TWO THEORIES ON INFORMATION ASYMMETRY IN FINANCE

by

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ABSTRACT OF THE DISSERTATION

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This dissertation includes two essays which investigate the effects of information asymmetry in liquidity risk pricing and in agency problems. The brief abstracts of these two essays are presented as follows.

The first essay investigates how a risk averse liquidity provider sets optimal limit order book under information asymmetry. I extend the model proposed by Copeland and Galai (1983). First, in response to increasing trade size, a severe risk averse liquidity provider offers convex negatively-sloped bid curves and concave positively-sloped ask curves under information asymmetry. In addition, the simultaneous existence of the risk averse liquidity provider and market information asymmetry is the necessary condition that the liquidity provider offers negatively-sloped bid curves and positively-sloped ask curves. Both numerical analysis and empirical evidence on the limit order book of Taiwan Index Futures support the findings in this essay.

In the second essay, I investigate the effects of information asymmetry under the two-tiered agency problem which is commonly observed in a typical organizational structure. I propose the two-tiered agency model and shows that imposing Joint Responsibility policy between Agent_1 (Chief Executive Officer) and Agent_2 (Chief Financial Officer) is NOT a good policy for Principal (Shareholders). Joint Responsibility is that Agent_1 is accused of not identifying in advance Agent_2 who takes on destructive risky projects. I design two cases (Case_1 excludes Joint Responsibility and Case_2 includes it) and prove that Principal's payoffs in Case_1 weakly dominate that in Case_2. In addition, static comparative analysis shows that how the change of the losses from the bad state of the high risky project, or the parameter of Agent_1's monitoring costs, alters Agent_1's monitoring and Principal's payoffs in equilibrium.

DEDICATION

This dissertation is dedicated to my parents who support and enthusiastically encourage me throughout my doctoral study.

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Essay I

The Optimal Limit Order Book by Risk Averse Liquidity Providers under Information Asymmetry

1.1 Introduction

Liquidity risk is one of the main issues on modern finance research. During financial crisis of 2007-2010, illiquidity has been discussed extensively and researchers pay more attention on what factors cause market illiquidity. In this paper, I investigate one of the indicators of the market liquidity—the bid-ask spread from the limit order book of a market. The bid-ask spread reflects the difference between what active buyers pay ad what active sellers receive. Continuous markets are characterized by the bid and ask prices at which trades can take place. Alternatively, illiquidity could be measured by the time it takes optimally to trade a given quantity of an asset [Lippman and McCall (1986)]. Stoll (2003) points out that these two approaches converge because the bid-ask spread can be viewed as the amount paid to someone else (i.e. the dealer) to take on the unwanted position and dispose of it optimally. Bid-ask spreads vary widely and a central issue is to find out what determines the bid-ask spread.

In this paper, I extend Copeland and Galai's (1983) model and show that how a liquidity provider sets optimal limit order book under information asymmetry. Copeland and Galai (1983) consider how a market-maker optimizes his/her position by setting bid-ask spreads in organized financial markets. They assume the dealer is risk neutral, and makes a commitment to buy a fixed quantity at the bid price or to sell at the ask price. As for the model in this paper, I assume that liquidity providers are identical, and thus their behaviors can be regarded as one representative agent's behavior. I find that a severe risk averse liquidity provider offers a convex negatively-sloped bid curve and a concave positively-sloped ask curve under information asymmetry. In addition, the simultaneous existence of the risk averse liquidity provider and market information asymmetry is the necessary condition that the liquidity provider offers negatively-sloped bid curves and positively-sloped ask curves. Both numerical analysis and empirical evidence on the limit order book of Taiwan Index Futures support the findings in this paper.

