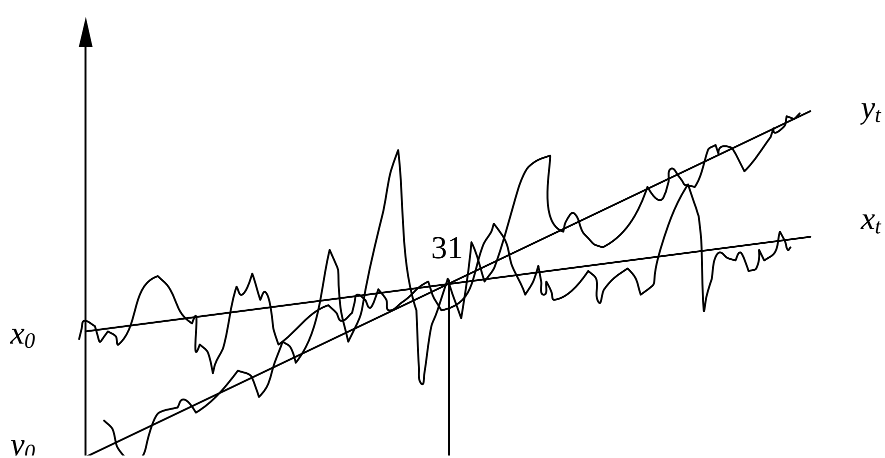
$$T^* = \frac{1}{\eta - \delta} \ln \frac{x_0}{y_0}$$

and the maximum value of the contract F_0 is given by (28).

Q.E.D.

Note that $E_0\left(x_{T^*}\right) = E_0\left(y_{T^*}\right)$. Because $x_0 e^{-\eta T^*} = y_0 e^{-\delta T^*}$, multiply both sides by e^{rT^*}, we get $x_0 e^{\alpha_x T^*} = y_0 e^{\alpha_y T^*}$, which means $E_0\left(x_{T^*}\right) = E_0\left(y_{T^*}\right)$. Intuitively, the optimal duration under commitment is simply the time when the expected values of x_t and y_t are equal and it is shown in Figure 2.2.

Figure 2.2



2.4.4 Without Commitment to the Duration of the Contract

In the above analysis, we assume that the buyer makes full commitment to the contract. That means, the buyer will not renegotiate with the seller the time to implement the new technology. In other words, the buyer commits not to renegotiate during the contract.

If, in contrast, the buyer has the freedom to choose the time to adopt the new technology, it will first contract on the existing technology, and act opportunistically on adopting the new technology. Intuitively the value of the contract will increase due to this added flexibility. We proceed to evaluate this flexibility.

Suppose now the buyer has the option to switch from technology A to B at any time. This option actually consists of two parts: a call option on the new technology at the price of total discounted profit flows from the old technology, and a put on the old technology at the price of the value of the new one. When this option is exercised, the buyer is sacrificing the future profit flows from the old technology to obtain the profit flows from the new technology.

Next we evaluate the total value of the contract with this option. Let $F(y_t, x_t)$ be the value of this contract. Since the option has no time limit, then the value function is not time dependent. Applying Ito's Lemma, we get

$$(29)\ dF = F_y dy + F_x dx + \tfrac{1}{2}\left[\sigma_y^2 y^2 F_{yy} + \sigma_x^2 x^2 F_{xx} + 2\rho_{xy}\sigma_x\sigma_y xyF_{xy}\right]dt$$

We use subscripts of F to denote partial derivatives.

Because the buyer will exercise the option when the value of F is maximized, thus according to the Bellman equation of optimality,

$$(30)\ rFdt = \max\{x_t + E[dF]\}$$

Substituting (29) into the Bellman equation, we get the partial differential equation:

$$(31)\ \tfrac{1}{2}\left[\sigma_y^2 y^2 F_{yy} + \sigma_x^2 x^2 F_{xx} + 2\rho_{xy}\sigma_x\sigma_y xyF_{xy}\right] + \alpha_x xF_x + \alpha_y yF_y + x - rF = 0$$

$F(y, x)$ should satisfy the boundary conditions:

$$(32)\ F(y, 0) = y/\delta$$

(33) $F(0, x) = x/\eta$

When the buyer makes the optimal decision to switch from technology A to B at calendar time τ in the future, i.e. exercises the option, $F^*(y_\tau, x_\tau)$ must satisfy the following value-matching condition:

(34) $F^*(y, x) = y^*/\delta$

as well as a smooth-pasting condition:

(35) $F_y^*(y, x) = 1/\delta$

The partial differential equation in (31) has a free boundary. To solve the equation, we resort to the natural homogeneity of the problem to reduce the problem to one-dimensional space. Notice that the value of the contract $F(y_t, x_t)$ should be homogeneous of degree 1,

(36) $F(y, x) = x\, f(y/x)$

We define $q_t = y_t / x_t$, the ratio of the profit flows of the new and old technology, then

(37) $F(y, x) = x\, f(q)$

We can derive the partial derivatives of $F(y, x)$ in terms of the derivatives of $f(q)$:

(38) $F_y(y, x) = f'(q)$, $F_x(y, x) = f(q) - qf'(q)$

$F_{yy}(y, x) = f''(q)/x$, $F_{xy}(y, x) = -qf''(q)/x$ $F_{xx}(y, x) = q^2 f''(q)/x$

Substitute these into (31) and combine terms, we obtain

(39) $\frac{1}{2}\sigma^2 q^2 f''(q) + (\eta - \delta) q f'(q) - \eta f(q) + 1 = 0$

where $\sigma^2 = \sigma_x^2 + \sigma_y^2 - 2\rho_{xy}\sigma_x\sigma_y$

We try the function $f(q) = Aq^{\beta} + m$, and see that it satisfies the above equation provided that $m = 1/\eta$ and β is a root of the following quadratic function:

(40) $\frac{1}{2}\sigma^2 \beta(\beta - 1) + (\eta - \delta)\beta - \eta = 0$

There are two roots to this quadratic equation, one positive and one negative. The boundary condition $F(0, x) = x/\eta$ implies that β should be the positive root given by:

(41) $$\beta = \frac{1}{2} - \frac{(\eta - \delta)}{\sigma^2} + \sqrt{\left[\frac{(\eta - \delta)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2\eta}{\sigma^2}}$$

From the boundary condition for the optimal execution of the option,

$F^*(y, x) = y^*/\delta$, i.e. $f(q^*) = q^*/\delta$

$F_y^*(y, x) = 1/\delta$, i.e. $f'(q^*) = 1/\delta$

We have

(42) $A = (\eta(\beta - 1))^{\beta-1} / (\delta\beta)^{\beta}$

And when the buyer actually switches to technology B, the ratio of the values of the two technologies q^* should satisfy

(43) $q^* = \frac{\beta}{\beta - 1} \cdot \frac{\delta}{\eta}$

We make the change of variables from q to y and x, and get Theorem 2 and 3.

Theorem 2. Under Assumption 3, if the buyer has the option to switch from technology A to B, then it will exercise the option as soon as x_t and y_t satisfy

$$\frac{y_t}{x_t} = \frac{\beta}{\beta - 1} \cdot \frac{\delta}{\eta}, \text{ where } \eta = r - \alpha_x,\ \delta = r - \alpha_y.$$

$$\text{where } \beta = \frac{1}{2} - \frac{(\eta - \delta)}{\sigma^2} + \sqrt{\left[\frac{(\eta - \delta)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2\eta}{\sigma^2}},$$

$$\text{and } \sigma^2 = \sigma_x^2 + \sigma_y^2 - 2\rho_{xy}\sigma_x\sigma_y$$

and if exercised at time τ*, the maximum payoff the buyer will realize, in terms of time* τ *dollars, is*

$$F_\tau = \frac{y_\tau}{\delta} \ .$$

Theorem 3. Under Assumption 3, at any time before the buyer switches from technology A to B, the total value of the contract on Technology A and B, with full flexibility in the timing of switching from A to B, is given by:

$$F_t = \frac{x_t}{\eta} + A y_t^{\beta} x_t^{1-\beta}$$

where $\beta = \frac{1}{2} - \frac{(\eta - \delta)}{\sigma^2} + \sqrt{\left[\frac{(\eta - \delta)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2\eta}{\sigma^2}}$,

and $A = (\eta(\beta - 1))^{\beta - 1} / (\delta\beta)^{\beta}$.

The analysis from (29) to (43) proves Theorem2 and 3.

Note that because x_t and y_t are stochastic, the time to adopt the new technology cannot be determined *ex ante*.

2.4.5 A Numerical Example

We compare the values of the contract under full commitment and no commitment in a numerical example.

Suppose the parameters take the following values: r=0.3, α_x=0.1, α_y=0.2, σ_x=1, σ_y=2, ρ_{xy}=0.5. The initial values are $x_0 = e^2$, $y_0=e$.

Then

$\eta=r-\alpha_x=0.2$, $\delta=r-\alpha_y=0.1$, $\sigma^2=3$

$$\beta=\frac{1}{2}-\frac{(\eta-\delta)}{\sigma^2}+\sqrt{\left[\frac{(\eta-\delta)}{\sigma^2}-\frac{1}{2}\right]^2+\frac{2\eta}{\sigma^2}}=1.059$$

$$A=(\eta(\beta-1))^{\beta-1}/(\delta\beta)^{\beta}=8.293$$

At t=0, the expected value of the contract with commitment to the duration is

$$F_0=\frac{x_0}{\eta}+y_0^{\frac{\eta}{\eta-\delta}}x_0^{-\frac{\delta}{\eta-\delta}}\left(\frac{1}{\delta}-\frac{1}{\eta}\right)=41.95$$

At t=0, the value of the contract without commitment to the duration is

$$F_0=\frac{x_0}{\eta}+Ay_0^{\beta}x_0^{1-\beta}=58.19$$

The difference between the two values is the value of flexibility and we see that the contract with flexibility has a higher expected value than the one without flexibility.

2.4.6 Discussion

Our result shows that flexibility in the contract length has a value. If *ex ante* the expected value of the contract with flexibility in length exceeds that of the contract with full commitment, then it will be irrational for the parties to make full commitment at the beginning.

Even if the parties have agreed on a contract length, renegotiation will occur *ex post* to gain higher surplus. This is consistent with standard incomplete contract theory: when the contingencies are indescribable, renegotiation will occur to eliminate the inefficiencies.

But contrary to standard incomplete contract theory, the anticipation of renegotiation will not cause the efficient outcome to collapse. Instead, a party can pay for the "right to renegotiate".

One should note that there might be a cost to facilitate flexibility. Signing a flexible contract instead of a committed one is Pareto-improving provided that the gain from flexibility exceeds the cost to accommodate flexibility. Suppose the cost is borne solely by the seller and the buyer needs to buy the right to renegotiate from the seller. Then with this price mechanism for renegotiation right, the seller will agree only if the price exceeds the expected cost. Thus flexible contracts will be chosen only when it is Pareto-improving.

The difficulty in pricing the “renegotiation rights” is that the parties may actually have different opinions on the variables used in the pricing formula and thus cannot agree on the price of the renegotiation rights.

The price of this renegotiation right reflects the value of an option. The price of an option on a financial asset can be uniquely determined because the asset is traded on the market and has a market price. However, pricing of the option to renegotiate involves values of profit flows, which is not a traded commodity or security and is firm specific. In real option theory for investment, this lack of objective measure is less a problem because it is one firm that is making its own decisions. In contracting, without the information provided by market, Pareto-improving transactions may fail to happen.

The formula for the value of the contract is derived under the assumption of risk-neutrality and the discount factor used is simply the interest rate. If the parties are risk-averse, then they will require a risk premium. The risk premium can be calculated according to the rate of return on the financial assets that have the same systematic risk as the IT contract. Under the assumption of complete markets, such a bundle of financial assets exist and a replicating portfolio for the contract can be constructed consisting of these assets. Thus in order to obtain the correct discount factor, we need to have the appropriate financial assets to replicate the real option the firm has for the IT contract.

As a possible solution to the lack of objective measurement for the profit flows and the discount factor, industry indices and markets for IT services may be developed. Such indices and markets will provide a solid base for estimating the stochastic processes followed by revenue flows generated by IT services and related trading activities in the markets will reveal investors risk attitudes, offering an objective measurement for the correct discount factor.

2.5 Concluding Remarks

In the paper, we study the issues involved in writing IT contracts. Because the payoffs for an IT service are highly uncertain, the contracts are incomplete by nature and subject to renegotiation.

We discuss two types of IT contracts: contracts for non-critical functions and contracts for critical functions. When the service being contracted on is non-critical for the buyer, buyers and sellers will prefer to trade in a market. This offers an explanation to the emerging business model of smart marketplace where service providers and customers meet and trade.

When the service is critical for the buyer, contract will be used. In anticipation of future renegotiation, the buyer and seller can trade the right to renegotiate, achieving efficient outcome.

Chapter 3 Information Technology Procurement Contracts: Uncertainty, Timing and Contractual Incompleteness

3.1 Introduction

In the recent economic downturn, the most conspicuous phenomenon may have been the failures of many upstart information technology (IT) firms. Large networking hardware companies such as Cisco, Lucent, Nortel, etc., affected by these failures, experienced unprecedented financial difficulty and many of them claimed billion-dollar losses due to write-downs on bad debt they failed to collect from their customers.

While the problems at each IT firm may be idiosyncratic, there is something in common among these industry giants: a majority of these companies had made significant amount of investments in clients or businesses partners who did not survive the economic downturn and thus could not collect payments from these parties, resulting in substantial losses. This phenomenon has been regarded as "over-investments" and some even think that over-investments in[1] IT actually triggered the economic downturn started in year 2000. The question is how the over-investments in contractual relationships between IT companies and their[2] clients occurred.

Contracts for bilateral trade have been one of most discussed areas in economics and management sciences. One of the most important arguments in contract theories is that when parties of a contract need to make relationship-specific investments, because of the so-called “holdup” of partial payoffs by the other party, a contract party will invest at less than the socially optimal levels (Grout 1984, Williamson 1985, Tirole 1986, Hart and Moore 1988).

In this paper, we attempt to explain the “over-investment puzzle” in IT contracts by endogenizing the timing of investment in a contractual relationship. We argue that “over-investment” can be viewed as “premature investment” in a dynamic view on contracts. The reason for premature investments in IT to be so devastating lies in the high uncertainties involved in developing and adopting new technologies. We develop a model where a buyer is procuring a technology from a seller, who has to make a relationship-specific investment. The investment can be made either before or after uncertainty is resolved. We show that with asymmetric information between the buyer and the seller, premature investments may occur.

We study IT contracts where the seller is building customized IT equipment, selling software or providing IT services for the buyer and the buyer can make deferred payments over a period of time. It describes the business practice called “vendor-financing” that has been widely adopted in the IT industry. The buyers of IT products and/or services usually have limited IT budget and are unsure of the benefits that the products may bring to the organization. On the other hand, the products being traded are novel and unproven, and normally capital-intensive. Because of the risky nature of the IT projects, bank loans are generally unavailable for the procurement of

IT. Thus the seller faces the challenge of selling to suspicious buyers with limited financial resources and this has led to the prevailing practice of vendor financing.

Vendor financing means that a vendor can finance its customers to buy its own products, allowing the buyer to pay back later according to a payment schedule specified in the contract. Vendor financing fills the funding void in the market for capital-intensive IT products and services. However, the practice also has caused many problems that the market has come to realize in a hard way. The accounting procedures for vendor finance allow the vendor to book revenue when the contract is signed. The risks of not being paid back are usually not reflected and when the buyer defaults, the seller will just write-down the loss as a “bad debt”. Thus the income of a company can be inflated and the losses recorded later are also not as informative as they should be. With the recent collapse of Enron, the accounting processes in IT companies have come into the spotlight and been scrutinized, revealing partially the dark side of vendor financing.

In this paper, we focus on the situation where the buyer and the seller are maximizing profits on IT procurement with vendor-financing contracts. We show under asymmetric information, the seller will inevitably make inefficient investments and, under certain conditions, will make premature investments. While the managers of the seller may employ vendor-financing contracts for their personal gains, it goes beyond the scope of the current paper and requires a separate paper.

3.2 Related Literature on Contracts

In analyzing the proper timing of investments in contractual relationships, we first examine how other researchers have treated the issue of timing in writing a contract.

In the literature on contracts, the time to make an investment has been regarded as exogenous and not as a decision variable. Since we are considering the timing of investment as a decision choice made by the parties and as a potential contractual term, one problem that arises is that whether the time of investment can be described in a contract *ex ante*. If the time of investment can be accurately described, then a contract that includes the timing requirement can be analyzed under the "complete contract" paradigm; if on the contrary it is not describable, then the theory of incomplete contract will apply.

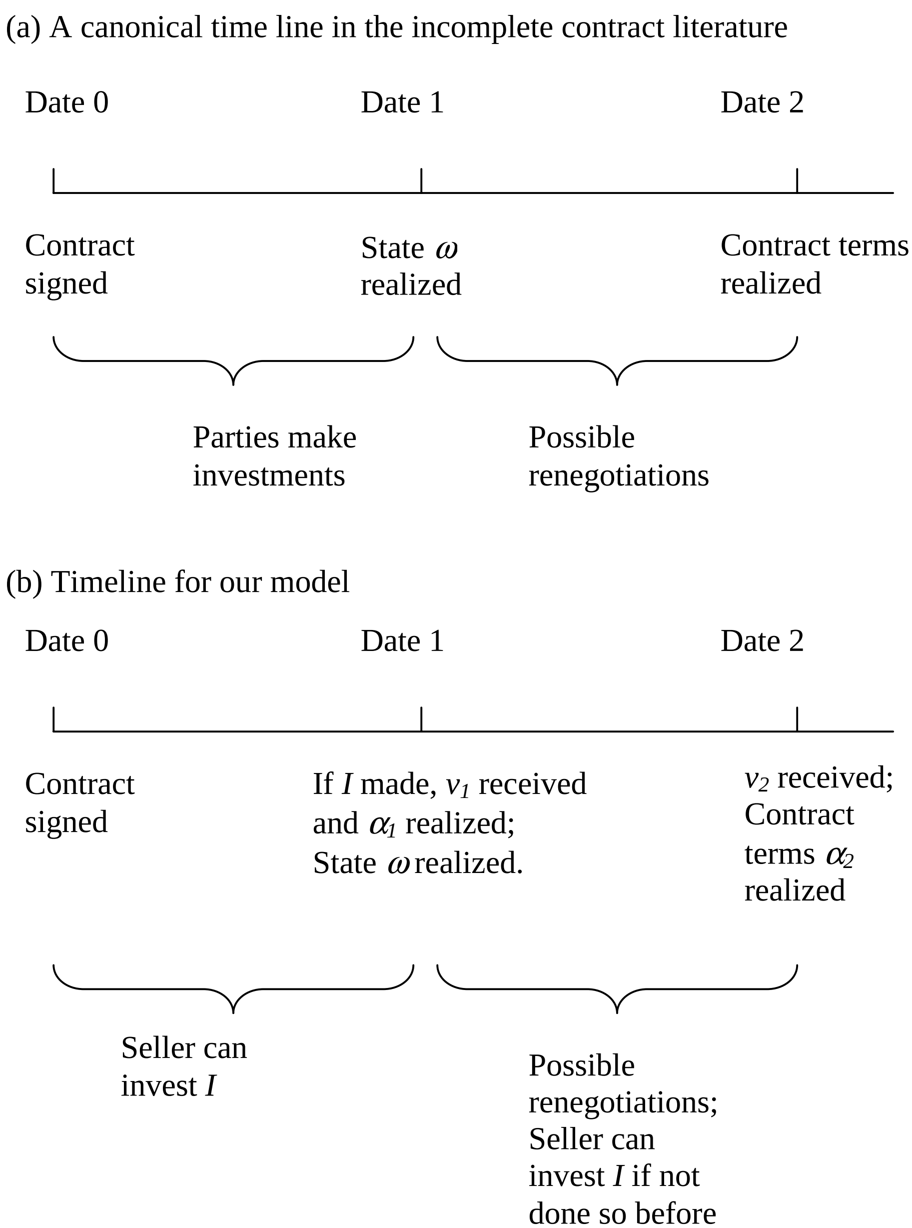
When the transaction costs of writing complete contracts – specifying all possible contingencies in a contract – are prohibitively high, parties will end up writing an incomplete contract. Transaction costs may come from unforeseen or indescribable contingencies and the costs of verifying and enforcing contracts (Tirole, 1999).