Stoll (2003) points out that there are several factors that determine the bid-ask spread in a security. First, suppliers of liquidity, such as the dealers who maintain continuity of markets, incur *order handling costs* for which they must be compensated. In a market without dealers, where limit orders make the spread, order handling costs are likely to be smaller than in a market where professional dealers earn a living. Second, the spread may reflect *non-competitive pricing*. For example, market makers may have agreements to raise spreads or may adopt rules, such as a minimum tick size, to increase spreads. Third, suppliers of immediacy, who buy at the bid or sell at the ask price, assume *inventory risk* for which they must be compensated. For instance, if a dealer buys an amount of shares at the bid, he/she risks a drop in the price and a loss on the inventory position. Inventory risk was first examined theoretically in Garman (1976), Stoll (1978), Amihud and Mendelson (1980), Ho and Stoll (1981, 1983). Fourth, placing a bid or an ask grants an *option* to the rest of the market to trade on the basis of new information before the bid or ask can be changed to reflect the new information [Copeland and Galai (1983)]. A fifth factor has received the most attention in the literature, the effect of *asymmetric information*. If some investors are better informed than others, the person who places a firm quote (bid or ask) loses to investors with superior information. As Bagehot (1971) first noted, the losses to informed traders must be offset by profits from uninformed traders if dealers are to stay in business and if limit orders are to continue to be posted. Glosten and Milgrom (1985) model the spread in an asymmetric information world. Important theoretical papers building on the adverse-selection sources of the spread include Kyle (1985), Easley and O'Hara (1987) and Admati and Pfleiderer (1988).

The factors determining spreads are not mutually exclusive. All may be present at the same time. According to Stoll (2003), the three factors related to uncertainty – inventory risk, option effect and asymmetric information – may be distinguished as follows. The inventory effect arises because of possible adverse *public* information *after* the trade in which inventory is acquired. The expected value of such information is zero, but uncertainty imposes inventory risk for which suppliers of immediacy must be compensated. The option effect arises because of adverse *public* information *before* the trade and the inability to adjust the quote. The option effect results from an inability to monitor and immediately change resting quotes. The adverse selection effect arises because of the presence of *private* information *before* the trade, which is revealed sometime after the trade. The information effect arises because some traders have superior information.

This paper has several new implications for the effects of inventory risk and asymmetric information. First, the risk attitude of the liquidity provider may affect the bid-ask spread. If the liquidity provider is risk neutral, trade size does not affect the bid-ask spread. However, if the liquidity provider is risk averse, increasing trade size enlarges the bid-ask spread, which implicates that the inventory risk is correlated with liquidity provider's risk attitude. This finding is similar to Easley and O'Hara (1987), who show that trade size introduces an adverse selection problem into security trading because, given that traders wish to trade, informed traders prefer to trade larger amounts at any given price. As a result, Easley and O'Hara (1987) suggest that market maker's pricing strategies must also depend on trade size, with large trades being made at less favorable prices. Second, if there is no information asymmetry in the market, a risk averse liquidity provider sets narrower bid-ask spreads for increasing trade size. These implications further show that inventory risk and asymmetric information is truly not mutually exclusive and may be related to the risk attitude of the liquidity provider.

The paper proceeds as follows. Section 1.2 introduces literature review on trading mechanism design and bid-ask spread modeling. Section 1.3 contains Copeland and Galai's (1983) model and the extended model in this paper. Section 1.4 contains several propositions and numerical analysis. Section 1.5 contains the empirical results from the limit order book of Taiwan Index Futures. Section 1.6 concludes the paper and some proofs are shown in Appendix.

1.2 Literature Review

In this section, I review the related literatures on the bid-ask spread. Demsetz (1968) is the first researcher interested in order imbalance: trading has a time dimension and at a fixed point in time, and there may be imbalance in buy and sell orders which are required to be executed immediately. The bid-ask spread is a price for immediacy. Garman (1976) considers two market clearing mechanisms – the double auction or the monopolistic dealer exchange, and shows that the dealer must set an ask price and a bid price to receive orders from public traders and to maximize profit per unit of time subject to the constraint that bankruptcy must not take place. In Garman's (1976) model, the bid-ask spread exists in order that specialist will not be ruined with probability one.

Amihud and Mendelson (1980) extend Garman's study to allow price adjustments according to inventory positions. In Amihud and Mendelson's (1980) framework, the bid-ask spread reflects monopoly power of the specialist. As competition gets in and increases, the bid-ask spread tends to zero. Besides, there exists an optimal inventory level; departing from this level induces a dealer to adjust bid and ask prices in order that inventory can go back to that level. Stoll (1978) takes a different view about the bid-ask spread: Market makers are those selling insurance to liquidity traders, and the spread is risk premium. Thus, the bid-ask spread in Stoll's (1978) model reflects compensation for market makers taking positions that make their portfolio deviate from their ideal positions. Stoll (1978) assumes that in order for a dealer to be willing to perform his or her function, engaging in market making should not lower his or her satisfaction. The bid-ask spread can be derived so that a dealer feels indifferent to or not to engage in market making.