In our model, the time to invest can be either before or after a random "state of the world" is realized. The "state of the world" decides the value of a project and many events may serve as a proxy of this random variable. For instance, if we regard a major change in the stock market indices as an indicator, then it would be impossible to specify the investment time in a contract – in particular we cannot require an investment to be made *before* an event that may occur at any time (or never occur). If, for another instance, the event representing the state of the world is a fixed date on which a government meeting is to be held, then we are able to contract on the investment time. In this paper, we discuss both describable and indescribable timing choices.

Generally speaking most contracts for IT procurement are incomplete by nature. Because of the uncertainties in technology developments, consumer perceptions and government policies, it will be almost impossible for parties to *ex ante* enunciate all the possible contingencies in a contract. So when we discuss the effect of contractual completeness, it is only in the sense of the specification in timing.

In the studies of incomplete contracts with timing of events exogenously given, a contract involves a series of actions taken by parties and exogenous events that happen to the parties. Though the labeling of the time line varies among models of incomplete contracts, the sequence of events is essentially the same (see Figure 3.1a): at date 0, a buyer and a seller sign a contract; between date 0 and date 1, parties make relation-specific investments; at date 1, the state of the world, a random variable, is realized and the buyer's valuation and the seller's cost are known. After date 1 parties may renegotiate, and decide to trade or not, and in the end at date 2 contract terms are realized.

Figure 3.1: Time lines



This sequence of events has been assumed and as far as we know no particular justification has been given. The first question one may ask is why investment(s) should precede the realization of the state of nature. More precisely, it is unknown whether the parties have the option to wait to invest after the state of nature is realized on date 1. In most papers (such as Hart and Moore 1988, Noldeke and Schmidt 1995, Che and Hausch 1999), it is not clear whether the parties can wait to invest, thus the sequence of events is exogenous and assumed without further elaboration.

In Maskin and Tirole (1999), the timing of events is self-enforced, because it assumes that the investment vector by parties “gives rise, stochastically, to a verifiable state of nature”. But this assumption may not hold for certain cases. The state of nature may follow its own course, independent of the parties’ investment levels. It may be more reasonable to assume that the uncertainty is resolved at a certain time and the investments can be made at any time at the discretion of the investing party rather than assuming that the realization of the state of nature is induced by the parties’ actions.

Our model addresses the issue of timing in the following way: investments can be made during different time periods and will result in different returns; the time of investment may be specified in a contract if it is feasible; if the time of investment is unspecified in the contract, then the investing party (in our model, the seller) can choose the time strategically.

The value of flexibility in the time to invest reflects the value of a "real option" that the seller has (Dixit and Pindyck 1994). We find that when the buyer and seller have symmetric information, the value of such a real option is fully realized while with asymmetric information there will be inefficiencies in the timing of investments, which from the real option point of view means the value of the option is not maximized.

The value of the ability to delay investment, which is the value of a real option, lies in that when the investment is delayed and the state turns out unfavorable, the parties give up the project and save the investment. So to fully realize the real option value, parties should be able to renegotiate. In the incomplete contract literature, there has been a debate over the ability to commit not to renegotiate. In our model, with the flexibility in investment time, rational parties are unable to commit not to renegotiate.

The main result of this paper shows that the socially efficient level investment may not be achieved under asymmetric information; depending on the parameters, premature as well as delayed investments may occur.

3.3 Contracting under Symmetric Information

3.3.1 The Model

In contracting on IT, it is often the case that the market for a new technology is promising and first-movers have an advantage in the short run. However, the future growth of the market is highly uncertain and there is a possibility that firms who procures the technology may not survive to gain fully from the technology.

We model this situation with a three-date, two-period model in which a buyer is considering procurement of technology from a seller. There are three dates: 0, 1 and 2 and the time intervals between two adjacent dates are called period 1 and 2 respectively. Period 1 can be interpreted as the foreseeable future while period 2 represents time far into the future, the state of which is uncertain for the time being. At date 0, a buyer and a seller sign a contract. At date1, the state of nature ω is realized and is observed by both parties. The state of nature determines the value of the project to the buyer at date 2, denoted by v_2. For simplicity, we assume that there are only two states of nature: ω_H and ω_L, with ω_H occurs with probability p. If $\omega = \omega_H$ then the payoff to the buyer will be $v_2 = V_H$; if $\omega = \omega_L$ then $v_2 = V_L$, which we normalize to 0.

In order to achieve v_2, the seller needs to make an investment of $0 < I < V_H$ at some point in time. If the seller makes the investment of I during time period 1, then the buyer will receive an extra payoff of v_1 ($< I$) at the end of period 1, right before date 1. That means, if the buyer obtains the technology in the near future, there is an accurately predicted payoff to it. If the investment is made during period 2, then only v_2 will be received. Figure 3.1(b) illustrates the sequence of the above events.

In this section we assume that all the information is symmetric. We will relax this assumption and discuss the asymmetric information case later in this paper. For simplicity, we assume the interest rate to be zero.

3.3.2 Contracting Choices

First, a contract that the buyer and seller sign should specify how the payoffs would be distributed between the two parties. In particular, if the buyer gets v_1 then she pays out α_1 fraction of v_1 to the seller upon receiving this payoff; and she pays α_2 fraction of v_2 to the seller when receiving v_2.

A complete contract should also specify when and how much the seller should make the investment. In the incomplete contract literature, it is often assumed that the level of investment is observable but not verifiable. Since it is not the focus of this paper, we assume that the level of investment is a discrete choice between a fixed amount I and 0.

Rather, we concentrate on a dimension of contract that has been largely neglected: the timing of the investment. If we denote the time of investment by τ, then a complete contract will explicitly demand that investment be made in the time period τ. We say a contract is complete in timing (it may be incomplete in other aspects) if it specifies τ and incomplete in timing if τ is unspecified.

In contrast an incomplete contract will only stipulate α_1 and α_2. We say a contract is incomplete in timing if it leaves τ unspecified.

In the following subsections we first give the first-best outcome and then study whether, and if so, how the first-best can be achieved with different contracting choices. We discuss a contract complete in timing (α_1, α_2; τ), and compare it with an incomplete contract (α_1, α_2). Note that both contracts can be incomplete if they do not describe all the contingencies.

3.3.3 The First-best Outcome

As a benchmark, we establish the social optimal outcome, in which the buyer and the seller act as one entity to maximize the total surplus. If the investment is made during period 1, then the expected total payoff (with the expectation taken at date 0) is:

(1) $$TS_1 \equiv TS(\tau = 1) = -I + v_1 + pv_H$$

If the investment is not made during period 1, then at date 1, the state of nature is realized. If $\omega = \omega_H$, since $0 < I < V_H$, it is socially optimal to make the investment during period 2; if $\omega = \omega_L$, since $v_2 = V_L = 0$, the investment should not be made. At date 0, the expected total surplus from this contingent plan is:

(2) $$TS_2 = TS\left(\tau \in \mathcal{T} : \tau = f(\omega),\ f : \Omega \to \mathcal{T}\right) = p(v_H - I)$$

with

(3) $$\Omega = \{\omega_H, \omega_L\},\ \mathcal{T} = \{2, \infty\},\ f(\omega) = \begin{cases} 2, & if\ \omega = \omega_H \\ \infty & if\ \omega = \omega_L \end{cases}$$

We assume that the outside option for this project yields a total payoff of 0. In other words, if the parties decide *ex ante* not to carry out the project and that no investment in the project will ever be made, the expected total surplus is 0. By assumption, we know that $TS_2 > 0$. We further assume that $TS_1 = -I + v_1 + pv_H > 0$. We introduce the socially optimal investment rule in Lemma 1.

Lemma 1: The socially optimal investment rule is:

If $v_1 > (1-p)I$ *, then invest in period 1*;

If $v_1 < (1-p)I$ *, then wait until* ω *is realized and invest in period 2 if and only if* $\omega = \omega_H$;

If $v_1 = (1-p)I$ *, then adopt either of the two above strategies.*

Proof: The one entity considering this project is confronted with three alternatives at date 0: (1) to invest in period 1, (2) to wait until after date 1 and (3) to abandon the project. The payoff from alternative 1 is given by (1). If she waits until ω is realized, the highest expected payoff is given by (2). By assumption, TS_1, TS_2 >0, thus (3) is dominated. Thus the optimal investment rule is to invest in period 1 if

(4) $-I + v_1 + pv_H > p(v_H - I)$, i..e. $v_1 > (1-p)I$.

The rest can be proved similarly.

Q.E.D.

Lemma 1 demonstrates the trade-off in an immediate investment: short-run benefits and the expected loss in unsuccessful investment. If the benefits exceed the cost, then immediate investment should be made; otherwise, investment should be postponed.

3.3.4 Contracts Complete in Timing

As defined earlier, a contract complete in timing specifies the time the seller makes investment. Such a contract is feasible only when the time of the realization of the state of nature can be unambiguously defined and other related transaction costs are not prohibitively high.

We assume that at date 0, the buyer makes a take-it-or-leave-it (TIOLI) offer to the seller. To simplify the discussions on the seller's choices, throughout this paper we assume that the seller participates when he is indifferent between participation (accepting the contract) and no participation (rejecting the contract). It can be interpreted as follows: participation in the projects yields an infinitesimal, non-pecuniary benefit to the seller, thus participating in the project with zero profit (breaking even) gives the seller a total payoff of 0_+ and is preferred to not participating.

For a contract complete in timing (α_1, α_2; τ), given τ=1, the buyer's problem is:

$$(5)\ \max_{\alpha_1,\alpha_2} \quad (1-\alpha_1)v_1 + p(1-\alpha_2)v_H$$

$$s.t.\ -I + \alpha_1 v_1 + p\alpha_2 v_H \geq 0 \quad \text{(seller's participation constraint)}$$

Obviously, the solution to (5), i.e. the optimal contract is any pair (α_1, α_2) that satisfies the seller's participation constraint with the "=" holding. We denote the optimal contract given τ=1 as C_1^*:

$$(6)\ C_1^* = \left\{\left(\alpha_1^*, \alpha_2^*\right) : \alpha_1^* v_1 + p\alpha_2^* v_H = I; \tau = 1\right\}$$

Note that there will be no renegotiation and the original contract will be carried out, although in the case of $\omega = \omega_L$, both parties get 0 in the second period. [3]

The buyer's payoff with C_1^* is:

$$u_1^B = -I + v_1 + pv_H = TS_1$$

The buyer's maximal payoff equals to the total surplus given that the investment is made in period 1. This is because the buyer is assumed to have all the bargaining power.

Now suppose $\tau \neq 1$. If the contract requires that the seller make the investment in period 2, i.e. $\tau = 2$, then the contract degenerates to (α_2; $\tau = 2$). However, this contract is not renegotiation-proof, because after ω is realized at date 1, if $\omega = \omega_L$, the parties will mutually agree to tear up the contract and no investment will be made.

We now look at parties' *ex ante* decisions. At date 0, if the parties commit not to renegotiate, then the total expected payoff is $pv_H - I$; however, if parties anticipate that they may renegotiate in period 2, the total payoff is $p(v_H - I) = pv_H - pI > pv_H - I$. Thus for rational parties, a contract in the form of (α_2; $\tau = 2$) can only be signed with the implicit mutual understanding that it can be

[3] The three regimes of renegotiation: full commitment; no commitment; partial commitment. We adopt the regime in which a contract can only be revoked when both parties agree. In other words, neither party can unilaterally break the contract

renegotiated. And the contract is essentially $\{\alpha_2; \tau \in \mathcal{T} : \tau = f(\omega)\}$ with $f(\omega)$ defined by (3), that is, the time of investment can be either period 2 or infinity (never) depending on the realization of ω.

Instead of a contract with implicitly anticipated renegotiations, the parties can alternatively write a complete contract, describing *ex ante* all the contingencies under which the investment will not be made. In the incomplete contract literature, it is often argued that the transaction costs of writing a complete contract may be too high, making this approach infeasible. In this stark model, a complete contract and an incomplete contract with anticipated renegotiation yield the same outcome and thus are regarded as equivalent [4]. We denote this contract by $\{\alpha_2; \tau \in \mathcal{T} : \tau = f(\omega)\}$ or simply $\{\alpha_2; \tau = f(\omega)\}$. Then an optimal contract should solve:

$$(7)\quad \max_{\alpha_2} \quad p(1-\alpha_2)v_H$$

$$s.t. \quad p(\alpha_2 v_H - I) \geq 0 \quad \text{(seller's participation constraint)}$$

Again the solution to (7) makes the seller's participation constraint hold with "=". We denote the optimal contract given $\tau = f(\omega)$ as C_2^*:

[4] Note that we still call this incomplete contract with anticipated renegotiation "a contract complete in timing" because the investment time is a term specified in the contract and not a strategy that the seller can choose. It is not a complete contract in the sense that it does not *ex ante* enumerate all the contingencies in which the investment will and will not be made; rather, it defines investment time as a function of the state of nature, which becomes publicly observable at a future date.

(8) $C_2^* = \{\alpha_2^* : \alpha_2 = I/v_H ; \tau = f(\omega)\}$

And the buyer's payoff with C_2^* is:

$$u_2^B = p(v_H - I) = TS_2$$

Since we assume the buyer has all the bargaining power, for both C_1^* and C_2^*, the buyer's payoff is always the total surplus under the same timing specification, while the seller breaks even. Thus in choosing between C_1^* and C_2^* the buyer will follow the same rule as the social planner does, which is described in Lemma 1 and the first best is achieved. Without loss of generality, we assume that the buyer chooses C_2^* when $v_1 = (1 - p)I$.

Thus we establish Propositions 1 and 2.

Proposition 1: Suppose the buyer is offering a contract complete in timing (α_1, α_2; τ) *to the seller. The buyer's optimal contract is given by:*

(9) $C^* = D \cdot C_1^* + (1 - D)C_2^*$

where

$$C_1^* = \{(\alpha_1^*, \alpha_2^*) : \alpha_1^* v_1 + p\alpha_2^* v_H = I; \tau = 1\}$$

$$C_2^* = \{\alpha_2^* : \alpha_2 = I/v_H ; \tau = f(\omega)\}$$

$$D = \begin{cases} 1, & if\ v_1 > (1-p)I \\ 0 & otherwise \end{cases}.$$

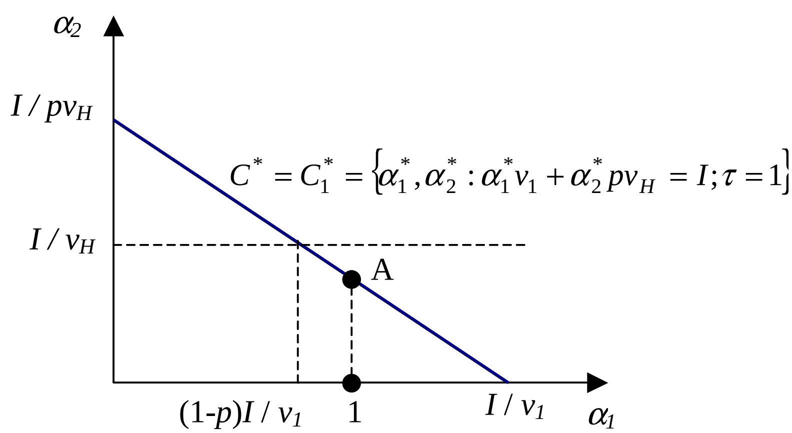
Proposition 2: The optimal contract complete in timing (α_1, $\alpha_2; \tau$) given by C^* in Proposition 1 achieves the first best outcome.

Figure 3.2 provides a graphic illustration of C^*. In panel (a), the optimal contract set under $v_1 > (1-p)I$ is the represented by the segment between (0, I / pv_H) and (I / v_1 , 0). In panel (b), the optimal contract set under $v_1 < (1-p)I$ is the represented by the horizontal line originated from (0, I / v_H). In these degenerated contracts, theoretically α_1 can take any non-negative number.

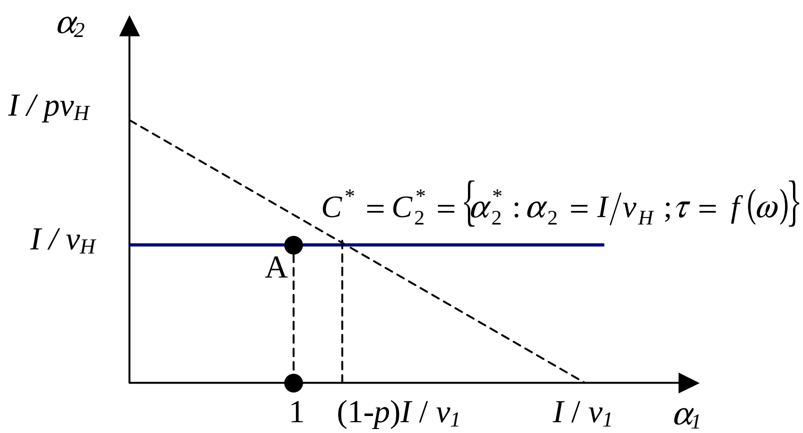
We note that in the above discussions we do not impose other restrictions to the ranges of α_1 and α_2. It should be noted that in the optimal contract set C_1^*, α_1 may be larger than 1. It is common that the buyer will not pay the seller any amount in excess of the perceived benefits. Also, the buyer may have no financial slack and is subject to cash constraint. Thus either voluntarily or reluctantly, the buyer may have a restriction on α_1 such that $\alpha_1 \leq 1$. With this constraint, the set of optimal contracts shrinks to the segment between (0, I / pv_H) and the point A in Figure 3.2. Similarly, for the degenerated optimal contract set C_2^*, now theoretically α_1 can only take values in the interval [0,1]. With such a constraint, the solution sets for the buyer are now subsets of those without, and because from any element in the choice set the buyer gets the same payoff, the outcome does not change. In summary, we have Corollary 1.

Figure 3.2: Optimal Contracts Complete in Timing

(a) $v_1 > (1-p)I$, i.e. $(1-p)I/v_1 < 1$



(b) $v_1 < (1-p)I$, i.e. $(1-p)I/v_1 > 1$



Corollary 1: The buyer's optimal contract complete in timing with cash constraint is given by:

$$C^* = D \cdot C_1^* + (1-D)C_2^*$$

where

$$C_1^* = \{(\alpha_1^*, \alpha_2^*) : \alpha_1^* v_1 + p\alpha_2^* v_H = I \text{ and } \alpha_1^* \le 1; \tau = 1\}$$

$$C_2^* = \{\alpha_2^* : \alpha_2 = I/v_H \ ; \tau = f(\omega)\}$$

$$D = \begin{cases} 1, & if \ v_1 > (1-p)I \\ 0 & otherwise \end{cases}.$$

And the first best outcome is achieved.

3.3.5 Contracts Incomplete in Timing

By definition, a contract incomplete in timing leaves investment time unspecified in the contract. Parties have to write contracts incomplete in timing when it is impossible to describe the time of the realization of the state of nature contingent on an event. Note that even when contracts complete in timing is feasible, parties can always choose to be incomplete in timing specification.

When parties write a contract incomplete in timing, the contract only specifies (α_1, α_2). Again we assume buyer makes a take-it-or-leave-it (TIOLI) offer to the seller. The renegotiations in period 2, after the state of nature is realized, are the same as in contracts with complete timing specifications. The difference is that now the seller can choose the time to make the investment strategically according to the contract the buyer offers, while in contracts complete in timing it is the buyer who includes time as a term in a contract. The game tree is illustrated in Figure 3.3.