Bagehot (1971) is the origin of the information-based models studying the impact of information asymmetry on asset trading. Bagehot (1971) shows that there is a difference between market gains and trading gains. For market making to be viable, liquidity traders must lose money to other traders. Consequently, information alone may lead to the presence of a bid-ask spread. Copeland and Galai (1983) consider how a market-maker optimizes his/her position by setting bid-ask spreads in organized financial markets. Copeland and Galai (1983) assume the dealer is risk neutral, and makes a commitment to buy a fixed quantity at the bid price or to sell at the ask price. Their model implicates that information can be the sole reason that a bid-ask spread exists.

Kyle (1985) considers a dynamic model of insider trading with sequential auctions, and examines the informational content of prices, the liquidity characteristics of a speculative market, and the value of private information to an insider. Kyle (1985) model has three kinds of traders: a single risk neutral insider, random noise traders, and competitive risk neutral market makers. The insider makes positive profits by exploiting his/her monopoly power optimally in a dynamic context, where noise trading provides camouflage which conceals insider's trading from market makers. Kyle (1985) model is a standard order-driven model in the literature.

Holden and Subrahmanyam (1992) extend Kyle's (1985) model and consider many insiders sharing the same information and trading a stock for more than one period. When the numbers of insiders or the periods approach infinite, insiders' expected profits tend to zero and the market becomes infinitely liquid. According to their model, as long as more than one insider share the same private information and there are plenty of opportunities to trade prior to the time their private information becomes public, imperfect competition will wipe out insider profits.

Spiegel and Subrahmanyam (1992) replace exogenously given noise traders by rational hedgers subject to endowment shocks. By replacing Kyle's (1985) noise traders by rational hedgers, and endogenizing these hedgers' behavior, Spiegel and Subrahmanyam (1992) obtain results that differ greatly from Kyle (1985). First, a linear equilibrium may fail to exist. The rational hedgers may reduce their trades so much that the market makers cannot break even by finding a linear pricing schedule, and the adverse selection problem can be so severe that it makes the market cease to function.

Second, increasing the number of hedgers (liquidity traders) may lead to a lower market depth. That is, an increase in the number of hedgers raises the price volatility which discourages risk averse traders from trading a large quantity, but it mitigates the adverse selection problem. Spiegel and Subrahmanyam (1992) also shows that an individual insider's expected profit can be non-monotonic in the number of insiders, and an individual liquidity trader's welfare can be non-monotonic in the number of insiders. The last result has implications for trade clustering. In a multi-market or multiple-trading-session extension of Spiegel and Subrahmanyam's static model, if hedgers have discretion over where and when to trade, they may prefer to trade in different markets or at different times.

There are several articles concerning applications of Kyle's (1985) model in the literature. Kyle and Vila (1991) consider the interactions between takeovers and noise trading. There is a raider who plays the role of the monopolistic insider in Kyle (1985). The raider can improve the value of the firm that issued the traded stock after stock trading. There are noise traders in the market, and the raider can observe the former's market orders before choosing his/her own. Kyle and Vila (1991) point out that as long as there is sufficient noise trading in the stock market and somehow the raider can obtain superior information about the noise trades, a profitable takeover will be able to take place. When the raider sees a heavy sell order from noise traders, he/she can buy it at a low cost, which encourages him/her to finish the takeover after stock trading, as the shares that he acquired before the declaration of takeover were obtained at a price lower than the expected value after the takeover.

Kyle and Wang (1997) apply Kyle's (1985) model to study the effects of over-confidence on security trading. Similar to Kyle (1985), there is a Gaussian normal random variable representing the noise trade, and there are risk neutral rational market makers competing in price to absorb order imbalance. Kyle and Wang's (1997) model is static and a linear equilibrium can be obtained. Because the insiders submit market orders, the trading resembles a Cournot duopoly, with an over-confident insider trading more aggressively, which discourages his/her rival from trading much. If there is only one insider and if he or she is over-confident, he or she ends up with a higher insider trading profits. ,

The first formal quote-driven model is due to Glosten and Milgrom (1985). Golsten and Milgrom (1985) show that the presence of traders with superior information leads to a positive bid-ask spread even when the specialist is risk-neutral and makes zero expected profits. The resulting transaction prices convey information, and a bid-ask spread implies a divergence between observed returns and realizable returns. Observed returns are approximately realizable returns plus what the uninformed traders anticipate losing to the insiders. The bid-ask spread is related to the precision of private information, the likelihood of informed trading, and the intensity of liquidity trading.

Easy and O'Hara (1987) relax Glosten and Milgrom's (1985) assumptions that each public trader can only sell or buy one unit. Thus, they are able to discuss the relationship between the equilibrium stock price and trading volume. Unlike Glosten and Milgrom's (1985), where a positive fraction of public traders are informed speculators in their settings, Easley and O'Hara (1987) assume there are two possibilities: either no information event has ever occurred, so that all public traders are uninformed, or an information event has occurred, so that a positive fraction of public traders become informed speculators. Thus, Easley and O'Hara (1987) provide an explanation for the price effect of block trades and demonstrate that both the size and the sequence of trades matter in determining the price-trade size relationship.

Bondarenko (2001) suggests that earlier market microstructure papers have often considered market makers' trading behavior as perfectly competitive. The classic models of asymmetric information (Kyle (1985), Glosten and Milgrom (1985), Easley and O'Hara (1987)) focus on the role of adverse selection created by the presence of better informed traders on price formation, but they do not deal with the strategic aspects of market makers' behavior. In these models, market makers are simply assumed to be perfect competitors who provide liquidity at prices that earn them a zero profit. The zero-profit assumption is a convenient abstraction which greatly simplifies the game-theoretical analysis of the models, but it is often at odds with the empirical facts about securities markets. Furthermore, the standard competitive models cannot explain how market makers may be able to cover substantial fixed costs associated with making a market in a security.

As for theories of trading volume in the literature, it is not until mid-1980's that we start to have a more complete understanding about the volume of trade, though the equilibrium and no-arbitrage asset pricing theories are developed before 1980's [Chen (2005)]. The finance literature suggests that trade can be motivated by either informational or non-informational motives. On one hand, non-informational motives are that two economic agents may want to trade because they have different endowments, different attitudes toward risks, or different time preferences. On the other hand, informational motives are those who have the same preferences and endowments may want to trade because they have different pre-trade belief about the future price and dividend processes of the traded assets. The differences in the pre-trade beliefs may come from the heterogeneous prior beliefs about the dividend to be distributed by the traded asset [Harris and Kreps (1978), Morris (1996)], from the differences of opinion about the statistical relationship between the intrinsic value of the traded asset and a public or private signal, or from the different private information the agents possess before trading.

According to the no-trade theorems by Kreps (1977), different private information alone cannot generate trade among investors holding the same prior beliefs. Thus, a feasible theory of trading volume must allow investors to either trade for non-informational reasons or to have heterogeneous pre-trade beliefs. Varian (1986) develops a two-period model to show that differences of opinion with heterogeneous pre-trade beliefs may result in high trading volume. Varian (1985) proves that if the decreasing absolutely risk averse investors' Arrow–Pratt measure for absolute risk aversion does not fall too fast when wealth rises, more divergent opinions should result in lower asset prices in an Arrow-Debreu economy. Moreover, Varian (1986) shows that heterogeneous beliefs alone can only cause an initial round of trading, and after that, the asset price moves when new information arrives at the market, but no new trades will occur, and differences of opinion about the interpretation of private signals persistently cause trades.

Admati and Pfleiderer (1988) develop a theory in which concentrated-trading patterns arise endogenously as a result of the strategic behavior of liquidity traders and informed traders. They try to explain why trading tends to be concentrated in particular time periods within the trading day. Admati and Pfleiderer (1988) assume that there are multiple insiders who possess short-lived private information and multiple liquidity traders who are endowed with fixed number of shares to buy or sell at each trading day. These traders are assumed to submit market orders to market makers, same as Kyle (1985). Suppose that some of the liquidity traders have limited discretion about when to fulfill their liquidity trades, but others do not. The former are called the discretionary liquidity traders, and the latter the non-discretionary liquidity traders. The discretionary liquidity traders would want to trade when the market makers are expected to provide the highest market depth in a day. Therefore, there is concentration of trading which results from strategic decisions of discretionary liquidity traders. On the other hand, if the information event on each day is stationary over time, even though there is concentration in trading, the information content and the variability of equilibrium prices will be constant over time.