Suppose the seller chooses to invest in period 1. Then the buyer's offer should solve:

$$(10) \qquad \max_{\alpha_1,\alpha_2} \quad (1-\alpha_1)v_1 + p(1-\alpha_2)v_H$$

$$s.t. \; -I+\alpha_1 v_1 + p\alpha_2 v_H \geq 0 \qquad \text{(seller's participation constraint)}$$

$$-I+\alpha_1 v_1 + p\alpha_2 v_H \geq p(\alpha_2 v_H - I) \qquad \text{(seller's incentive compatibility)}$$

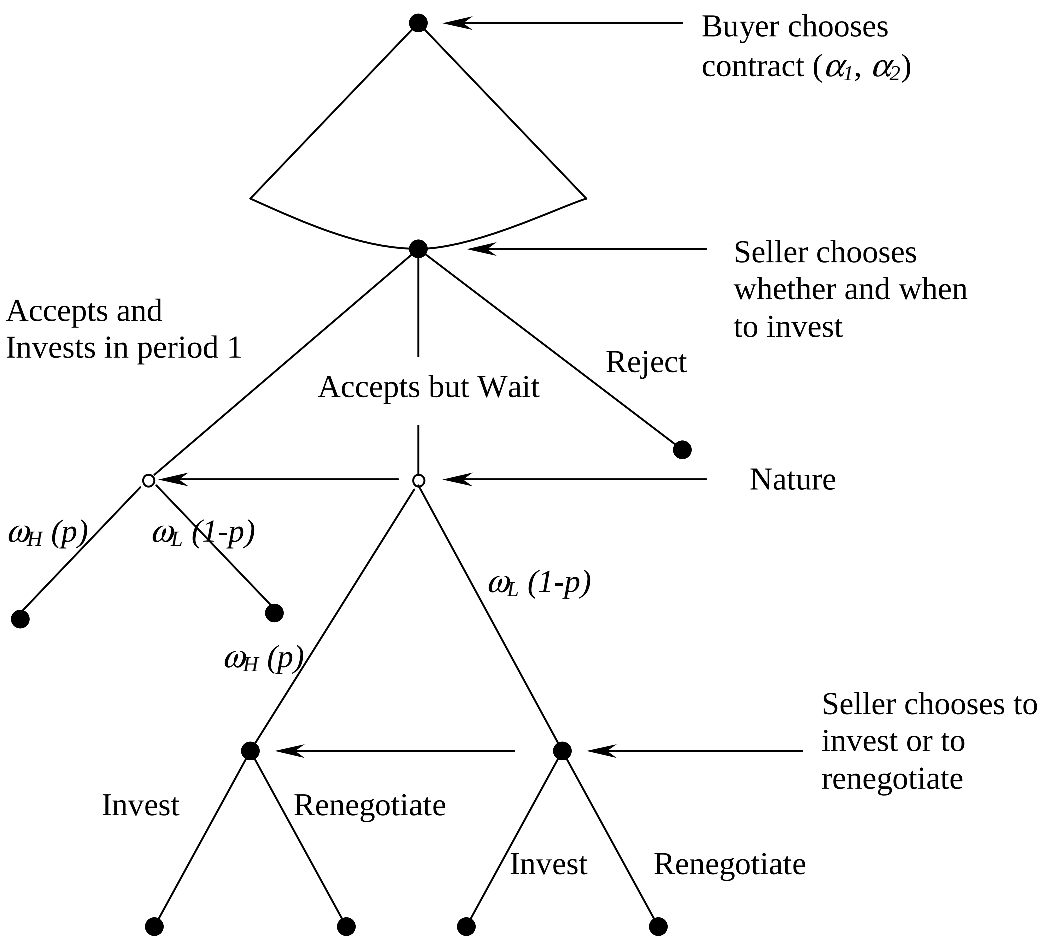
The solution set to (10) is:

$$(11) \qquad C_{i1}^* = \{(\alpha_1^*,\alpha_2^*): \alpha_1^* > I(1-p)/v_1 \text{ and } \alpha_1^* v_1 + p\alpha_2^* v_H = I\}$$

The buyer's payoff from C_{1i}^* is given by:

$$u_{1i}^B = -I + v_1 + pv_H = TS_1$$

Figure 3.3: The extensive form of the contracting game incomplete in timing with symmetric information



We see that the buyer gets the total surplus, leaving the seller with the reservation payoff of zero.

Now suppose that the seller chooses to wait until period 2. Then the buyer's offer should solve:

(12) $$\max_{\alpha_2} \quad p(1-\alpha_2)v_H$$

s.t. $p(\alpha_2 v_H - I) \geq 0$ (seller's participation constraint)

$p(\alpha_2 v_H - I) \geq -I + \alpha_1 v_1 + p\alpha_2 v_H$ (seller's incentive compatibility)

The solution set to (12) is:

(13) $$C_{i2}^* = \left\{\left(\alpha_1^*, \alpha_2^*\right) : \alpha_1^* \leq I(1-p)/v_1 \text{ and } \alpha_2^* = I/v_H\right\}$$

The buyer's payoff from C_{2i}^* is given by:

$$u_{2i}^B = p(v_H - I) = TS_2$$

In equilibrium, knowing the best response of the seller to the contract offer, the buyer will choose C_{1i}^* if $TS_1 > TS_2$, and C_{2i}^* if $TS_2 > TS_1$. Propositions 3 and 4 summarize the above results.

Proposition 3: Suppose the buyer is offering a contract incomplete in timing (α_1, α_2) *to the seller. The subgame perfect equilibria are:*

(i) *When* $v_1 > (1-p)I$ *, the buyer chooses* (α_1^*, α_2^*) *from the set*

$C_{i1}^* = \{(\alpha_1^*, \alpha_2^*) : \alpha_1^* > I(1-p)/v_1 \text{ and } \alpha_1^* v_1 + p\alpha_2^* v_H = I\}$ *and the seller accepts and invests in period 1;*

(ii) *When* $v_1 < (1-p)I$ *, the buyer chooses* (α_1^*, α_2^*) *from the set*

$C_{i2}^* = \{(\alpha_1^*, \alpha_2^*) : \alpha_1^* < I(1-p)/v_1 \text{ and } \alpha_2^* = I/v_H\}$ *and the seller accepts and waits until period 2;*

(iii) *When* $v_1 = (1-p)I$ *, the buyer chooses* (α_1^*, α_2^*) *from the set*

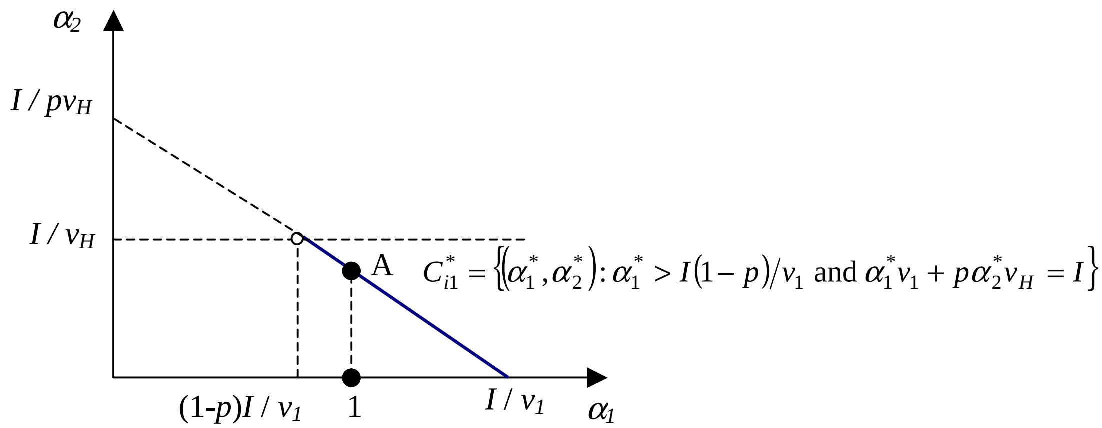
$C_{i3}^* = C_{i1}^* \cup C_{i2}^* \cup \{(\alpha_1^*, \alpha_2^*) : \alpha_1^* = 1 \text{ and } \alpha_2^* = I/v_H\}$ *and the seller accepts and may either invest in period 1 or wait until period 2.*

Proposition 4: The optimal contract incomplete in timing (α_1^*, α_2^*) *achieves the first best outcome.*

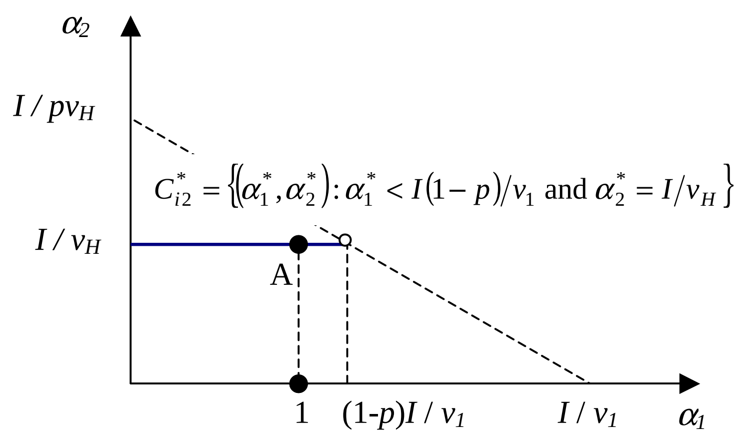
Compared with the contracts complete in timing, we see that the contracts both complete and incomplete in timing can achieve the first-best outcome. However, when the contract is incomplete in timing, the sets of optimal contracts from which the buyer can choose from are reduced. In Figure 3.4(a), the optimal contract set under $v_1 > (1-p)I$ is now the segment between $(I/v_H, (1-p)I/v_1)$ and (I / v_1, 0). In Figure 3.4(b), the optimal contract set under $v_1 < (1-p)I$ is now the horizontal segment with $\alpha_2 = I / v_H$ and $\alpha_1 \in [0, (1-p)I/v_1]$.

Figure 3.4: Optimal Contracts Incomplete in Timing

(a) $v_1 > (1-p)I$, i.e. $(1-p)I/v_1 < 1$



(b) $v_1 < (1-p)I$, i.e. $(1-p)I/v_1 > 1$



Remarks: One open question in the contract theory is whether the indescribability of contingencies changes optimal contracts. Maskin and Tirole (1999) show that the indescribable contingencies do not change the optimal contracts and develop irrelevance theorems. Hart and Moore (1999) argue that the optimal contract with describable contingencies can yield the first-best, while with indescribability contracting may be less valuable or even valueless, the latter leading to null contract as optimal contracts. In our very simple model, with symmetric information structure, the indescribability of contingencies reduces the sets of optimal contracts, though welfare of parties remains unchanged. So transaction costs may change contracting decisions.

We now discuss the impact of cash constraint. If the buyer has a cash constraint that requires $\alpha_1 \leq 1$, then the sets of optimal contracts may be reduced even further. As Figure 3.4 shows, the set now becomes the segment between $\left(I/v_H, (1-p)I/v_1\right)$ and the point A. Similarly, for the set C_2^*, because $(1-p)I/v_1 > 1$, with the constraint C_2^* is now restricted to $\alpha_1 \in [0,1]$. Similarly to Corollary 1, we have:

Corollary 2: For contracts incomplete in timing (α_1, α_2) with cash constraint, the subgame perfect equilibria are:

(i) When $v_1 > (1-p)I$, the buyer chooses (α_1^*, α_2^*) from the set $C_{i1}^* = \left\{(\alpha_1^*, \alpha_2^*) : I(1-p)/v_1 < \alpha_1^* \leq 1 \text{ and } \alpha_1^* v_1 + p\alpha_2^* v_H = I\right\}$ and the seller accepts and invests in period 1;

(ii) When $v_1 < (1-p)I$ *, the buyer chooses* (α_1^*, α_2^*) *from the set*

$C_{i2}^* = \{(\alpha_1^*, \alpha_2^*): 0 \le \alpha_1^* \le 1 \text{ and } \alpha_2^* = I/v_H\}$ *and the seller accepts and waits until period 2;*

(iii)When $v_1 = (1-p)I$ *, the buyer chooses* (α_1^*, α_2^*) *from the set*

$C_{i3}^* = C_{i1}^* \cup C_{i2}^* = C_{i2}^*$ *(because* $C_{i1}^* = \varnothing$*) and the seller accepts and may either invest in period 1 or wait until period 2.*

And the first best outcome is achieved.

Again with cash constraint, the set of optimal contracts becomes subset of those in the same scenario but without cash constraint. Because parties' payoffs remain constant in the continuum of equilibria, as long as the set of optimal contracts under cash constraint is not empty, the welfare does not change.

3.4 Contracting under Asymmetric Information

3.4.1 Asymmetric Information on Buyers' Type

In the above model we assume that all the information is symmetric between the buyer and the seller, which may not be quite realistic. Importantly, the buyers may differ in the probability that the state of nature will be favorable and this information is private to the buyer while the seller cannot observe it. In standard game theory terminology, we call this information the "type" of the buyer. The seller only knows the distribution of the types of buyers. Suppose all the other structures of the model remain the same.

To keep it simple, we assume there are only two types of buyers: high type and low type. For both types of buyers, there are two states of nature: ω_H and ω_L. For a high type buyer, ω_H occurs with probability p_H while for a low type ω_H occurs with probability p_L with $p_L<p_H$. In the population of buyers, a proportion of λ is the high type and the rest are the low type. In other words, if a seller is offered a contract, the offering firm is a high type with probability λ.

To make the case interesting, we assume that for the high type, it is socially optimal to invest in period 1 while for the low type, it is socially efficient to wait until after the state of nature is realized at date 1.

Assumption 1: $(1-p_H)I < v_1 < (1-p_L)I$

Again we assume that the buyer makes a take-it-or-leave-it (TIOLI) offer to the seller at date 0. We are going to study the contracting problems with both complete and incomplete specification in timing. Specifically, we are going to see whether contracts in both cases can serve as a "signal" to successfully convey the information of the buyer's type.

3.4.2 Contracts Complete in Timing with Asymmetric Information

First we examine what the optimal contracts will be if contracts complete in timing (α_1, α_2; τ) are possible. Figure 3.5 shows portions of the signaling-contracting game between the buyer and the seller (the renegotiations after the seller accepts the contract are omitted).

Proposition 5: Suppose the type of the buyer is private information to the buyer, and p_H and p_L satisfy Assumption 1. If a contract complete in timing can be written, then the signaling-contracting game has a separating equilibrium characterized by:

(i) The high type buyer chooses

$$C_{1H}^* = \left\{ \left(\alpha_1^*, \alpha_2^*\right) : \alpha_1^* v_1 + p_H \alpha_2^* v_H = I \text{ and } \alpha_1^* > \frac{p_H v_1 - p_L I (1 - p_H) v_1}{(p_H - p_L) v_1} ; \tau = 1 \right\}$$

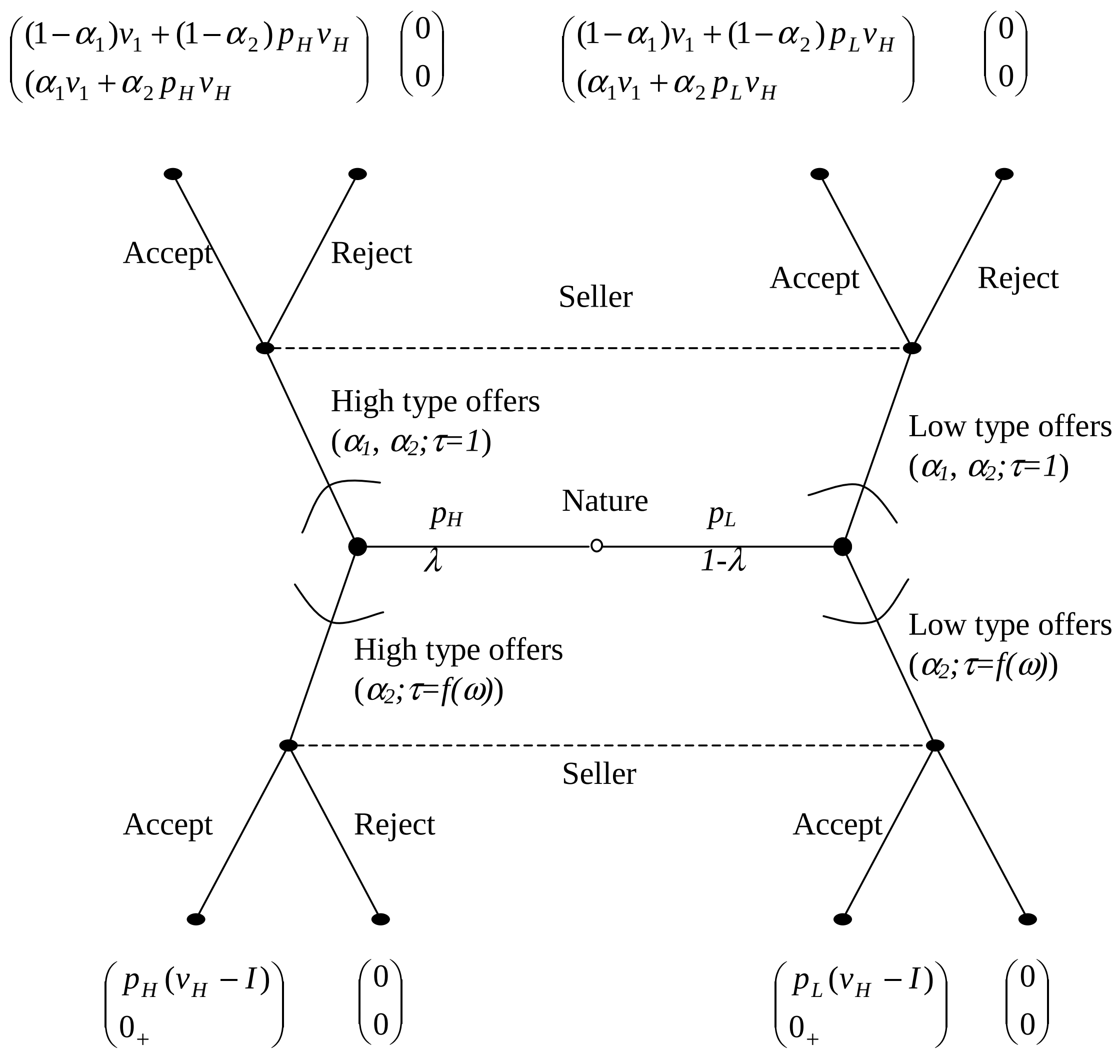
The low type buyer chooses $C_{2L}^* = \left\{ \alpha_2^* : \alpha_2 = I / v_H \,; \tau = f(\omega) \right\}$;

(ii) The seller accepts and makes investment in period 1 when offered C_{1H}^*; and accepts and waits until period 2 when offered C_{2L}^*.

Proof:

Suppose the high type buyer is offering a contract with $\tau = 1$, the best she can do provided that the seller will accept is to offer C_1^* as derived before, with p=p_H.

Figure 3.5: Portions of the extensive form of the game of writing contracts complete in timing with asymmetric information



(14) $C_{1H} = \{(\hat{\alpha}_1, \hat{\alpha}_2): \hat{\alpha}_1 v_1 + p_H \hat{\alpha}_2 v_H = I; \tau = 1\}$

And the buyer gets

$$u_{1H}^B = -I + v_1 + p_H v_H = TS_{1H}$$

When the high type buyer is offering a contract with $\tau = f(\omega)$, the best she can do with the seller participating is to offer:

(15) $C_{2H} = \{\tilde{\alpha}_2 : \tilde{\alpha}_2 = I/v_H ; \tau = f(\omega)\}$

And the high type buyer gets

$$u_{2H}^B = p_H (v_H - I) = TS_{2H}$$

By Assumption 1, $u_{1H}^B > u_{2H}^B$, thus the high type will choose C_{1H} over C_{2H}.

For a low type buyer, if he offers the same contract C_{1H} as the high type does, he gets

$$u_{1L}^B = -I + v_1 + p_L v_H + \hat{\alpha}_2 (p_H - p_L) v_H$$

If he offers contract C_{2H}, then he gets

$$u_{2L}^B = p_L (v_H - I)$$

To have the separating equilibrium, we need to have

$u_{1L}^B < u_{2L}^B$, i.e.

$$(16) - I + v_1 + p_L v_H + \hat{\alpha}_2 (p_H - p_L) v_H < p_L (v_H - I)$$

From (16), and the condition $\hat{\alpha}_1 v_1 + p_H \hat{\alpha}_2 v_H = I$ given in (14), we have

$$(17)\, \hat{\alpha}_1 > \frac{p_H v_1 - p_L I (1 - p_H) v_1}{(p_H - p_L) v_1}$$

If the $\hat{\alpha}_1$ in C_{1H} satisfies (17), then the seller believes that it is the high type buyer that is offering C_{1H} and the low type firm offering C_{2H}, and in both cases the seller's dominant strategy is to "Accept". Given the seller accepts the both offers, the both types of buyers have no incentive to deviate from their contract offers. Thus (i) (ii) and (iii) constitute a separating equilibrium.

Q.E.D.

Proposition 6: The separating equilibrium defined in Proposition 5 achieves the first-best outcome.

Remarks: Propositions 5 and 6 show that when it is feasible to write contracts complete in timing, then there is a separating equilibrium in which the first-best is achieved. This is not surprising since the specification in time can serve as a signal for the buyer to fully reveal the information on her type. We can easily incorporate the transaction cost of writing a contract complete in timing in this model: when the transaction cost is relatively low and there is net gain in signaling with the specification, then separating equilibrium exists and high type buyers can distinguish themselves by specifying the investment time.