Following Kyle (1984), Admati and Pfleiderer (1988) allow endogenous information acquisition. Kyle (1984) shows that a higher level of noise trading induces more traders to engage in costly information acquisition and to become insiders, and consequently the equilibrium price becomes more informative. Similarly, Admati and Pfleiderer (1988) show that the concentration of trading becomes more obvious when the number of insiders on each trading day is endogenously determined. This is because if traders can decide when to become informed, they may want to trade on the day when discretionary liquidity traders concentrate their trades. If insiders on the same trading day share the same short-lived information, they may compete with each other, and thus having more insiders on one day may improves liquidity traders' welfares. This case may not be true if insiders have heterogeneous private information. For example, adding one more insider to a trading may make the order imbalance more informative, so the equilibrium slope of price as a function of order imbalance may rise, which may discourage liquidity traders.

As for empirical tests on the bid-ask spread in markets, there are also many researchers working on this field. Heston, Korajczyk, and Sadka (2010) exam intraday predictability in the cross-section of stock returns and find a striking pattern of return continuation at half-hour intervals. They postulate that systematic trading and institutional fund flows lead to predictable patterns in trading volume and order imbalances among common stocks. If these patterns are fully anticipated, then they should not cause predictability in stock returns. However, Heston, Korajczyk, and Sadka (2010) find periodicity in the cross-section of stock returns. To study the nature of intraday periodicity, they divide the trading day into 13 half-hour trading interval. A stock's return over a given trading interval is negatively related to its returns over recent intervals, consistent with the negative autocorrelation induced by bid-ask bounce and lack of resiliency in markets. Moreover, there is a statistically significant positive relation between a stock's return over a given interval and its subsequent returns at daily frequencies. That is, according to Heston, Korajczyk, and Sadka (2010), knowing that the equity return of ABC, Inc. is high between 11:00 AM and 11:30 AM today has explanatory power for the return on ABC, Inc. equity at the same time tomorrow and on subsequent days. This effect is statistically significant for at least 40 trading days.

Easley, Engle, O'Hara and Wu (2008) propose a dynamic econometric microstructure model of trading and investigate how the dynamics of trades and trade composition interact with the evolution of market liquidity, market depth, and order flow. A fundamental insight of the microstructure literature is that order flow is informative regarding subsequent price movements. This informational role arises because orders arrive from both informed and uninformed traders, and market observers can infer new information regarding the value of the asset from the composition and existence of trades. Thus, market parameters such as volume, volatility, market depth, and liquidity are all linked in the sense that each is influenced by the underlying order arrival processes. Easley et al (2008) show that both informed and uninformed trades are highly persistent, but that the uninformed arrival forecasts respond negatively to past forecasts of the informed intensity.

Bondarenko (2001) develops a dynamic market microstructure model of liquidity provision in which many strategic market makers compete in price schedules for order flow from informed and uninformed traders. In equilibrium, market makers post price schedules that are steeper than efficient ones, and the market bid-ask spreads can be decomposed into two components, one due to adverse selection and the other due to imperfect competition. At any time, the two components are proportional to each other with a coefficient of proportionality depending on the number of market makers. Moreover, Bondarenko (2001) proposes several hypotheses regarding the time-series and cross-sectional properties of prices and the bid-ask spreads.

Bangia et al (1998) argue that liquidity risk associated with the uncertainty of the spread, particularly for thinly traded or emerging market securities under adverse market conditions, is an important part of overall risk and is therefore an important component to model. Thus, Bangia et al (1998) develop a simple liquidity risk methodology that can be easily and seamlessly integrated into standard value-at-risk models, and they show that ignoring the liquidity effect can produce underestimates of market risk in emerging markets by as much as 25%-30%.

Chaput and Hderington (2002) investigate spread and combination trading in the Eurodollar options market and find that spreads and combinations collectively account for over 55% of large trades (trades of 100 contracts or more) in the Eurodollar options market and almost 75% of the trading volume due to large trades. Besides, Chaput and Hderington (2002) confirm that traders use spreads and combinations to construct portfolios which are highly sensitive to directional changes in the underlying asset value – though they are often not completely delta neutral. Furthermore, Chaput and Hderington (2002) find evidence that effective bid-ask spreads are larger on orders exceeding 500 contracts or more than on orders of between 100 and 500 contracts and evidence that effective bid-ask spreads are larger on combinations which short volatility.

Foucault (1999) provides a game theoretic model of price formation and order placement decisions in a dynamic limit order market. In Foucault's (1999) model, investors can choose to either post limit orders or submit market orders. Limit orders result in better execution prices but face a risk of non-execution and a winner's curse problem. Handa et al (2003) extend Foucault (1999) and show that the size of the spread is a function of the differences in valuation among investors and of adverse selection. They models quote setting and price formation in a non-intermediated, order driven market where trading occurs because investors differ in their share valuations and the advent of news that is not common knowledge.

Chung, Jo, and Shefrin (2003) examines the empirical relation among trading volume, the bid-ask spread components, informational variables, and price volatility using a structural model that treats the spread components, trading volume, and price volatility as endogenous. Their empirical results indicate that although liquidity trading dampens the effect of informational precision on trading volume, the net effect of informational precision is positive. Moreover, while higher differential beliefs lead to greater trading by informed traders, it exerts a commensurate negative impact on liquidity trading. As a result, the net effect of differential beliefs on trading volume is insignificant. This new finding refutes the generally accepted belief in the volume literature that greater differences of opinion induce more trading.

Loderer and Roth (2003) investigate the pricing discount for limited liquidity. Unlike previous studies that have examined the relation between historical returns and liquidity, Loderer and Roth (2003) looks directly at current stock prices. This approach requires less data and yields up-to-date information about limited liquidity discounts. They analyze data from the Swiss exchange and the Nasdaq during 1995-2001, and find a statistically and economically significant price-liquidity relation in both markets. Moreover, they test the robustness of that relation with a procedure which does not rely on specific distributional assumptions, and the median discount can reach 30 percent according to the evidence.

Pasquariello (2000) analyzes the intraday relationship between bid-ask spreads and market return volatility for US Dollar/Deutschemark quotes. He identifies a statistically and economically significant Reverse U-shaped pattern in the bid-ask spread in 1996. Tests of the stability and ordering of market volatility, performed across several different fractions of the day, reveal that variances of intra-day returns are heterogeneous and ordered, declining around the Asian lunch break, increasing steadily during the London morning trading hours, peaking at the opening of New York to subsequently fall with the closing of the European markets. Results also indicate that market volatility is significantly higher during intraday versus overnight periods.

Theissen (2000) report the results of eighteen market experiments that were conducted in order to compare the call market, the continuous auction and the dealer market. Transaction prices in the call and continuous auction markets are much more efficient than prices in the dealer markets. The call market shows a tendency towards underreaction to new information. Execution costs are lowest in the call market and highest in the dealer market.

Hasbrouch (1999) presents an empirical microstructure model of bid and ask quotes that features discreteness, random costs of market making. Applied to intraday quote at fifteen-minute intervals for Alcoa (a randomly chosen Dow stock), the results show that quote exposure costs contain stochastic components that are persistent and large relative to the deterministic intraday “U” components. On the other hand, Serendnyakov (2005) suggests a new quote-based model for decomposing the bid-ask spread into three components: adverse selection, inventory holding and order processing, and examine intra-daily behavior of the components for actively traded stocks. Besides, Serednyakov (2005) investigate the impact of decimalization on the spread and its components and contribute to the debate on how trading systems affect the spread and its sources.

Mercorelli et al (2008) construct a model specific for an electronic order-driven exchange. The model both captures adverse selection and the impact of order flows on price discovery and includes the imbalance of supply and demand inherent in the public limit order book. Moreover, Mercorelli et al (2008) investigate the change to anonymity on the Australian Securities Exchange (ASX) and find that following the change to anonymity, both adverse selection and the demand/supply imbalance have an increased impact on prices while order flow has a decreased influence, suggesting the change to anonymity has improved market efficiency.

Cartea and Jaimungal (2010) suggest that Algorithmic Trading (AT) and High Frequency (HF) trading, which are responsible for over 70% of US stocks trading volume, have greatly changed the microstructure dynamics of tick-by-tick stock data. Thus, Cartea and Jaimungal (2010) employ a hidden Markov model to examine how the intraday dynamics of the stock market have changed, and how to use this information to develop trading strategies at ultra-high frequencies. In particular, they show how to employ the model to submit limit orders to profit from the bid-ask spread and provide evidence of how HF traders may profit from liquidity incentives.