3.4.3 Contracts Incomplete in Timing with Asymmetric Information

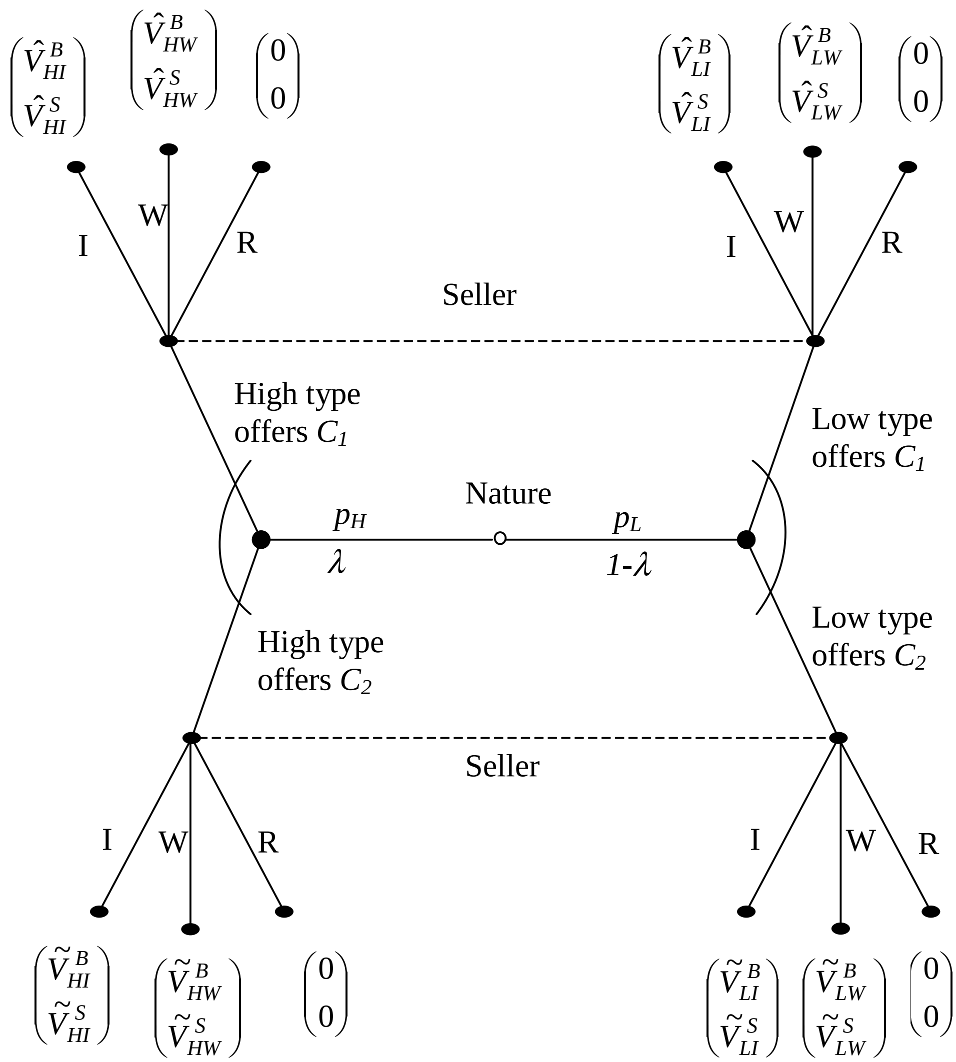
When parties write a contract incomplete in timing, the contract only specifies (α_1, α_2). Again we assume buyer makes a take-it-or-leave-it (TIOLI) offer to the seller. The renegotiations in period 2, after the state of nature is realized, are the same as in contracts with complete timing specifications. Portions of the game tree are illustrated in Figure 3.6.

In Proposition 7, we show that with cash constraint on the buyer, there will be no separating equilibrium.

Proposition 7: Suppose the buyer with private information on its type is offering a contract incomplete in timing (α_1, α_2) *to the seller. If the buyer has cash constraint in payment, then there is no separating Perfect Bayesian Nash equilibrium.*

Proof: We prove the non-existence of the separating equilibrium with the high type offering a contract $(\hat{\alpha}_1, \hat{\alpha}_2)$ such that the seller will choose to invest in period 1 and the low type offering a different contract $(\tilde{\alpha}_1, \tilde{\alpha}_2)$ such that the seller will choose

Figure 3.6: Portions of the extensive form of the game of writing contracts incomplete in timing with asymmetric information



Buyer's strategies: the buyer can choose a contract from a continuum of (α_1, α_2).

Seller's strategies:
- "I": Accept the contract and invest in period 1;
- "W": Accept the contract but wait until period 2;
- "R": Reject the contract.

to wait until period 2. For such an equilibrium to exist, first we need to have the seller to invest in period 1 when offered $(\hat{\alpha}_1, \hat{\alpha}_2)$ with the belief that it is from a high type buyer and to wait when offered $(\tilde{\alpha}_1, \tilde{\alpha}_2)$ with the belief that it is from a low type buyer.

(18) $$-I + \hat{\alpha}_1 v_1 + p_H \hat{\alpha}_2 v_H > p_H (\hat{\alpha}_2 v_H - I)$$

(19) $$p_L (\tilde{\alpha}_2 v_H - I) > -I + \tilde{\alpha}_1 v_1 + p_L \tilde{\alpha}_2 v_H$$

Given the seller's strategy and beliefs, the buyer should not deviate from the chosen contract of her type. Thus we have

(20) $$(1 - \hat{\alpha}_1) v_1 + p_H (1 - \hat{\alpha}_2) v_H > p_H (1 - \tilde{\alpha}_2) v_H$$

(21) $$p_L (1 - \tilde{\alpha}_2) v_H > (1 - \hat{\alpha}_1) v_1 + p_L (1 - \hat{\alpha}_2) v_H$$

From (20) and (21) we get

(22) $$\hat{\alpha}_1 < 1 + \tilde{\alpha}_2 \frac{p_H v_H}{v_1} - \hat{\alpha}_2 \frac{p_H v_H}{v_1}$$

(23) $$\hat{\alpha}_1 > 1 + \tilde{\alpha}_2 \frac{p_L v_H}{v_1} - \hat{\alpha}_2 \frac{p_L v_H}{v_1}$$

So,

$$(24) \qquad 1+\frac{p_L v_H}{v_1}\left(\tilde{\alpha}_2-\hat{\alpha}_2\right)<\hat{\alpha}_1<1+\frac{p_H v_H}{v_1}\left(\tilde{\alpha}_2-\hat{\alpha}_2\right)$$

Since $p_L<p_H$, we must have $\tilde{\alpha}_2>\hat{\alpha}_2$ for (24) to hold. Thus we have $\hat{\alpha}_1>1$, the cash constraint is violated.

Suppose in (24) the strict inequality signs can be changed into equal signs. Then when $\tilde{\alpha}_2=\hat{\alpha}_2$, we have $\hat{\alpha}_1=1$. This is equivalent to having (20) and (21) both hold with "=". That means both types of buyers would be indifferent between two contractual choices and might randomize between different contracts, in which case a separating equilibrium is not achieved.

Q.E.D.

Proposition 7 shows that with cash constraint on the buyer, the high type buyer will be unable to offer a contract different from that offered by the low type so as to reveal her type. For a high type to reveal her true type, she has to offer more than v_1 for the seller to believe it is from a high type who is confident in her future success so that she can undertake short-run losses. As long as the incentive scheme is capped at the maximum of the payoff from that period, the low type can always copy the contract offered by the high type.

Proposition 8: In writing contracts incomplete in timing with asymmetric information and cash constraint in payment, there are two possible sets of pooling equilibria:

(i) *When* $v_1 > (1-\bar{p})I$ *, with* $\bar{p} = \lambda p_H + (1-\lambda) p_L$*, both types of buyers choose* (α_1^*, α_2^*) *from the set*

$C_{ia1}^* = \{(\alpha_1^*, \alpha_2^*) : I(1-\bar{p})/v_1 < \alpha_1^* \leq 1 \text{ and } \alpha_1^* v_1 + \bar{p}\alpha_2^* v_H = I\}$ *and the seller accepts and invests in period 1;*

(ii) *When* $v_1 < (1-\bar{p})I$ *, both types of buyers choose* (α_1^*, α_2^*) *from the set*

$C_{ia2}^* = \{(\alpha_1^*, \alpha_2^*) : 0 \leq \alpha_1^* \leq 1 \text{ and } \alpha_2^* = I/v_H\}$ *and the seller accepts and waits until period 2.*

Proof: To prove (i), first we look at the seller's choice. When the both types of buyers are offering a contract $(\alpha_1^*, \alpha_2^*) \in C_{ia1}^*$, the seller chooses to invest in period 1 if and only if:

(25) $$\begin{aligned} &\lambda(-I + \alpha_1 v_1 + p_H \alpha_2 v_H) + (1-\lambda)(-I + \alpha_1 v_1 + p_L \alpha_2 v_H) \geq \\ &\qquad \lambda p_H (\alpha_2 v_H - I) + (1-\lambda) p_L (\alpha_2 v_H - I) \end{aligned}$$

(26) $$\lambda(-I + \alpha_1 v_1 + p_H \alpha_2 v_H) + (1-\lambda)(-I + \alpha_1 v_1 + p_L \alpha_2 v_H) \geq 0$$

Inequalities (25) and (26) are equivalent to

(27) $\alpha_1 > I(1-\bar{p})/v_1$ and

(28) $\alpha_1 v_1 + \bar{p}\alpha_2 v_H \geq I$

A contract offer $(\alpha_1^*, \alpha_2^*) \in C_{ia1}^*$ satisfies (27) and (28). Thus given such a contract the seller does not deviate from the strategy "accepts and invests in the first period".

By Proposition (7), we know that the high type buyer cannot successfully offer a contract different from that offered by the low type when there is cash constraint. Of all the contracts that satisfy (27) and (28), the optimal contracts for a buyer are those let (28) hold with "=". Thus we prove (i) is a pooling equilibrium.

Proof of (ii) can be done similarly.

Q.E.D.

The intuition behind Proposition 8 goes as follows. Since the high type cannot distinguish themselves from the low type, as established in Proposition 7, the low type can always offer the same contract as offered by the high type. In the pooling equilibrium where premature investments are made, the optimal contracts that buyers offer leaves the seller with zero expected payoff, earning positive payoffs from the high type while losing money to the low type. Thus the low type actually gets a payoff that is higher than the maximum that she herself can bring to the society while the high type gets less than the value she brings. That gives room for a pooling equilibrium where none of the buyers have an incentive to deviate from the contract.

Proposition 9: For contracts incomplete in timing with asymmetric information and cash constraint in payment, the first-best cannot be achieved.

(i) When $v_1 > (1-\bar{p})I$ *, there will be premature investments;*

(ii) When $v_1 < (1-\bar{p})I$ *, there will be delayed investments.*

Proof: By Assumption 1, it is socially efficient to invest in period 1 only for the high type and to wait until after the state of nature is realized for the low type. Thus the result follows from Proposition 8.

Q.E.D.

According to Lemma 1, the social optimum is achieved when the trade-offs in an immediate investment are properly evaluated. Now because of the lack of effective signal, the two types of buyers cannot be distinguished. When *on average* the short-run benefits exceed the expected loss in failed projects, the sellers will invest in the first period, with (1-λ) proportion of the investments being premature.

From Proposition 9, we can also see that higher expected short-run profits (v_1), the more likely premature investments will be made, while higher investment may deter sellers from investing prematurely.

Remarks:

1. We have already shown that indescribability of timing changes the set of optimal contracts. Now with asymmetric information, the indescribability or prohibitively high transaction cost of specifying investment time lead to inefficiencies.
2. Different from the prediction of incomplete contract theory stating that under-investments emerge in contractual relationships, we show that premature investments may occur.

3.5 Conclusions and Future Research

In this research, we focus on the time of investment as a decision variable in writing contracts. As far as we know, this has not been done before. We recognize that in an uncertain environment the ability to wait to invest has a value – real option value – and the proper timing of investments depends on the tradeoffs between short-run benefits and the expected loss from failed projects.

The most important finding of this research is that in presence of asymmetric information and cash constraints on the buyer, contracts incomplete in timing lead to inefficiencies in investments. In particular, when the short-run benefits are relatively high, premature investments will occur. With our simple model, we are able to explain what has happened in IT investments over the last couple of years.

Premature investments can be highly detrimental, as shown in the U.S. economy. Understanding that with currently high profit margins but future uncertainty premature investments may occur sheds lights on how buyers and sellers should design a contract and make decisions in a contractual relationship. In particular, buyers may try to effectively send signals to the sellers to reveal its strength. In our model we assume that all the public information is “correct”, while in reality it is far from being true. From the results derived in this paper, we can easily see that when the market overestimates the current profit margin and the portion of successful (or simply sustainable) buyers and underestimates the investments required, the issue of premature investments exacerbates.

We study the issue of timing of investments in contracts under both complete and incomplete contract framework. When the time of the investment cannot be specified or can only be specified at prohibitively high costs, contracts incomplete in timing will be used.

Our model addresses some important issues of incomplete contracts. We show that when there is flexibility in investment time, rational parties are unable to pre-commit not to renegotiate. This is due to the real option value. When one entity is making investment decisions, the real option value is fully realized. When two parties are involved and have written an incomplete contract, only through *ex post* renegotiation can the real option value be realized.

Our results also show that transaction costs in writing complete contracts may change the outcome of optimal contracts.

Future research can be done in several directions. Besides more general specifications on investments, distribution of values and buyer types, it will be interesting to extend the model in the following ways:

First alternative roles of parties can be explored. In the current model the buyer has all bargaining power, and it will be interesting to examine the effects of bargaining power on the results. The situation where both buyers and sellers are making investments is also worth studying. We study the case in which buyers have private information. In reality it may also be true that the seller has private information or, more generally private information on both sides.

Second, in this research we assume that the parties are rational and their information is "correct". It will be important to extend the model to the situation where parties' information may be wrong. It should be noted that parties may make investments simply to refine their information.

In this paper we find that contract that is more complete dominates the less complete ones. However, it is important to study where parties may strategically write less complete contracts (Bernheim and Whinston 1998).

Lastly, empirical research on this topic will be interesting and helpful. This research is motivated by the over-investments in IT industry. It is important to test whether this model helps explain the premature investments and predict the outcome.

Chapter 4 Corporate Governance in the Information Technology Industry: Nature of New Technology and Incentive Schemes for Executives

4.1 Introduction

The collapse of Enron Corp. has challenged faith in Corporate America. Prior to it, the burst of the Internet bubble and bankruptcies of dot-coms had shown how risky it could be to invest in unproven enterprises, in the "post-Enron" era, however, as the controversial accounting practices and excessive executive pay in high technology companies have gradually come to light, the public has realized that there is more to worry about than pure technological issues.

In this research, we argue that the nature of new technology exacerbates agency issues in these companies and imposes a new challenge to corporate governance structure. From the social welfare point of view, the agency issues in high technology firms may prevent the public to invest enough in these firms, thus impede the society's technological innovations.

4.1.1 Technology Companies: Excessive Executive Pay and Poor Stock Performance

Facts in the business world show that high technology companies do not always reward their investors with high return; actually many of them do not, as investors in technology companies have found out when NASDAQ dropped from the height of 5048.6 in March 2000 to 1387.06 in September 2001 (it is now 1650, as of May 9, 2002). If top executives were compensated according to their performance, one would expect that the top management have suffered as much as their shareholders. But it turns out that these executives are not only getting paid, but have reaped considerable gains.

Among the 20 top-paid executives in the United States in 2001, 65% of them are executives of high technology companies, including computer, software, and biotechnology, and among the top 10, 80% of them are from high tech industries.[5] Some of these CEOs are from companies whose investors are also enjoying high returns; for example, Howard Solomon, the CEO of Forest Laboratories ranks third on the Executive Scoreboard with $148.5 million in total pay ($147.3 from exercised options, restricted shares and long-term incentive payments) while shareholders' total return for the same fiscal year is 40%. However, many other top officers took home record compensation packages while the investors are suffering huge losses. For example, Lawrence Ellison of Oracle earned $706.1 million in 2001, all from exercising stock options, while shareholders' value declined 57%. Other cases include Steve Jobs of Apple Computer with $84 million in pay while stock value of the company dropped 40%, and David Ricky of Applied Micro Circuits with $59.5 million compensation (98.5% from selling shares and/or exercising stock options) while shareholders lost 78% of their money.

[5] "Special Report: Executive Pay", by Louis Lavelle, with Frederick F. Jespersen in New York and Michael Arndt in Chicago, *BusinessWeek*, April 15, 2002

It should be noted that many of these executives also lose in their pay-related total wealth when their companies' stock price dropped drastically. For instance, Larry Ellison's pay-related wealth declined by 58% since 2000 mainly because of his unexercised stock options. However, what is startling is that these executives were able to cash in at least part of their stocks and stock options before the stock price plummeted. According to data from Thomason Wealth Management, some insiders of companies cashed in at least $75 million in stocks since the start of 2000 while witnessing a stock price decline of at least 90% in that period (see the Table 1).[6] Among them was Jozef Straus, CEO of JDS Uniphase who ranked second on the executive scoreboard with $150.8 million total pay in 2001, only second to Larry Ellison. He sold/exercised his stock holdings and stock options to reap $168.9 million ($150.8 million in 2001) since the year 2000 while investors almost lost all their money. It is even more shocking to see that the CEOs of i2 Technologies and Foundry Networks were able to sell stocks for gains of more than $400 million while shareholders' money evaporated. One singular fact from this data is that all these extreme episodes of conflicting interests between shareholders and managers happened in technology industry.

[6] "I got mine, Jack", by Katrina Keller, *Forbes* Vol. 168, No 10, April 29, 2002.

Table 1: Insiders who cashed in at least $75 million in stock since 2000

while the stock price declined of at least 90% in that period

Insider	Company	Industry	Value of stock sold ($mil)[1]	Stock price performance[1]
Sanjiv Sidhu	I2 technologies	software	454.3	-90%
Bobby R. Johnson Jr.	Foundry Networks	telecom	405.6	-95
Jozef Straus	JDS Uniphase	telecom	168.9	-93
Keith Krach	Ariba	telecom	168.2	-95
Daniel Smith	Sycamore Networks	telecom	129.1	-96
Naveen Jain	InfoSpace	software	111.4	-97
JoMei Chang	Vitria Technology	software	84.0	-93

1. From Jan 1, 2000 to Mar 29, 2002. Includes indirectly owned shares.

Sources: Thomason Wealth Management; Interactive Data Corp. via FactSet Research Systems.

Stocks and stock options granted to corporate leaders are designed to align their interests with those of shareholders. In the 1990s, more and more companies, especially those involving high technology, developed compensation schemes for managers that offer stocks and stock options. However, as shown in the above examples, obviously the interests of the executives and the shareholders are disconnected, and it is astonishing that their gains from the same company during the same period of time even moved in completely different directions. As Laura Tyson pointed out, clearly "something is amiss" in the corporate governance structure of these companies.

4.1.2 How the Nature of Technology Gives Rise to Special Agency Issues

The above examples reveal that it is in technology companies that the disparateness between the gains of the managers and that of the investors is most conspicuous. Our analysis shows that this is not because these managers tend to be more corrupt than their counterparts in other industries, but a result of the combination of these factors: the nature of new technologies, stocks and stock options as compensation and the limited restrictions on managers' selling stocks and exercising options.

Many ongoing investigations into technology companies have put the spotlight on the accounting issues of these companies; however, we think that we should first try to better understand the nature of technology development and then examine the implications of these characteristics.

Basically any rational investor knows that there is a risk in corporate investment and is also aware that investing in emerging technologies has a higher expected return that comes, inevitably, with higher risks. Innovative technologies may provide new vessels to increase business productivity dramatically. Examples include online auctions, Web services, Web caching, and Peer-to-Peer (P2P) networks. Note that innovative technologies are not constrained to information technologies (IT), although IT certainly is a large part of it. For example, biotechnologies including micron technology, anti-cancer drugs are in the dawn of exciting breakthrough. Once productivity increase is converted into operational profit, as in companies like eBay and Google, investors can be rewarded with very high returns. However, it is also possible that the technology may turn out to fail and there may be no return for the tremendous investment, thus the downside of technology investment is also larger than traditional investment.

But the most significant uncertainty in technology investments goes beyond the simple volatility of return. Central to the nature of technology innovations is that the potential for a new technology to succeed and bring in profits is unknown. In traditional industries, businesses may succeed or fail, but it is easier for people to predict the likelihood of success for a certain firm based on all available information on the firm and the industry. As a result, researchers usually assume that the probability distribution of the rate of return to a company's stock is common knowledge among economic agents. But for new technologies, it is hard to tell how innovative and promising a new technology is, and more difficult to tell which technology is superior and more likely to win over other competing technologies. For example, in developing search engines, many technologies seemed promising at first and only after a period of time can people tell that Google's algorithm yields the best result.

Warren Buffett, the world's greatest stock market investor as well as a publicly admitted technophobe said he does not invest in technology stocks because he does not know how to evaluate the relative advantage of new technologies. Even venture capitalists that specialize in evaluating new technology start-ups can expect only a very small proportion of all the projects they invest in to finally succeed, despite that they spend huge amount of resources trying to predict the prospects of new technologies.

Thus investing in technology stock inevitably involves forming a belief in the relative strength of the technology ("bet" is the word used by Warren Buffett). Investors may order technology firms in terms of the superiority of their technology. It should be noted that technology supremacy does not guarantee the success of a business. Companies with any type of technology may succeed or fail. Failure may be caused by intense competition and new advances in technology. The Web portal industry is a good example where, although online index and search services greatly reduced customers' search cost, fierce competition drives some of the largest portals to bankruptcy while leaving others struggling to survive. Furthermore, new technologies developed by rivals may put companies using older technologies into hard situations. The invention of Web caching is a heavy strike to the once popular Web hosting service, as the former one provides a new scalable solution to e-business at a much lower cost than the latter one. Web hosting providers like Exodus are now burdened with huge sunk cost in unused capacity. However, intrinsically more innovative technology is much more likely to succeed, because technological advantage makes the firm more immune to competition (as a better technology will eventually be perceived and accepted by more people) and less likely to be surpassed by future developments in the short run.

We think that it is crucial to understand technology investments that people can only form beliefs on the potential of a new technology. This fundamental characteristic leads to another key feature of our model: people update their beliefs as more information on the technology is revealed over time. Specifically, all agents may have the same initial belief on technology based on publicly available information such as research reports and venture capital investments. As the technology is being tested on the market, people may boost or lose their confidence in the merits of the technology. Thus in high technology industries, there is a learning process on the information. Next we will introduce how this learning process together with executives' compensation schemes leads to agency issues special to technology firms.

4.1.3 Stocks and Stock Options and the Agency Issue in Technology Firms

In high technology industries, such as the information technology and bioengineering technology, because of the nature of new technology discussed above, everyone, including both the managers and the financiers, has to learn the potentials and risks of a new technology over a period of time. However, the learning processes are different for managers and investors. The managers of these firms have access to first-hand information regarding the potential of the technology, such as internal reports from R&D, marketing, customer service, technical support, and finance departments. The investors, on the other hand, can only gain better understanding by being told, such as from companies' press releases and financial reports. In other words, investors rely on the management to provide updated information on the new technology. In traditional industries, though there is information asymmetry between insiders and investors, investors have rational expectations on the rate of return because the production technology is well understood. In high technology industries, however, the fundamental difference in the ways to learn more about technology leads to a special issue. Because the updated information is transferred from the managers to the public, the managers have a chance to purposefully mislead the public for their own personal interests. And stocks and stock options give them such incentives.

Because of the uncertainties and risks involved, it is common practice for high-tech companies to offer high-powered compensation schemes such as stock ownership, stock options to attract, motivate, and reward top executives. For these growth-oriented companies, stocks and options are also a great way to preserve cash while giving executives great potential in future wealth.

Such compensation schemes ignore the fundamental characteristic of technology and have led to severe conflicts of interests between investors and managers mentioned in the previous section. With large amount of awarded stocks and low-priced options, the CEOs may find it in their interests to manipulate the beliefs on the potential of the project that the public holds. For example, even the profits from a new software are lower than predicted, the company may employ some unusual accounting practice (see Lin and Whinston 2002) to meet or even beat market expectations, and with the public gaining confidence in the company, the manager will cash in his stocks/stock options. Another way for companies to manipulate the information revelation process is to pay stock analysts to give high recommendation to the stock.[7]

There is plenty of evidence showing that top managers of technology firms do cash in when the public is still confident and a drastic fall in the stock price usually follows the sale of stocks by managers. As the Mercury News stock index of Silicon Valley's top 150 companies decreased by 20 percent in 2000, the gains from stock options exercised by Silicon Valley top executives soared 135 percent. More

[7] The scandal around Merrill Lynch analyst Henry Blodget is a good example. See “Reforming Wall Street” from Forbes website at http://www.forbes.com/2002/05/22/0523wallstreet.html for new developments.

importantly, executives cashed in options on about 93 million shares during 2000, 75 percent more shares than they exercised in the previous year. And the average gain per share was $44, up from $33 in 1999. For example, Cisco, the networking giant whose stock hit a historic peak early 2000 illustrates how Silicon Valley's executives cashed in. During the company's fiscal year, which ended July 31, 2000, Cisco's top six executives exercised 6.7 million options for a gain of $307.8 million, compared with 6 million shares exercised at a gain of $220.5 million in the prior year. All the options were exercised before Cisco's stock hit an all-time high of $80.06 on March 27, 2000.[8] The cashing in by JDS Uniphase executives followed a similar pattern.

Experts have pointed out that an increase in option exercises can be a signal of problems with the company or the stock price. “You really don't see executives exercising options in the normal case until they sense bad times are going to occur,” said Dave Swinford, managing director of Pearl Meyer & Partners, an executive-compensation consulting firm based in New York.[9]

However, under the current legal structure for the sale of stocks and execution of options by executives, the public gets to know that the management has exercised excessive stock options only when it is too late. In the next subsection, we discuss the loophole in the current rules that has led to agency issues particularly in technology companies.

[8] “Valley exec compensation soars as stock plummet”, by Elise Ackerman, *Mercury News*, Sun, Jun. 17, 2001

[9] same source as 5.

4.1.4 Legal Structure for Insiders Trading

Currently, Section 16 of the Securities Exchange Act of 1934 is the law that addresses the insider trading issues. Under Section 16, directors, officers and principal security holders are required to file changes in their holdings of the company's securities (Form 4) within 10 days after the end of the month during which the transactions occur. If they fail to report within this time period, they are considered to be delinquent and should file such transactions in Form 5 within 45 days after the end of the fiscal year. However, the Security and Exchange Commission (SEC) only investigates a small number of instances of late disclosure; in 2001 it went after 8 such offenders while in 2000 only 3 and in 1999 four. Punishments are usually limited to agreements to comply with the rule in the future.[10] Such loopholes have led to the insiders trading problems described in previous subsections of this paper.

The SEC has realized that the existing regulations are inadequate in providing timely information to investors. On April 12, 2002, the SEC proposed amending the Form 8-K filing rules to require the disclosure by the company of trading in its securities by its directors and executive officers. Under this proposal, companies will be obliged to disclose transactions in company equity securities including derivatives with an aggregate value of $100,000 or more within two business days. Furthermore, employee benefit plan grants and awards, transactions and loans with smaller value

[10] "A few CEOs still selling stocks in secret", by Adam Gellar, Associated Press, April 7, 2002

will be subject to disclosure no later than the second business day of the week following the relevant event.[11]

The proposed rules will significantly reduce the room for the management to mislead investors' views of company prospects for personal gains. However, our research shows that as long as the information is disclosed after the transaction, investors may still fall victims of manipulated information. Besides, even if the proposed rules were adopted, if there were no effective punishments to the insiders for delayed disclosure, there would be no reason to believe that the problem would be alleviated.

4.1.5 Main Results and Literature on Corporate Governance

The study of corporate governance tries to answer the questions why suppliers of finance to corporations trust their money with the managers and how they are assured of getting a return on their investment.

In this research, we discuss a new dimension of corporate governance, motivated mainly by the high technology industry. The current literature deals with how the investors ensure that the managers do not abscond with the money. However the managers can also cash in their holdings simply by manipulating the information the investors have. We argue that for a governance mechanism to work, the

[11] http://www.sec.gov/rules/proposed/33-8090.htm

information structure is fundamental and if the information can be manipulated, any governance mechanism may lose its power.

Existing theories of outside financing fall into two categories: theories that rely on governance and that do not. The latter body of literature explains the puzzle of outside finance by reputation-building and excessive investor optimism. While empirical evidence shows that the concerns of reputation and investor over-optimism are important, it is hard to imagine that these factors alone make investors part with money for securities that are unprotected and thus potentially worthless (Shleifer and Vishny 1997). To support the enormous size of capital markets in advanced market economies, there should be legal protections and governance mechanisms.

The corporate governance theories are based on contract theories. Investors of a firm sign a contract with the manager to specify the rights and responsibilities of each party. Generally speaking, debt contracts give the creditors claims to fixed payments and legal rights in bankruptcy procedures; shareholders have the right to vote and the managers often have the "duty of loyalty" to the shareholders (SV 1997). There is a large body of literature on how the capital structure and debt structure may or may not solve the problem of corporate governance. In SV 1997, they focus on the role of large investors in corporate governance.

Another solution to the governance issue is to align the manager's interests with those of investors by offering incentive contracts in the form of share ownership, stock options, etc. However, high powered incentive contracts have the serious problem of “self-dealing”. Stein (1989) presents a “signal-jamming” model in which managers with shares of the firm manipulate earnings, and while investors are not fooled and discount the inflated earnings, the managers and investors are trapped in this “signal-jamming” equilibrium. Yermack (1997) provides empirical evidence on managers’ self-dealing.

In our model, the agency problem is not due to the separation of ownership and control, but to the asymmetry in the control of information revelation. The current literature lacks discussion on the information structure because in traditional industries, it will be hard for the managers to cheat on financial statements and any cheating will be relatively easy to be detected. It is also very costly for the managers to cheat. However in the high tech industry, as discussed above, due to the uncertain nature of technology and the mechanisms of information revelation, the managers may manipulate the information revelation and thus manipulate the learning process of the public.

In most models, the investment opportunities are risky in that there is a probability distribution of returns, but the distribution is known ex ante and often assumed to be common knowledge. The novelty of the our model lies in that the distribution of the return from an investment opportunity is unknown *ex ante*, and people only have beliefs on the possible distributions. The current literature describes mature industries well where experts can evaluate an investment opportunity with more accuracy, but it fails to explain the situations in a new industry. In a new industry, the return to an investment is largely uncertain and has to be learned over time.

Our model deals with the learning process of the information and issues occurring during the learning process, which presents new challenges to corporate governance. At the beginning, the manager and the public are equipped with the same prior beliefs on the investment opportunity. In the next period, if the manager has learned something while the public has not, there will be room for the manager to conceal certain information from the public. So in our model, the manager is not only manipulating the information, he is also trying to manipulate the learning process of the public, in pursuing his own interests.

In our model, the corporate governance structure includes an incentive scheme in the form of share ownership, and the legal protections for creditors. We show that in industries with uncertainty, these mechanisms, despite their effectiveness in motivating the managers to make maximal efforts, will on the other hand cause the managers to untruthfully reveal the outcome to the market after the efforts are made and the outcome is realized.

The first main result of this paper is that in technology companies where the public and management have asymmetric learning processes, managers with stocks have an incentive to manipulate the information revealed to the public for a personal gain. We contribute to the literature by identifying this special agency problem in technology firms and it is highly consistent with reported facts.

The untruthful reporting is costly to the society in two ways: first the manipulation itself is costly (such as bribes to accounting firms and Wall Street analysts); second, the market price does not fully reflect all the available information, specifically, given that the public is well aware of this agency issue, the stock price is lower than the efficient price (one that incorporates all available information) for a good return and higher for a bad return; third, if the public has inaccurate perception, it will make the economy more volatile.

The second main result is that the riskier a new technology is, the more severe the agency issue. This result explains why we observe more management scandals in new technology investments. To our knowledge, as prior literature on agency issues applies to wide range of companies, our result shows the connection between new technology investment and worsen agency issue, thus specifically highlights companies involved in new technology investments.

A severe consequence is that, once the public is aware of the agency issue intrinsic to new technology investments, it will be highly costly for new technology companies to attract investments, as its stocks will be discounted by the market, which is anticipating a higher possibility of corrupt management team in the company. In the extreme case, investors completely abandon the investment opportunity on the new technology and switches back to traditional investment opportunities, *even if* the new technology, ex ante, is far more profitable in expectation than traditional investments should there be no agency issue.

In other words, the current corporate governance environment may discourage investors from investing in new technologies, leading to under-investments in new technology.

Our research also links the corporate governance theory to the theory of reputation and investor optimism. Our model differs from that of a Ponzi scheme where managers of high-tech firms are purely fooling the public with non-existent investment opportunities. First of all there is a true investment opportunity and it is efficient to invest *ex ante*, based on all the information available. But there is a learning process in which parties learn the true type of the investment opportunity over time. So in our model the investors are not purely irrationally optimistic; they may be overly optimistic on the managers' moralities, and even when they truly know the possibility of being cheated their best response may still yield higher-than-true-value stock price.

Our research is closest to Stein (1989) who raises the question of how managers may distort earnings to manipulate the financial information provided to investors. However, in Stein (1989), the process of the natural earnings is common knowledge and the investors only could not observe the realizations of the random variables. In our model, the profile of the investment opportunity is unknown to everyone at the beginning. Also, in Stein (1989), in equilibrium the manager does not have any information advantage over investors while in our model he does.

In this paper, the managers are compensated by stock ownership. Among high-tech firms, offering stocks and/or stock options is a common practice. Stock awards and stock options are offered to the managers such that they would have an incentive to work for the investors. In our model, the agency issue occurs when the manager is selling his shares when the market price is high. The shares the manager is selling may come from stocks awarded to him or stock options he has exercised at the grant price, almost inevitably much lower than the market price. Actually, the award of stock ownership can be viewed as stock options with a strike price of zero exercised by the company on behalf of the manager. Thus in our model the distinction between the two forms of compensation is unimportant.

There has been heated debate over how the stock options offered to corporate executives and employees should be accounted for. It has been argued that un-expensed stock options are partly responsible for the misleadingly high stock prices. While it is extremely important to explore whether and how the stock options issued to employees should be expensed, making the financial statements more informative and transparent, it is out of the scope of this paper. As far as this paper concerns, the manager's interest is largely aligned with that of the investors as long as he holds on to the shares of the company; but the investors should really be alerted when the manager is trying to sell his shares or cash in his options – that is what they should worry about most.

4.2 The Model

4.2.1 Investment in New Technologies and Initial Beliefs

We model a public company that lives for two periods. There are three dates: 0, 1 and 2 and the time intervals between two adjacent dates are called period 1 and 2 respectively. On date 0 the public company has equity E held by shareholders and debt D held by creditors. On date 2 all uncertainty resolves.[12] The debt also matures at date 2 with interest rate of r for each period, $r > 0$ (interests are paid at the end of period 2). The risk-free rate, i.e. the discount factor is 0.

At date 0, the company has two investment strategies to choose from. One strategy is to invest in a project with a traditional technology[13] that gives a deterministic[14] gross rate of return of a per period, where $a > 1$. The other strategy is to invest in a new technology that may either succeed or fail. If the new technology succeeds, it yields a gross rate of return of g and when fails, the return is b. Compared with the traditional strategy, investing in a new technology results in a higher return if it is successful but a much lower return if it fails, implying the risky nature of

[12] We can have a model where the company lives for more than three periods. Nevertheless, it only complicates the analysis without yielding more insights.
[13] One extreme example is to save the money in a bank.
[14] A deterministic return simplifies the analysis. We can also introduce risk to the traditional strategy without affecting the results as long as the traditional strategy's risk is small.

technology investment, i.e. $g > a > b > 0$. Let the probability of success (getting a good return) be β, and the probability of failure (getting a bad return) be $1-\beta$, where $1 > \beta > 0$. Both investment opportunities live only one period, and the company earns profits at date 1. At date 1, it again faces an opportunity to choose between two strategies: to continue with the technology investment, or to switch back to traditional investment. Either way the profit earned in period 1 is reinvested into the firm to get more profits in period 2. We assume that switching investment strategies at date 1 incurs no switching cost.

We are interested in the case where bad results from the technology investment can devastate the company and lead to bankruptcy. Therefore we make the following assumption:

Assumption 1 (Possible bankruptcy):

$$ab(E+D) > (1+r)^2 D > b^2(E+D)$$

Assumption 1 says that bankruptcy may happen, and it will occur when the company chooses the new technology project at both date 0 and date 1, and gets bad return in both periods 1 and 2; however, if the company gets a bad result in period 1, then switching to traditional technology at date 1 will save the company from possible bankruptcy.

As we mentioned, the risky nature of technology investments lies in that the true probability for a technology to succeed, i.e. the true value of β, is unknown to any party, the managers or investors of the company. We model this by assuming that the new technology can be either of high type (a superior, more innovative technology) or low type (a less innovative technology). If it is a high (low) type technology, the probability of getting a good return in each period is β_h (β_l), and the probability of getting a bad return is $1-\beta_h$ ($1-\beta_l$), where $\beta_h > \beta_l > 0$, $\beta_h + \beta_l < 1$ and $\beta \in \{\beta_h, \beta_l\}$. Note that the investment in a new technology yields an uncertain return even if its type is known.[15]

There are three groups of agents in our model: the manager of the company, the shareholders and creditors. Investors including shareholders and creditors fund the public company, while a manager manages the company. In our model the creditor's role is passive and the game is between the manager and shareholders. Shareholders have the right to decide which investment strategy to pursue, and the manager implements the selected strategy, and observes and reports the outcome.[16] Shareholders, creditors, and the manager are all risk-neutral.

Shareholders, creditors, and the manager initially share the belief that the investment has a probability of γ_0 to be of high type, i.e. $P(\beta = \beta_h) = \gamma_0$. For

[15] This is the simplest possible model to address the learning process that we will discuss shortly.
[16] It is equivalent to say that: the manager selects investment strategy; however, if the selection does not maximize shareholders' value given all the information shareholders have, the manager will be fired which he wants to avoid.

notational convenience we define $\eta_0 = \gamma_0 \beta_h + (1-\gamma_0)\beta_l$, which is the initially believed probability of a good period 1 result. Promising technology investment is further characterized by the following assumption:

Assumption 2 (Promising technology investment):

$$\eta_0 g + (1-\eta_0) b > a$$

Assumption 2 says that based on their initial beliefs, all parties expect a higher return from the technology investment than from the traditional investment.

The high risk in technology investment largely comes from the lack of understanding of the business potential of new technologies, and their possible impact on industrial organization structures. Nevertheless a company can better learn its position after it stays in the business for a while for reasons including the maturing of the technology, a better understanding of market demand, and the stabilization of competition. As an example, nowadays we see a more stabilized Web portal industry in US compared with the end of last century, and investors are savvier in valuing the major companies. Although it is still hard, or impossible, to predict what the *exact future* will be, companies will have a better understanding of the *probability* of a good or bad future once they are experienced.

In our model, the learning process is reflected by the fact that the return in period 1 can help the company, including the manager and investors, to better estimate which type of investment it has.[17] For example, if the outcome after period 1 is good and this information is fully observed by all interested parties, then they will gain confidence in the project; if, on the other hand, the return in the first period is low, people will realize that the initial belief, γ_0, is too optimistic. Then investors may want the company to discontinue the investment and turn to the traditional strategy. The stock price will accordingly change to reflect the adjusted value of the company.

The agency issue occurs when only the manager can observe the first period result and has discretion in reporting the result to the public. We will first discuss the case where shareholders have access to all the information and therefore can make fully informed decisions, and then present the model where the manager can conceal information.

4.2.2 The First Best Case

Before introducing the agency issue, we first briefly analyze what investment strategy shareholders will choose if they are fully informed. Therefore in this subsection, and only in this subsection, we assume that shareholders can observe the first period outcome. In this first best case, in making the investment decisions the shareholders simply solves a maximization problem. The sequence of events are as

[17] It may take years for a company to fully understand its investment's potential, and thus the learning process may take many periods. However to model the agency issue related to technology investment, a three period model is enough to reveal all the intuitions.

follows: at date 0, the shareholders decide to invest in new technology or traditional technology based on the expected present value using all available information; at date 1, the outcome is realized; the shareholders observe it and update their beliefs on the nature of the technology; they also choose the investment strategy for period 2 based on the updated beliefs; at date 2, the period 2 outcome is realized.

Lemma 1. Suppose shareholders can observe the result in period 1.

i) If the outcome after period 1 is good, shareholders update their belief on the investment being a high type to $\gamma_{1g} = P(\beta = \beta_h \mid g) = \dfrac{\beta_h \gamma_0}{\beta_h \gamma_0 + \beta_l (1-\gamma_0)}$;

ii) If the outcome after period 1 is bad, shareholders update their belief on the investment being a high type to $\gamma_{1b} = P(\beta = \beta_h \mid b) = \dfrac{(1-\beta_h)\gamma_0}{(1-\beta_h)\gamma_0 + (1-\beta_l)(1-\gamma_0)}$.

(All proofs are in the Appendix. To save space, we omit proofs for straightforward results.)

Lemma 2. Suppose shareholders can observe the result in period 1. Then if

$[\gamma_{1b}\beta_h + (1-\gamma_{1b})\beta_l][gb(E+D) - (1+r)^2 D] > [ab(E+D) - (1+r)^2 D]$,

shareholders prefer the company to continue the technology investment no matter the result in period 1; otherwise shareholders will require the company switch to the traditional strategy.

When the condition in Lemma 2 holds, it is less interesting since the company should keep investing in the new IT, i.e. the information revealed by period 1 result has little impact on investment strategy. For the rest of paper we focus on the more interesting case where a bad result in period 1 is sufficient to let the company drop the technology investment:

Assumption 3. (Risky technology investment)

$$[\gamma_{1b}\beta_h + (1-\gamma_{1b})\beta_l][gb(E+D)-(1+r)^2 D] < [ab(E+D)-(1+r)^2 D]$$

It is straightforward from assumption 3 that the optimal choice for the company (and thus for all investors) is to repeat the technology investment in period 1 if period 1 result is good, and to switch to the traditional strategy otherwise.

4.2.3 The Agency Issue

The agency issue arises when the manager has a personal interest that conflicts with that of shareholders. In this model, the personal interest is to cash in the stocks before investors learn bad news about the technology investment. Consequently, the manager may have incentive to keep the technology investment even if period 1 result is bad, as what happened in companies like Enron and Global Crossing. Agency issues have been studied in various economic environments (see Shleifer and Vishny (1997) for a survey of agency issues in corporate governance). Our model focuses on the relationship between the agency issue and the intrinsically risky nature of technology investments, which, to our knowledge, is never studied before.

The agency issue is modeled as follows. Investors have the voting power to decide in each period what investment strategy to pursue, and then a risk-neutral manager is obliged to implement the strategy.[18] However the financial performance of the company is observable only to this manager who then reports the outcome to public. As is common for technology related industry, this manager's compensation is related to the company's performance. Without loss of generality, we further restrict the specific incentive mechanism to stocks[19]: At date 0, the manager is granted α proportion of all stocks. α is small enough such that it has only negligible effect on the company's asset. The manager can cash out the stocks at either date 1 or date 2.

Both in reality and in the literature, companies reward the managers with stocks to induce highest level of efforts. We choose not to model the effort explicitly because we focus on the effect of stock ownership that leads to untruthful reporting of outcome. Nevertheless, in our model the rationale for compensating the manager with stocks can be understood as follows: the stock ownership motivates the manager to exert efforts in period 1 such that the project will fully realize its potential and succeed with probability β_h or β_l (depending on the intrinsic characteristic of the project); without the effort, the probability of getting a good result will be lower than β_h (β_l). After the first period outcome has realized however, the manager needs to

[18] See footnote 6.
[19] Our model and its results easily apply to stock options with slight modification.

decide what to report to the public and his stock ownership will play a role other than an incentive to work hard.

Central to the agency problem are the manager's ability to fool investors about the company's performance in period 1, and his ability to hide his stock transactions, which are stated in Assumptions 4, 5 and 6.

Assumption 4 (Unobservable period 1 result)

The result in period 1 is only observable to the manager. Furthermore, when period 1 result is bad, by incurring a cost of C for the company, the manager can cheat by maneuvering the income statement and reporting a fake good result to investors.

As we pointed out in the Introduction, the novelty of new technologies enables managers to cheat on the company's performance relatively easily, as investors have little knowledge to justify the reported results.

Assumption 5 (Unobservable insider trading)

At date 1, shareholders cannot observe the manager's sale of his stocks.

Assumption 6 (Existence of liquidity traders)

At date 1, there are liquidity traders of the company's stocks in the market whose order flow is a random variable with zero mean and variance σ^2.

Assumption 5 ensures that the manager's timing decision will not act as a signal of what he observed in period 1. Without Assumption 5, it can be shown that investors need not to pay attention to the reported period 1 result since the manager's timing decision is a sufficient indicator of the true period 1 result: if the manager sells at period 1, the true period 1 result is bad; if he does not, the true period 1 result is good. Assumption 6 means that the managers can hide his transactions among liquidity orders, such that a net sell order at date 1 does not indicate insiders' trading. In Section 5 we further discuss the microstructure of trading and its impact when we propose remedies to the agency issue.

Let $\hat{g}$ ($\hat{b}$) be the result that the manager reports to shareholders, which we call "reported result" as to distinguish from the true "result". Given Assumption 4, when period 1 outcome is bad, i.e. b, the manager may report $\hat{g}$ to boost stock price. On the other hand, when period 1 outcome is good, i.e. g, the manager has no incentive to report $\hat{b}$ since doing so only reduces his possible gain from stocks.

Although fooling investors may help the manager to get more payoffs from cashing stocks, it could also hurt the manager when his cheating behavior damages the company, which in turn damages his own reputation and, if cheating behavior got caught, brings even monetary and legal punishments to him. In this paper we focus on the extreme case where the company could be damaged to bankruptcy as stated in Assumption 1. When bankruptcy happens, the manager suffers a loss of d.

Managers differ in their moralities, concerns for reputation, and specific measures they use in covering up the true financial result of the firm, which directly affect the probability of being investigated and the punishments to be imposed. Suppose that $d \in [\underline{d}, \overline{d}]$ with a continuous and strictly increasing distribution function $F(\cdot)$[20]. $0 \le \underline{d} < \overline{d} \le \infty$. Since *d* differentiates managers, for convenience we call *d* the "type" of the manager. We assume that $\underline{d}, \overline{d}$ and $F(\cdot)$ are common knowledge while only the manager observes his own type.

Below we list the sequence of events in our model:

Date 0: Investors choose period 1 investment strategy (new-tech or traditional investment)

Date 1: Period 1 outcome is realized (*g* or *b* under new-tech, and *a* under traditional investment)

Date 1: The manager observes the true period 1 outcome. If period 1 is the new-tech investment, the manager decides whether to cheat or not.

Date 1: Investors observe the reported period 1 outcome and accordingly adjust the stock price to reflect the new information. Then investors choose

[20] A continuous and strictly increasing distribution function simplifies the analysis. Nevertheless, for our results to hold, we can instead have a weaker assumption: the distribution function is continuous and strictly increasing near the marginal type as defined in Lemma 6.

investment strategy for period 2, and the manager decides whether to sell his stocks at date 1.

Date 2: Period 2 outcome is realized. Since this is the last date, all uncertainty resolves. If the company goes bankrupt (total asset is smaller than total debt), the cheating behavior is discovered and the manager is punished; otherwise the (possibly) cheating behavior keeps unknown to investors and the manager is not punished.

Given the large number of decision points, the complete extensive form game is both too large to draw out and hard to analyze. In next section we first simplify the game tree to a reasonable size before we present the results.

4.3 The Results

4.3.1 Signal-jamming

Our model falls into the broad range of sender-receiver games (Green and Stokey 1980, Crawford and Sobel 1982). This model has the signaling (Spence 1973) component, as the manager's type is his private information that will be partially revealed when he chooses his action (to cheat or to be honest) in a semi-separating equilibrium as we later show. This model also has the signal-jamming (Holmstrom 1999, Fudenberg and Tirole 1986) component, as the purpose of the manager's action is to "jam" the transmission of nature's signal on the new investment's type (high or low) to investors.

The signal-jamming component in our model is more important as investors only care about whether or not the manager jammed nature's signal: once the new technology investment is chosen at date 0 and if the reported result in period 1 is good, it could be a fake result that is forged by a cheating manager in a bad period 1, or it could be a true result in a good period 1. As a result, even if an equilibrium exists and a reported good period 1 result is observed, investors are not sure on both the true period 1 result (nature's signal) and whether or not the manager cheated (manager's signal).

Although the signal from nature is jammed by the manager's action, investors can still uncover partial information using Bayes' rules. To distinguish the updating rules in this section from ones in the benchmark case in Section 2, we keep the notation "γ_1" for the benchmark case, and use "$\hat{\gamma}_1$" for this section. Note that $\hat{\gamma}_{1\hat{b}} = \gamma_{1b}$ since the manager will never report bad when period 1 result is good.

Lemma 4. In any equilibrium $\hat{\gamma}_{1\hat{g}} \geq \gamma_0$.

From Lemma 4 we know that, at period 1 if the reported result is good, investors should have an expectation of the technology investment that is no worse than their expectation in period 0. Intuitively, the worst possible equilibrium is that a manager of any type will always cheat when period 1 result is bad, and consequently investors should ignore any reported good result in period 1 since it carries no information. Then $\hat{\gamma}_{1\hat{g}} = \gamma_0$. All other possible equilibria carry at least a little useful information since some types of managers will honestly report a bad period 1 result, which implies that $\hat{\gamma}_{1\hat{g}} \geq \gamma_0$.

Lemma 5. Upon hearing a good reported result in period 1, investors will let the manager repeat the technology investment.

Lemma 5 is a direct result of Lemma 4. Also notice that if the reported result in period 1 is bad, it must be that the true result is also bad, which leads investors to favor the traditional investment. So investors' decision problem in period 1 is trivial. Consequently we can simplify our game tree, as shown in Figure 4.1. For notational simplicity we introduce $U_1 \sim U_5$, as shown in Figure 4.1 which are final payoffs for the company following different paths.

In Figure 4.1 we also omit the manager's stock selling decision as it follows the following pattern: In this game tree, if period 1 result is good, the manager will sell stocks in date 2 when all uncertainty resolves and the stock value is not underestimated. If period 1 result is bad, his timing decision depends on his decision about cheating: if he cheats, apparently he will sell stocks at date 1 to take advantage of the asymmetric information; if he is honest, he can sell the stock in either date 1 or date 2 since both yields the same expected payoff for him in period 1.

4.3.2 The Sub-Game Equilibrium When Date 0 Choice Is The New Technology Investment

Since this is a multi-period model with incomplete information, the equilibrium concept we use is Perfect Bayesian Equilibrium (PBE). Based on the company's choice at date 0, there are two distinguishable sub-games: the one where the company chooses the new technology investment in date 0, which we call the new technology sub-game, and the one where it chooses the traditional investment in date 0, which we call the alternative sub-game. Investors favor the choice that gives them the higher expected return. It is straightforward to see that the agency issue does not exist in the alternative sub-game as it provides the manager no chance to profit from cheating. In this subsection, as well as in subsections 3.3 and 3.4, we focus on the new technology sub-game.

Generally, we assume that there exists a PBE for the new technology sub-game where, if $d \in M$ ($d \in N$), the manager cheats (does not cheat) when period 1 result is bad. $M \cup N = [\underline{d}, \overline{d}]$, and $M \cap N = \Phi$. So *M* is the set of cheating types and *N* is the set of honest types.

We first show in Lemma 6 that *M* and *N* will not interlace with each other:

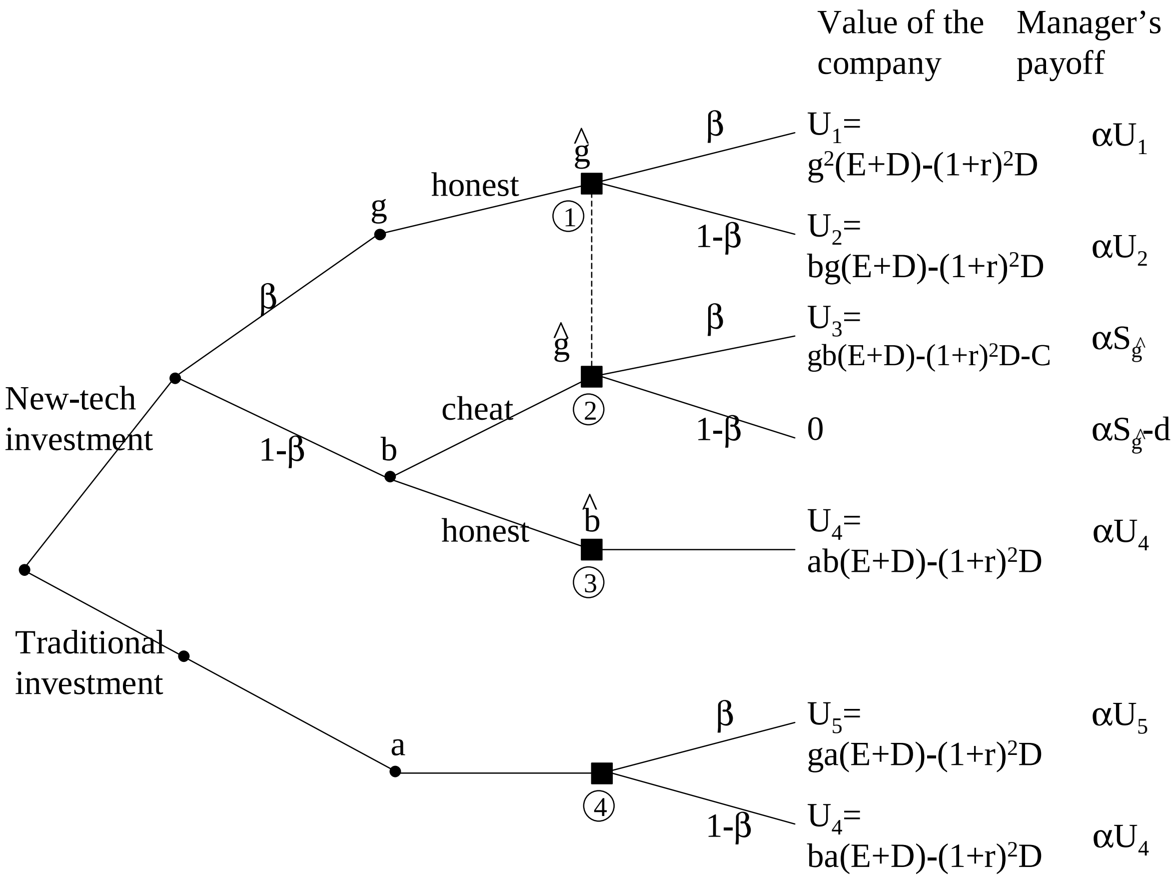


Figure 4.1. The simplified game tree

Note on Figure 1: On the four square nodes the following optimal decision processes are already determined and thus omitted in the figure:

- Node 1: investors continue the new technology investment, and the manager holds on to the stocks until date 2
- Node 2: investors continue the new technology investment, and the manager sells all stocks in date 1
- Node 3: investors switch to the traditional investment, and the manager is indifferent to selling stocks at either date 1 or date 2
- Node 4: investors switch to the new technology investment, and the manager is indifferent to selling stocks at either date 1 or date 2

Lemma 6: Given a PBE for the new technology sub-game, there exists $d_m \in [\underline{d}, \overline{d}]$ such that

- either $M = [\underline{d}, d_m)$, and $N = [d_m, \overline{d}]$,
- or $M = [\underline{d}, d_m]$, and $N = (d_m, \overline{d}]$.

We call d_m the marginal type. A marginal type manager's behavior depends on the specific value of d_m. If $d_m \in (\underline{d}, \overline{d})$, he is indifferent to cheating or being honest in a bad period 1; if $d_m = \underline{d}$, he is either indifferent to both strategies or prefers being honest; if $d_m = \overline{d}$, he is either indifferent to both strategies or prefers cheating. In the latter two cases, uncertainty in the marginal type manager's behavior comes from the discontinuity on the bounds of feasible types. If the set of feasible types is unbounded, i.e. $\underline{d} = 0$ and $\overline{d} = +\infty$, then uncertainty resolves.

Given a continuous and monotonically increasing $F(\cdot)$, the probability of a manager being the marginal type is only infinitesimal. So from here on we ignore the discussion of the choice of the marginal type. Therefore, let $M = [\underline{d}, d_m)$, and $N = (d_m, \overline{d}]$.

Depending on the value of d_m, three types of equilibria could emerge. If $d_m = \underline{d}$, it is a pooling equilibrium where no manager cheats; if $d_m \in (\underline{d}, \overline{d})$, it is a semi-separating equilibrium where a low type manager cheats while a high type will not; if $d_m = \overline{d}$, it is a pooling equilibrium where any type manager cheats.

Given a PBE and d_m, let ϕ denote the probability that the manager will cheat in a bad period 1, then $\phi = F(d_m)$. The following Lemma shows how investors will update their believes about the technology investment on receiving a reported period 1 result:

Lemma 7. Given a PBE for the new technology sub-game and d_m, at period 1,

If reported result is good,

$$\hat{\gamma}_{1\hat{g}} = P(\beta = \beta_h \mid \hat{g}) = \frac{((1-\phi)\beta_h + \phi)\gamma_0}{((1-\phi)\beta_h + \phi)\gamma_0 + ((1-\phi)\beta_l + \phi)(1-\gamma_0)};$$

If reported result is bad, $\hat{\gamma}_{1\hat{b}} = P(\beta = \beta_h \mid \hat{b}) = \gamma_{1b} = \dfrac{(1-\beta_h)\gamma_0}{(1-\beta_h)\gamma_0 + (1-\beta_l)(1-\gamma_0)}$.

Given the updated believes, investors will re-evaluate the technology investment. Since $\hat{\gamma}_{1\hat{b}} = \gamma_{1b}$, investors will let the manager switch to the traditional investment upon receiving a bad reported period 1 result; when a good reported result is received, Lemma 4 shows that investors will let the manager repeat the technology investment. In either case, stock price will accordingly adjust to reflect the changing believes, as shown in the following Lemma.

Since the path following a bad reported result is simple, later on we do not need to use the notation $\hat{\gamma}_{1\hat{b}}$. Then we can simplify the notation of $\hat{\gamma}_{1\hat{g}}$ to $\hat{\gamma}_1$, which will later save us considerable spaces.

Lemma 8. Given a PBE and d_m, at period 1,

If reported result is good, the value of the company is updated to

$$S_{\hat{g}} = \frac{\hat{\gamma}_1\beta_h(\beta_h U_1 + (1-\beta_h)U_2) + \hat{\gamma}_1(1-\beta_h)\phi\beta_h U_3 + (1-\hat{\gamma}_1)\beta_l(\beta_l U_1 + (1-\beta_l)U_2) + (1-\hat{\gamma}_1)(1-\beta_l)\phi\beta_l U_3}{\hat{\gamma}_1(\beta_h + (1-\beta_h)\phi) + (1-\hat{\gamma}_1)(\beta_l + (1-\beta_l)\phi)}$$

;

If reported result is bad, $S_{\hat{b}} = U_4$.

Notice that $S_{\hat{g}}$ is a function of ϕ, thus also a function of d_m. Therefore we can write $S_{\hat{g}}$ as $S_{\hat{g}}(d_m)$. For notational convenience, define *e* as the solution to

$$e = \alpha \frac{S_{\hat{g}}(e) - U_4}{\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l)}, \qquad (1)$$

which will be used in Theorem 1 and Proposition 1. We first show the existence of a solution to equation (1):

Theorem 1. *A unique solution to*

$$e = \alpha \frac{S_{\hat{g}}(e) - U_4}{\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l)}$$

exists.

Lemmas 7 and 8 establish the belief updating rules and stock price updating rules in any given PBE. In equilibrium the manager knows these updating rules. As a result, after observing the true period 1 outcome and before making the decision of cheating or not, the manager is well aware of the consequences of each alternative. He cheats if and only if his gain from cashing stocks in period 1 outruns his expected loss due to possible bankruptcy in period 2. This leads to Proposition 1 as shown below.

Proposition 1.

Suppose at date 0 the company chooses the new technology investment.

i) If $e \in (\underline{d}, \overline{d})$, the unique PBE is a semi-separating equilibrium in which, if period 1 result is bad, the manager cheats if $d < d_m$, and is honest if $d \geq d_m$, where $d_m = e$.

ii) If $e \leq \underline{d}$, the unique PBE is a pooling equilibrium in which the manager never cheats, and thus $d_m = \underline{d}$.

iii) If $e \geq \overline{d}$, the unique PBE is a pooling equilibrium in which the manager always cheats, and thus $d_m = \overline{d}$.

Proposition 1 establishes that, if $e \geq \underline{d}$, the manager does have the possibility to cheat. There exists a marginal type such that, if the manager's type is below this marginal type, meaning he has less possible personal damage after a bankruptcy, he will always cheat.

Proposition 1 is a strong result in the sense that it holds for all possible functional forms of $F(\cdot)$, i.e. the distribution of the loss to the manager when bankruptcy happens, as long as $F(\cdot)$ is continuous and monotonically increasing in $[\underline{d}, \overline{d}]$. Proposition 1 is also surprising since, unlike most signaling games, multiple equilibria do not emerge. Intuitively, on the one hand, since $P(g \mid \hat{g})$ is a decreasing function of d_m as shown in the proof of Proposition 1, the manager's gain from cheating (and thus from rising stock price) is a decreasing function of d_m, which is also fixed in the equilibrium. On the other hand, the manager's expect loss from bankruptcy is an increasing function of his type. Therefore, there exists a cutting type that, below this cutting level the manager finds cheating profitable while above this cutting level he finds the contrary.

Corollary 1. If $e \geq \underline{d}$, the existence of the agency issue may lead to inefficient investment, and thus in expectation harms shareholder value.

Corollary 1 follows from the fact that, the manager's cheating behavior in a bad period 1 results in the continuing of the technology investment, which leads to worse expected result than the one in the first-best case.

4.3.3 Risky Technology Investment Worsens The Agency Problem

In the preceding subsection we established the relation between unobservability of interim outcome and the agency issue for risky technology investments. In this subsection we address a further question: does the agency issue worsen when the technology investment is riskier? In other words, are highly innovative technologies more likely to be haunted by agency issues?

Formerly, we consider that, giving the same expected return from the technology investment at period 0, what are the impacts of the variance of the return on managerial behavior and investment return. Given any *R*>*a*. Let $\Delta = \{g, b \mid \eta_0 g + (1-\eta_0) b = R\}$, which is the set of returns that have expected return of *R* at period 0. In this subsection we only consider returns that subject to $(g, b) \in \Delta$. We immediately know that a larger variance of the return implies a larger *g*, and vise versa.

In the first-best case discussed in Section 2, risk comes from possible bad result, which is more likely when the technology investment is of low type, i.e. $\beta = \beta_l$. Nevertheless investors can partially hedge the risk by switching to the traditional and safer investment once they discover that period 1 result is bad. As a result, the following Lemma shows that in the first-best case investors prefer a larger *g* for any $(g, b) \in \Delta$.

Lemma 9. In the first-best case where shareholders can observe period 1 result, shareholder value in period 2 is an increasing function of *g* for $(g, b) \in \Delta$.

Intuitively, in the first-best case the expected value of γ_1 at period 0 is γ_0, therefore if the company repeats the technology investment, the expected marginal return in period 2 is still *R*. However, switching to the traditional investment will give the company a predictable return in period 2, which helps the company to hedge risks when period 1 result is bad. Then since the expected return from the technology investment, conditioning on a good period 1, is an increasing function of *g*, overall shareholders can get a better expected return from a larger *g*. In other words, investors prefer risky technology investments if the traditional investment can be used to partially hedge the risk if a bad period 1 result happens.

Nevertheless, once we consider the agency issue, the contrary could happen, as shown in Proposition 2.

Proposition 2. Suppose at date 0 the company chooses the new technology investment. Given $(g,b)\in\Delta$ and $e\in(\underline{d},\overline{d})$. If

$$\frac{g}{R}<\frac{1/\eta_0}{2-\frac{\beta_l}{1-\beta_l}\Big/\frac{\eta_0}{1-\eta_0}}, \tag{2}$$

the possibility that the manager cheats upon a bad period 1 result is an increasing function of *g*.

Proposition 2 shows that, given equation (2), more innovative technologies worsen the agency issue. In other words, the riskier the technology investment is, the *more additional risk* the agency issue adds on to it.

When equation (2) will hold? One specific example, as justified by the following corollary, is the case of investment in innovative technologies, which is often characterized by a large risk (small β_l) and huge gain upon success (large g).[21]

Corollary 2. Suppose at date 0 the company chooses the new technology investment. Given $(g,b)\in\Delta$ and $e\in(\underline{d},\overline{d})$. If β_l is enough small and g is enough large, the possibility that the manager cheats upon a bad period 1 result is an increasing function of g.

Note that equation (2) may not necessarily lead to a worse shareholder value, as when g increases there are two conflicting momentums that affect the shareholder value:

$$\frac{dS_{\hat{g}}}{dg}=\frac{\partial S_{\hat{g}}}{\partial g}+\frac{\partial S_{\hat{g}}}{\partial e}e'(g)$$

The first momentum is the direct effect of g on $S_{\hat{g}}$, $\frac{\partial S_{\hat{g}}}{\partial g}$, as shown in Lemma 9, which increases shareholder value. The second is the effect of e (or equivalently,

[21] Meantime, β_h can be either large or small as long as it is much larger than β_l.

the indirect effect of *g*) on $S_{\hat{g}}$, $\frac{\partial S_{\hat{g}}}{\partial e} e'(g)$, as shown in Proposition 2, which decreases shareholder value. Intuitively, the first momentum comes from the fact that, the combination of an innovative technology and an hedging alternative technology results in a higher expected return, while the second momentum comes from the fact that the manager's cheating behavior harms shareholders. Corollary 3 gives a condition to determine which effect is stronger:

Corollary 3. Given $(g,b) \in \Delta$ and $e \in (\underline{d}, \overline{d})$. If

$$e'(g) < \frac{\eta_0}{1-\eta_0} \bullet \frac{\alpha a(E+D)}{\gamma_{1b}(1-\beta_h)+(1-\gamma_{1b})(1-\beta_l)}, \qquad (3)$$

then at period 0, expected shareholder value is a decreasing function of *g*.

4.3.4 Large Stock Holdings induce the Manager to Cheat

Proposition 3. Suppose at date 0 the company chooses the new technology investment. The manager is more likely to cheat if α, his stock holdings, is large.

Proposition 3 follows directly from Proposition 1. Stocks and stock options[22] are long viewed as proper instruments to align the management's incentives with shareholder values. However, Proposition 3 contradicts this common belief. The central reason for why this misalignment happens is the information asymmetry

[22] The analysis in this paper can be extended to the case where the manger has stock options. Note that if the strike price for the options is zero, it is equivalent to the case where the manager just holds stocks.

problem: knowing how investors value messages, a manager who has more information than investors can behave strategically to lead the fluctuation of the stock price and to profit from the fluctuation.

4.3.5 The Agency Issue May Prevent Investment in New Technologies

In subsections 3.2, 3.3 and 3.4 we consider the sub-game where date 0 choice is the new technology investment. In this subsection we analysis shareholders' decision in date 0, i.e. which sub-game to choose.

First consider the sub-game where at date 0 the company chooses the traditional investment. Since the company still has no experience on the new technology, at date 1 shareholders still hold the initial belief. Then given Assumption 2, shareholders will favor the new technology investment at date 1.

Proposition 4. If $a(\eta_0 g + (1-\eta_0)b)(E+D) - (1+r)^2 D > S_{\hat{g}}(\eta_0 + (1-\eta_0)\phi) + S_{\hat{b}}(1-\eta_0)(1-\phi)$, at date 0 the company will choose the traditional investment.

Although at date 0 the new technology has a higher expected return than the traditional one, in equilibrium shareholders expect the agency issue once they choose the new technology investment. Consequently they discount the value of the new technology investment *ex ante*. In the worst case, they turn away from the new technology investment.

Note that if the condition in Proposition 4 holds, investors will abandon the new technology investment *even if* the manager is honest (i.e. with a large d). In other words, the existence of ethically corrupt managers (i.e. with a small d) spills the whole new technology economy. As James F. Parker, CEO of Southwest Airlines commented, "I think it's unfortunate that the misdeeds of a few have had the effect of creating questions and undermining the confidence of business in general" (Restoring Trust In Corporate America, Business Week, June 24, 2002).

4.4 Extensions

In the model presented in Section 2 there exists a true distribution of manager's types in period 1. We assumed that investors know this distribution. Nevertheless in reality this is often not the case: several corporate managers have voiced the concern that, after the Enron debacle, the public tends to exaggerate the ethical problem in corporate management. Then the question we ask in this subsection is: how does biased public beliefs on the manager's type affect the manager's decision on cheating?

Let $\hat{F}(\cdot)$ be investors' belief on the distribution function of the manager's type. If $\hat{F}(\cdot)$ is different from $F(\cdot)$, we say that investors have biased belief. Since the manager will not have less information than investors, he also knows $\hat{F}(\cdot)$.

Accordingly let $\hat{d}_m$ be the marginal type in equilibrium under $\hat{F}(\cdot)$. d_m still denotes the marginal type if investors know $F(\cdot)$.

Proposition 5. Given $\hat{d}_m \in (\underline{d}, \overline{d})$,

if $\hat{F}(d) > F(d)$ for any $d \in [\underline{d}, \overline{d}]$, then $\hat{d}_m < d_m$;

if $\hat{F}(d) < F(d)$ for any $d \in [\underline{d}, \overline{d}]$, then $\hat{d}_m > d_m$;

Proposition 5 shows that if investors are biased towards distrusting the manager the manager will be less likely to cheat. Intuitively, it is because investors have little faith in a reported good period 1 result, and thus they will heavily discount it, which makes cheating less attractive to the manager. In other words, Proposition 5 is somehow surprising as it says that biased public belief (towards distrusting the management) will end up benefit shareholders by alleviating the agency problem.

On the other hand, Proposition 5 also suggests that the burst of agency issues following the debacle of dot-com bubbles is closely related to the public's years of overlooking the ethical problems involved in corporate governance – investors were often easily persuaded by positive income statements that the high technology investment a certain company is pursuing is able to deliver constant high returns. Sometimes the public was ignoring possible ethical problems even when the income statements are highly suspicious was it in the traditional investment arena.

It is worthy to note that whether or not the manager knows the truth distribution of the manager's type, $F(\cdot)$, is irrelevant to the results in Proposition 5.

4.5 Remedies to the Agency Issue: Pros and Cons

There is no doubt that central to the agency issue is the information asymmetry problem. It is not surprising to see that a lot of proposed remedies to this agency issue focus on various ways to reduce information asymmetry, such as fixing the accounting and reporting system, timely disclosure of stock transactions by the management, and requiring the executives to hold on to their stocks during their tenure. Another remedy suggested by many is more strict enforcement of ex *post* punishment.

In this section we show that, surprisingly, a tighter accounting system, though desirable and promising in partly alleviating the problem, will not eliminate the incentive for managers to cheat. Furthermore, reforming the accounting system can be very costly. The call for prompt revelation of insiders' stock transactions after the fact is along the lines of providing timely information to the public, but it is not enough. We then argue that the most effective solution is to require managers to announce their stock trading *before* they can make any transaction such that the announcement serves as a signal to the public.

4.5.1 Fixing the Accounting and Reporting System

A direct remedy to the agency issue is to improve the accounting and reporting system such that the result from an investment can only be truthfully reported to investors.

The notorious document shredding scandal is not the first time that Arthur Andersen fails to bring critical financial information to the attention of American investors. In all these cases investors end up losing huge amounts of money. Therefore it is not surprising to see that GAAP is now widely criticized not only by common investors but also a lot of financial specialists. It seems that all the criticism calls for a tighter accounting system that will properly highlight important financial information, which formerly were easily buried among hundreds of footnotes that investors hardly notice.

It is straightforward from our model that, if the accounting rules make it impossible for the manager to forge reports, which is equivalent to the cost of manipulating the financial reports, C in our model is infinite, there is no base for the manager to cheat. Nevertheless, as economist Burton G. Malkiel puts it, "there is no way to fix generally accepted accounting principles so that full transparency is assured."[23] The best we can anticipate is that the changes will makes it *more difficult*

[23] "The Market Can Police Itself," Wall Street Journal, June 28, 2002.

for managers to cheat. It is not surprising if managers fight back with more complicated, therefore more costly, deceptive schemes to circumvent the rules.

Note that in our model we assume that *the cost of manipulating the financial reports, C, is shouldered by the company*, not the manager. Our assumption comes from the fact that, report manipulating is often done through so called “financial engineering”, which transforms assets and liabilities into various forms by establishing partnerships. The costs of building the partnerships are paid by the company, not the manager. As shown in the Enron case, a corrupt management created thousands of partnerships using a considerable amount of investors’ money when the complexity of the partnership structure helped to fool the investors.

Proposition 6. The value of the company following the new technology sub-game, $S_{\hat{g}}(\eta_0 + (1-\eta_0)\phi) + S_{\hat{b}}(1-\eta_0)(1-\phi)$, is a decreasing function of *C*.

An increase in *C* has two opposing effects on $S_{\hat{g}}$: first, the expected value of the firm at date 2, U_3 decreases, which tends to decrease $S_{\hat{g}}$; second, *e* decreases, i.e. the manager is less likely to cheat, which tends to increase $S_{\hat{g}}$. From the proof of Proposition 6 we know that, the first effect strictly dominates the second effect, and overall an increasing cheating cost leads to decreasing expected value of the company at date 0.

Proposition 6 shows that, if tighter accounting rules make cheating more costly to the company, it will make the company less valuable. Intuitively, investors anticipate the manager to spend more of the company's resources in this cat-and-mouse game trying to find and to take advantage of any loopholes in the accounting system, which reduces the value of the company. Note that if the cost to the company resulted from cheating, C, is large enough, the condition in Proposition 4 may hold. Then directly from Proposition 4 we know that it not only cannot solve the agency issue, but also further deters investors away from new technologies.

A tightened accounting system is also likely to change the distribution of managers' personal cost of dishonest reporting. Conceivably, it may shift the support of d to the right, and/or result in a new distribution of d that stochastically dominates the old one. In either case, fewer managers will cheat and it is possible that this effect may offset the detrimental result from an increased C.

Thus the result from an improved accounting system is ambiguous. Furthermore, fixing the accounting system can be very costly and time-consuming. While we fully realize the necessity of a better accounting system with as few loopholes as possible, we think new regulations on information revelation can be more effective in solving the market failure caused by the jammed signal discussed in this paper.

4.5.2 Disclosing Before Insider Trading

A second remedy tries to better battle against the manager's short-term interest: before the manager sells stocks in period 1, he must disclose it. Furthermore, there should be enough time between the disclosure and the selling so that the capital market has enough time to react.

In this remedy, the manager's disclosure makes his timing decision publicly observable. Consequently his timing decision becomes a second signal (the first is the reported period 1 result) of the true period 1 result.

Lemma 10. Suppose that the manager can sell stocks only after he discloses his intention to investors, then his timing decision combined with the reported result is a perfect signal of period 1 result.

Lemma 10 shows that, if the manager is required to disclose before selling, the combination of the two signals – the reported result and the timing of his sales of stocks – sends a perfect message to investors about the true period 1 result. The next proposition shows that this voids his incentive to cheat.

Proposition 7. Suppose that the manager can sell stocks only after he discloses it to investors, then he will never cheat.

Given Proposition 7, we believe that “disclosing before insider trading” is a suitable solution to the agency issue. Unlike the remedy of a better accounting system where there are still spaces for the manager to maneuver information, under this remedy there is no way for the manager to cheat. Furthermore and comparing with the accounting remedy, this remedy of timely disclosure is significantly easier to implement and much easier to police. The latter is specifically important as when it is necessary for prosecutors to fight a corrupt manager in court, it is relatively easy to see if the manager broke the law by simply checking when he disclosed and sold his stocks. By contrary, it is much difficult to check if the manager did anything wrong with the accounting system. As Houston criminal and civil defense attorney David Berg put it for the Enron case: “They’re going to say, ‘Look, I’m not an accountant. I told (Andersen) what I wanted to do, and they said it was O.K.’”.[24]

As we mentioned in the introduction, the SEC is aware of the inadequacy of providing information to investors. The SEC accordingly proposed to shorten the time between a manager’s stock trading and the reporting to two business days for transactions of value over $100,000. However as we have shown, as long as the information is disclosed after the transaction, the manager can always fully reap his personal gain. Therefore in our model it does not reduce the manager’s incentive to cheat. And as long as there is any fraud, there is a social cost (*C*) that has been wasted.

[24] Mike France and Dan Carney, “Why Corporate Crooks Are Tough To Nail,” Business Week, July 1, 2002.

Note that in reality selling stocks may be more complex than that in our model. For example, the manager may not be able to unload all his stocks in one day due to limited market demand. In this case the SEC's proposal can mitigate the agency issue, because selling the stocks or exercising the options will be significantly less profitable for the manager if he cannot finish all the transactions before the information is disclosed.

An alternative remedy is to require the manager to hold onto their shares, acquired either through stock awards or the exercise of options, while employed by the company. 25 In our model, this means the manager can only sell his stocks in period 2. However this may not be realistic if the managers stay in office for a prolonged period. Besides, it fails to utilize an important signal to increase information transparency. 5.3. Reducing the shares that the manager owns

The agency issue will not exist if the manager does not own any stock (or any derivatives) at all. Generally, we have the following result:

Proposition 8. d_m is a decreasing function of α.

Although from Proposition 8 we know that reducing the stocks that the manager owns reduces his short-term incentive to cheat, this remedy is questionable as it actually misaligns the manager's incentives with investors' long-term interests.

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[25] Burton G. Malkiel, "The Market Can Police Itself," Wall Street Journal, June 28, 2002.

In other words, less stock holdings means the manager's compensation is less connected to the performance of the company, which in turn provides the manager weaker incentives to work hard for the company. If the manager is paid with a fixed salary, the manager will not exert every effort trying to make the project a success.

In sum, if we can solve the problem with regulations on advance disclosure of insiders' transactions, we do not need to abandon stocks and stock options that are effective in inducing efforts.

4.6 Conclusions

The harm that the recent burst of corporate scandals did on the economy has three folds. First, in order to maneuver financial statements, corrupt managers spend corporate resources on certain accounting tricks that never pay back. Second, investors are misled by erroneous income statements and thus allow managers to make inefficient decisions on investment strategies. Third, deterred by possible agency issues, investors may avoid new investment opportunities that on expectation have a better return.

By focusing on new technology investments, this paper reveals that there is a connection between the rising information economy where new technologies are emerging at a speed that is unparalleled in history, and the surge of agency issues. Specifically, the fact that new technologies are both risky and unfamiliar to the public gives managers a chance to maneuver the information revelation process and to profit from it. Therefore in the process of solving the recent corporate scandal problems, special attention should be given to the new technology sector, especially innovative technologies.

Among the proposed remedies we show that the most effective solution is to require managers to announce their intentions of stock transactions *before* the transactions happen instead of *after*, no matter how promptly. We also show that the though a tighter accounting system is helpful, but without proper regulation on advance disclosure, under-investment in the technology sector will still occur.

Appendix

Proof of Lemma 4:

Suppose at date 0 investors anticipate to see a good reported result with probability *p* following the sub-game where date 0 choice is the new technology. Then

$$p\hat{\gamma}_{1\hat{g}} + (1-p)\hat{\gamma}_{1\hat{b}} = \gamma_0$$

Since $\hat{\gamma}_{1\hat{b}} = \gamma_{1b} \leq \gamma_0$, we have $\hat{\gamma}_{1\hat{g}} \geq \gamma_0$.

Q.E.D.

Proof of Lemma 6:

We only need to show that, in the PBE, it is impossible to have $\underline{d} \leq d_1 < d_2 \leq \overline{d}$ such that $d_1 \in N$ and $d_2 \in M$. Assume that, to the contrary, this is true.

Let $P(g \mid \hat{g})$ be the possibility that investors believe the true period 1 result is good conditional on a reported good period 1 result. Given a PBE, $P(g \mid \hat{g})$ is a certain number. For a manager of type *d*, his gain from cheating is

$\alpha[P(g \mid \hat{g})V_1 + (1 - P(g \mid \hat{g})V_3 - V_5]$, and his loss from bankruptcy is

$d[\gamma_1(b)(1-\beta_h) + (1-\gamma_1(b))(1-\beta_l)]$.

Since $d_1 \in N$, we have

$$\alpha[P(g \mid \hat{g})V_1 + (1 - P(g \mid \hat{g})V_3 - V_5] \leq d_1[\gamma_1(b)(1-\beta_h) + (1-\gamma_1(b))(1-\beta_l)]$$

Since $d_2 \in M$, we have

$$\alpha[P(g \mid \hat{g})V_1 + (1 - P(g \mid \hat{g})V_3 - V_5] \geq d_2[\gamma_1(b)(1-\beta_h) + (1-\gamma_1(b))(1-\beta_l)]$$

These two inequalities result in $d_1 \geq d_2$, which contradicts the assumption that $d_1 < d_2$.

Q.E.D.

Proof of Theorem 1: There is a unique solution to

$$e = \alpha \frac{S_{\hat{g}}(e) - U_4}{\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l)} \qquad \text{(A1)}$$

A solution to (A1) is nothing but a fixed point of $f(e)$, where

$$f(e) \equiv \alpha \frac{S_{\hat{g}}(e) - U_4}{\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l)}$$

Note that everything in $f(e)$ is a parameter or a function of parameters except $S_{\hat{g}}(e)$.

So to prove the existence and uniqueness of a solution to (A1), we only need to examine the properties of $S_{\hat{g}}(e)$. Recall that

$$S_{\hat{g}}(e) =$$

$$\frac{\hat{\gamma}_1\beta_h(\beta_h U_1 + (1-\beta_h)U_2) + \hat{\gamma}_1(1-\beta_h)\phi\beta_h U_3 + (1-\hat{\gamma}_1)(\beta_l^2 U_1 + \beta_l(1-\beta_l)U_2) + (1-\hat{\gamma}_1)(1-\beta_l)\phi\beta_l U_3}{\hat{\gamma}_1(\beta_h + (1-\beta_h)\phi) + (1-\hat{\gamma}_1)(\beta_l + (1-\beta_l)\phi)}$$

(A2)

where

$$\hat{\gamma}_1 = \frac{1}{1 + \frac{1-\gamma_0}{\gamma_0}\frac{(1-\phi)\beta_l + \phi}{(1-\phi)\beta_h + \phi}}$$

So $S_{\hat{g}}(e)$ can be more accurately written as $S_{\hat{g}}(\phi(e))$.

We first look at the properties of $S_{\hat{g}}$ as a function of ϕ, then look at the properties of $S_{\hat{g}}(e)$.

Note that as a cdf, $\phi \in [0,1]$. We first show that for $\phi \in (0,1)$, $S_{\hat{g}}$ is strictly decreasing in ϕ, i.e. $\frac{dS_{\hat{g}}}{d\phi} < 0$. To make the proof concise, we summarize this result in Lemma A1, the proof of which follows.

Lemma A1: For $\phi \in (0,1)$, $\frac{dS_{\hat{g}}}{d\phi} < 0$.

Now we look at $S_{\hat{g}}$ for $\phi = 0$ and $\phi = 1$, and have

$S_{\hat{g}\max} = S_{\hat{g}}(\phi = 0)$, i.e. (A2) evaluated at $\phi = 0$ and

$S_{\hat{g}\min} = S_{\hat{g}}(\phi = 1)$, i.e. (A2) evaluated at $\phi = 1$.

Next we examine the properties of $S_{\hat{g}}$ as a function of e.

Since $\phi = F(d_m)$ is a continuous, strictly increasing function of d_m for $d_m \in (\underline{d}, \overline{d})$, and $\phi(e \le \underline{d}) = 0$, $\phi(e \ge \overline{d}) = 1$, we have:

$\frac{dS_{\hat{g}}}{de} < 0$ for $e \in (\underline{d}, \overline{d})$, and

$S_{\hat{g}}(e \le \underline{d}) = S_{\hat{g}}(\phi = 0) = S_{\hat{g}\max}$

$S_{\hat{g}}(e \ge \overline{d}) = S_{\hat{g}}(\phi = 1) = S_{\hat{g}\min}$

Thus $S_{\hat{g}}(e)$ is bounded both above and below. Furthermore, for $f(e)$, $\overline{d}$

$\frac{df}{de} < 0$ for $e \in (\underline{d}, \overline{d})$,

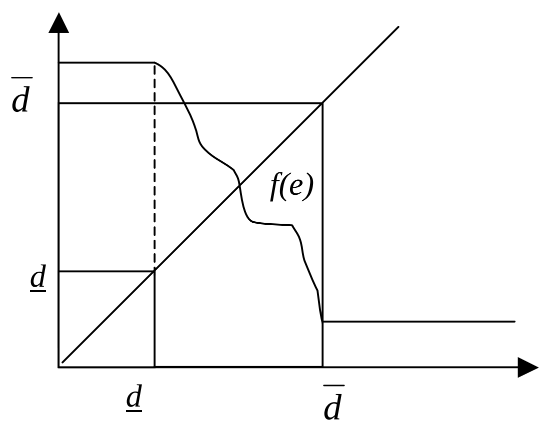
$f(e \le \underline{d}) = f(e)|_{S_{\hat{g}\max}} = f_{\max}$,

$f(e \ge \underline{d}) = f(e)|_{S_{\hat{g}\min}} = f_{\min}$.

Thus, $f(e)$ is a non-increasing function of e for all e.

Figure A1 illustrates one case of $e = f(e)$.

Figure A1



To prove that $f(e)$ has a fixed point, we define $A = [\lambda, \mu]$ where $\lambda < \min\{f_{\min}, \underline{d}\}$ and $\mu > \max\{f_{\max}, \overline{d}\}$, thus $f(e)$ is a continuous function from A into itself, where A is a nonempty, compact, convex set. Based on Brouwer's Fixed Point Theorem, there is a solution to $e = f(e)$.

Since $f(e)$ is non-increasing in e for all e, the solution to $e = f(e)$ is unique.

Q.E.D.

Lemma A1: For $\phi \in (0,1)$, $\frac{dS_{\hat{g}}}{d\phi} < 0$.

Proof of Lemma A1:

First we prove that $\hat{\gamma}_1$ is a decreasing function of ϕ.

$\hat{\gamma}_1$ can be rewritten as $\hat{\gamma}_1 = \frac{1}{1 + \frac{1-\gamma_0}{\gamma_0}\frac{(1-\phi)\beta_l + \phi}{(1-\phi)\beta_h + \phi}}$. Define $y(\phi) \equiv \frac{(1-\phi)\beta_l + \phi}{(1-\phi)\beta_h + \phi}$.

We have $\frac{d\hat{\gamma}_1}{d\phi} = \frac{-\frac{1-\gamma_0}{\gamma_0} y'(\phi)}{\left[1 + \frac{1-\gamma_0}{\gamma_0} y(\phi)\right]^2}$.

Notice that $y'(\phi) = \frac{\beta_h - \beta_l}{[(1-\phi)\beta_h + \phi]^2} > 0$, so $\frac{d\hat{\gamma}_1}{d\phi} < 0$.

Since

$S_{\hat{g}}(e) =$

$$\frac{\hat{\gamma}_1\beta_h(\beta_h U_1 + (1-\beta_h)U_2) + \hat{\gamma}_1(1-\beta_h)\phi\beta_h U_3 + (1-\hat{\gamma}_1)\left(\beta_l^2 U_1 + \beta_l(1-\beta_l)U_2\right) + (1-\hat{\gamma}_1)(1-\beta_l)\phi\beta_l U_3}{\hat{\gamma}_1(\beta_h + (1-\beta_h)\phi) + (1-\hat{\gamma}_1)(\beta_l + (1-\beta_l)\phi)}$$

(A2)

Define:

$$A \equiv \hat{\gamma}_1\left(\beta_h + (1-\beta_h)\phi\right) + (1-\hat{\gamma}_1)\left(\beta_l + (1-\beta_l)\phi\right)$$

$$C \equiv \hat{\gamma}_1\beta_h\left(\beta_h U_1 + (1-\beta_h)U_2\right) + \hat{\gamma}_1(1-\beta_h)\phi\beta_h U_3 + (1-\hat{\gamma}_1)\left(\beta_l^2 U_1 + \beta_l(1-\beta_l)U_2\right) \\ + (1-\hat{\gamma}_1)(1-\beta_l)\phi\beta_l U_3$$

Then, $\dfrac{dS_{\hat{g}}(e)}{d\phi} = \dfrac{AB-CD}{A^2} = \dfrac{X}{A^2}$ where

$$B \equiv \frac{dC}{d\phi} = \frac{d\hat{\gamma}_1}{d\phi}\beta_h\left(\beta_h U_1 + (1-\beta_h)U_2\right) + \frac{d\hat{\gamma}_1}{d\phi}(1-\beta_h)\phi\beta_h U_3 + \hat{\gamma}_1(1-\beta_h)\beta_h U_3 \\ - \frac{d\hat{\gamma}_1}{d\phi}\left(\beta_l^2 U_1 + \beta_l(1-\beta_l)U_2\right) + (1-\hat{\gamma}_1)(1-\beta_l)\beta_l U_3 - \frac{d\hat{\gamma}_1}{d\phi}(1-\beta_l)\phi\beta_l U_3$$

$$D \equiv \frac{dA}{d\phi} = \frac{d\hat{\gamma}_1}{d\phi}\left(\beta_h + (1-\beta_h)\phi\right) + \hat{\gamma}_1(1-\beta_h) + (1-\hat{\gamma}_1)(1-\beta_l) - \frac{d\hat{\gamma}_1}{d\phi}\left(\beta_l + (1-\beta_l)\phi\right)$$

After considerable amount of algebraic procedures, we simplify the above terms to:

$$A = \beta_l + (1-\beta_l)\phi + \hat{\gamma}_1(\beta_h - \beta_l)(1-\phi)$$

$$B = \frac{d\hat{\gamma}_1}{d\phi}(\beta_h - \beta_l)\left[(\beta_h + \beta_l)U_1 + (1-\beta_h-\beta_l)(U_2 + \phi U_3)\right] + (1-\beta_l)\beta_l U_3 \\ + (\beta_h - \beta_l)(1-\beta_h-\beta_l)\hat{\gamma}_1 U_3$$

$$C = \beta_l\left[\beta_l U_1 + (1-\beta_l)(U_2 + \phi U_3)\right] + \hat{\gamma}_1(\beta_h - \beta_l)\left[(\beta_h + \beta_l)U_1 + (1-\beta_h-\beta_l)(U_2 + \phi U_3)\right]$$

$$D = \frac{d\hat{\gamma}_1}{d\phi}(1-\phi)(\beta_h - \beta_l) + (1-\beta_l) - \hat{\gamma}_1(\beta_h - \beta_l)$$

Define $U_a = (\beta_h + \beta_l)U_1 + (1 - \beta_h - \beta_l)(U_2 + \phi U_3)$

For $X = AB - CD$, we collect all the terms with $\frac{d\hat{\gamma}_1}{d\phi}$ as a common factor and can rewrite X as

$$X = \frac{d\hat{\gamma}_1}{d\phi}E + F\ .$$

In E, with the term $(\beta_h - \beta_l)(1-\phi)U_a\hat{\gamma}_1$ being cancelled out, we get

$$\frac{d\hat{\gamma}_1}{d\phi}E = \frac{d\hat{\gamma}_1}{d\phi}(\beta_h - \beta_l)[(\beta_l + (1-\beta_l)\phi)U_a - (1-\phi)\beta_l(\beta_l U_1 + (1-\beta_l)(U_2 + \phi U_3))]$$

Substitute $U_a = (\beta_h + \beta_l)U_1 + (1 - \beta_h - \beta_l)(U_2 + \phi U_3)$ in, we get

$$\frac{d\hat{\gamma}_1}{d\phi}E = \frac{d\hat{\gamma}_1}{d\phi}(\beta_h - \beta_l)\left\{\begin{aligned}&(U_1 - U_2)[\phi(\beta_h + \beta_l) + (1-\phi)\beta_h\beta_l]\\ &+ \phi[U_2 + (\phi - \beta_h\phi - \beta_l\phi - \beta_h\beta_l + \beta_h\beta_l\phi)U_3]\end{aligned}\right\}$$

Because $U_1 > U_2 > U_3 > 0$, we have

$(U_1 - U_2)[\phi(\beta_h + \beta_l) + (1-\phi)\beta_h\beta_l] > 0$ and

$$\begin{aligned}\phi[U_2 + (\phi - \beta_h\phi - \beta_l\phi - \beta_h\beta_l + \beta_h\beta_l\phi)U_3] &> \phi U_3[1 + \phi - \beta_h\phi - \beta_l\phi - \beta_h\beta_l + \beta_h\beta_l\phi] \\ &> \phi U_3[1 - \beta_h\beta_l + \phi(1 - \beta_h)(1 - \beta_l)] \\ &> 0\end{aligned}$$

We know $\frac{d\hat{\gamma}_1}{d\phi} < 0$ and $(\beta_h - \beta_l) > 0$, so $\frac{d\hat{\gamma}_1}{d\phi} E < 0$.

Next we need to show that $F < 0$. Recall that F is the sum of all the terms in $X = AB - CD$ that do not have $\frac{d\hat{\gamma}_1}{d\phi}$ as a factor. We group these terms such that F can be rewritten as a sum of negative terms, i.e. $F = \sum_{i=1}^{11} F_i$, where $F_i < 0$ for i = 1, …, 11.

Specifically,

$$F_1 = \beta_l^2(1 - \beta_l)(U_3 - U_1) < 0$$

$$F_2 = \beta_l\hat{\gamma}_1(\beta_h - \beta_l)[(1 - \beta_h - \beta_l)U_3 - (1 - \beta_l)U_2] < 0$$

$$F_3 = \beta_l(1 - \beta_l)^2(\phi U_3 - U_2) < 0$$

$$F_4 = \hat{\gamma}_1(1 - \beta_l)(\beta_h - \beta_l)[\beta_l(1 - \phi)U_3 - (\beta_h + \beta_l)U_1] < 0$$

Since $(1 - \beta_h - \beta_l) > 0$, we have

$$F_5 = \hat{\gamma}_1^2(1 - \beta_h - \beta_l)(\beta_h - \beta_l)^2[(1 - \phi)U_3 - U_2] < 0$$

$$F_6 = -\hat{\gamma}_1(1-\beta_h-\beta_l)(\beta_h-\beta_l)U_2 < 0$$

$$F_7 = -\hat{\gamma}_1^2(1-\beta_h-\beta_l)(\beta_h-\beta_l)^2\phi U_3 < 0$$

And we also have

$$F_8 = -\beta_l(1-\beta_l)^2\phi U_3 < 0$$

$$F_9 = -\beta_l^2(\beta_h-\beta_l)^2\hat{\gamma}_1 U_1 < 0$$

$$F_{10} = -\beta_l\hat{\gamma}_1(1-\beta_l)(\beta_h-\beta_l)\phi U_3 < 0$$

$$F_{11} = -\hat{\gamma}_1^2(\beta_h+\beta_l)(\beta_h-\beta_l)^2 U_1 < 0$$

So, $X = AB - CD = \frac{d\hat{\gamma}_1}{d\phi}E + F < 0$

Therefore, $\frac{dS_{\hat{g}}(e)}{d\phi} = \frac{X}{A^2} = \frac{AB-CD}{A^2} < 0$

Q.E.D.

Proof of Proposition 1:

By Theorem 1, we know that there is a unique solution to

$$e = f(e) = \alpha\frac{S_{\hat{g}}(e) - U_4}{\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l)}.$$

Depending on the relationship between $f_{\max}$, $f_{\min}$, $\underline{d}$, and $\overline{d}$, there are three types of cases:

i) When $f_{\max} > \underline{d}$ and $\overline{d} > f_{\min}$, then $e \in (\underline{d}, \overline{d})$.

This case includes four scenarios:

$f_{\max} \geq \overline{d} > f_{\min} \geq \underline{d}$; $f_{\max} \geq \overline{d} > \underline{d} \geq f_{\min}$;

$\overline{d} \geq f_{\max} > f_{\min} \geq \underline{d}$; $\overline{d} \geq f_{\max} > \underline{d} \geq f_{\min}$.

Graphs illustrate clearly that $e \in (\underline{d}, \overline{d})$. The unique PBE is a semi-separating equilibrium in which, if period 1 result is bad, the manager cheats if $d < e$, and is honest if $d \geq e$.

ii) When $\overline{d} > \underline{d} \geq f_{\max} > f_{\min}$, then $e = f_{\max} \leq \underline{d}$, the unique PBE is a pooling equilibrium in which the manager never cheats.

iii) When $f_{\max} > f_{\min} \geq \overline{d} > \underline{d}$, then $e = f_{\min} \geq \overline{d}$, the unique PBE is a pooling equilibrium in which the manager always cheats.

Q.E.D.

Proof of Proposition 2:

Let $k = \frac{\gamma_1(1-\beta_h)+(1-\gamma_1)(1-\beta_l)}{\alpha}$. Notice that different *g*'s does not affect the belief updating process, i.e. belief updating only depends on whether *g* or *b* happens, not the specific values of *g* or *b*. Therefore *k* is independent of *g*. Also notice that $S_{\hat{g}}$ and U_4 depend on *g*. Then equation (1) can be rewritten as:

$$ke - S_{\hat{g}}(e,g) + U_4(g) = 0$$

…(A1)

Then we have $e'(g) = [\frac{\partial S_{\hat{g}}(e,g)}{\partial g} - U_4'(g)] \Big/ [k - \frac{\partial S_{\hat{g}}(e,g)}{\partial e}]$. Note that $k > 0$, $\frac{\partial S_{\hat{g}}(e,g)}{\partial e} < 0$ and $U_4'(g) = -\frac{\eta_0}{1-\eta_0} a(E+D) < 0$, we only need to show that $\frac{\partial S_{\hat{g}}(e,g)}{\partial g} > 0$. $\frac{\partial S_{\hat{g}}(e,g)}{\partial g}$ can be rewritten as:

$$\frac{\partial S_{\hat{g}}(e,g)}{\partial g} = \gamma_0((1-\phi)\beta_h + \phi)\rho_h(g) + (1-\gamma_0)((1-\phi)\beta_l + \phi)\rho_l(g),$$

…(A2)

where $\rho_h(g) = 2\beta_h^2 g + \beta_h(1-\beta_h)(1+\phi)(\frac{1}{1-\eta_0}R - 2\frac{\eta_0}{1-\eta_0}g)$, and

$$\rho_l(g) = 2\beta_l^2 g + \beta_l(1-\beta_l)(1+\phi)(\frac{1}{1-\eta_0}R - 2\frac{\eta_0}{1-\eta_0}g)$$

Since $\phi \in [0,1]$, equation (2) leads to $\rho_l(g) > 0$ for any ϕ. Also it is straightforward to see that $\rho_h(g) > \rho_l(g)$, then from (A2) we have $\frac{\partial S_{\hat{g}}(e,g)}{\partial g} > 0$.

Q.E.D.

Proof of Corollary 2:

It is straightforward to see that $(1-\eta_0)\frac{b}{R} > \frac{1}{2}$ implies equation (2). Given enough small β_l, when $g \to \infty$, we have $\eta_0 \to \beta_l$ and *b* approaches *R*, therefore the condition in Corollary 2 holds.

Q.E.D.

Proof of Proposition 6:

Consider that the direct cost to the company when the manager cheats, C, increases to $\hat{C}$, where $\hat{C} > C$. Accordingly we use “^” to distinguish the solutions under $\hat{C}$.

Notice that $\hat{U}_3 < U_3$. Then from

$$\alpha(S_{\hat{g}}(e;U_3) - U_4) = e(\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l))$$

…(A2)

we have $\alpha(S_{\hat{g}}(e;\hat{U}_3) - U_4) < e(\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l))$

We also have $\alpha(\hat{S}_{\hat{g}}(\hat{e};\hat{U}_3) - U_4) = \hat{e}(\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l))$.

…(A3)

We first show that $\hat{e} < e$. Assume, to the contrary, that $\hat{e} \geq e$. Then notice that $\frac{dS_{\hat{g}}}{de} < 0$, we have

$\hat{e}(\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l)) \geq e(\gamma_{1b}(1-\beta_h) + (1-\gamma_{1b})(1-\beta_l))$
$> \alpha(S_{\hat{g}}(e;\hat{U}_3) - U_4) \geq \alpha(\hat{S}_{\hat{g}}(\hat{e};\hat{U}_3) - U_4)$, which contradicts (A3). Therefore $\hat{e} < e$.

Then we show that $\hat{S}_{\hat{g}} < S_{\hat{g}}$. Notice that $(\gamma_{1b}(1-\beta_h)+(1-\gamma_{1b})(1-\beta_l))$ is a constant, then from (A2) and (A3) we have $\alpha(\hat{S}_{\hat{g}}(\hat{e};\hat{U}_3)-U_4)<\alpha(S_{\hat{g}}(e;U_3)-U_4)$, i.e. $\hat{S}_{\hat{g}} < S_{\hat{g}}$.

Q.E.D.

Proof of Lemma 10:

We only need to show that the manager can never have a pooling strategy in terms of timing.

If period 1 result is good, the manager will report good. Then public belief is updated to $\hat{\gamma}_1$. However, since $\hat{\gamma}_1 < \gamma_{1g}$, the value of the company is actually discounted. Then it is optimal for the risk-neutral manger to wait until period 2 to sell his stocks.

If period 1 result is bad. If the manger cheats, apparently he will sell in period 1 since that's the only period he has better information; if he is honest and reports bad, investors know that the true period 1 result is bad. Then the stock price is correctly updated which makes the manager indifferent to selling in period 1 or in period 2.

Therefore:

- report good and hold on to the stock: *g*
- report good and sell in period 1: *b*
- report bad: *b*

Q.E.D.

Proof of Proposition 7:

From Lemma 10 we know that now investors can perfectly learn the true result in period 1. Proposition 7 follows directly from the fact that stock price will be the lowest if the manager report good and plan to sell in period 1 given that investors know the cheating cost, *C*, for the company.

Q.E.D.

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