Obizhaeva and Wang (2006) show that the dynamics of the supply/demand is of critical importance to be optimal trading strategy of a given order. Using a limit-order-book market, Obizhaeva and Wang (2006) develop a simple framework to model the dynamics of supply/demand and its impact on execution cost. They show that the optimal execution strategy involves both discrete and continuous trades, not only continuous trades as previous work suggested. The cost savings from the optimal strategy over the simple continuous strategy can be substantial. On the other hand, Alfonsi et al (2008) consider optimal execution strategies for block market orders placed in a limit order book (LOB) and build on the resilience model proposed by Obizhaeva and Wang (2006) but allow for a general shape of the LOB defined via a given density function. Therefore, Alfonsi et al (2008) can allow for empirically bowered LOB shapes and obtain a nonlinear price impact of market orders. Applying their results to a block-shaped LOB, they obtain a new closed-form representation for the optimal strategy of a risk-neutral investor, which explicitly solves the recursive scheme given in Obizhaeva and Wang (2006).

Schwartz, Sipress and Weber (2010) introduces how modern trading relies on information technology and how algorithmic trading and high-frequency trading works. He introduces a useful tool for trading: TraderEx, which is based on computer-driven algorithmic models and helps investors do critical investment decisions by formulating a variety of algorithms. Moreover, Schwartz (2010) introduces how micro markets works and the levels of economic efficiency that markets and the people operating in them can achieve, which help me formulate the model in this paper.

Gabaix et al (2003) suggest that power laws appear to describe histograms of relevant financial fluctuation, such as fluctuations in stock price, trading volume and the number of trades. They find that the exponents that characterize these power laws are similar for different types and sizes of markets, for different market trends and different countries. They propose a model based on the hypothesis that large movements in stock markets arise from the trades of large participants, and show that the power laws observed in financial data arise when the trading behavior is performed in an optimal way. Moreover, Gabaix et al (2002) quantify the relations between price change over a time interval and two different measures of demand fluctuations, defined as the difference between the number of buyer-initiated and seller-initiated trades, and the difference in number of shares traded in buyer-initiated and seller-initiated trades. Their findings suggest that the conditional expectation functions of price change for a given market impact function display concave functional forms that seem universal for all stocks.

1.3 The Model

1.3.1 The Case When the Liquidity Provider is Risk Neutral

First of all, I introduce the case when the liquidity provider is risk neutral. The symbol S_0 is defined as the current "true" price of the security as perceived by the liquidity provider, who buys at the bid price, K_B, or sells at the ask price, K_A. The quote is usually very short-lived as it can be terminated with the next transaction or with the arrival of new information.

The assumptions which determine the exogenously given framework for the model are listed below:

a) There are no taxes and short-selling is unconstrained.

b) Information about the realization of s is generated by exogenous events and informed traders convey it to the marketplace. The liquidity provider or uninformed traders are uninformed as to the realization of $f(s)$ until after an informed trade takes place. The uninformed trader is also motivated by exogenous independent events.

c) p_I $(0 < p_I < 1)$ is the probability, determined exogenously, that the next request for a quote is motivated by superior information regarding the next price realization, and $p_L = 1 - p_I$ is the probability that the quote request is motivated by uninformed traders.

d) Asset markets are anonymous in the sense that the dealer does not know, ex ante, whether or not the other side of the transaction possesses superior information.

e) Once at the trading post, the consummation of trades is a function of the bid-ask spread, i.e., both uninformed and informed traders have price-elastic demand.

f) The liquidity provider is risk neutral and thus an expected profit maximizer.

The liquidity provider's objective is to choose bid and ask prices which maximizes his/her profits. If he/she sets the bid-ask spread too wide, he/she loses expected revenues from uninformed traders but reduces potential losses to informed traders. On the other hand, if he/she establishes a spread which is too narrow, the probability of losses incurring to informed traders increases, but is offset by potential revenues from uninformed trading. The liquidity provider's optimal bid-ask spread is determined by a tradeoff between expected gains from uninformed trading and expected losses to informed trading.

This model is an instantaneous quote model, which specifies that the liquidity provider waits before offering his/her quote until a trader requests it. The quote is offered with knowledge that in the next instant the "true" price may jump to a new level if the trader is informed or remain unchanged if the trader is uninformed. No time interval passes between a quote, the trade, and the revelation of a new price.

Given that the liquidity provider withholds his/her quote until requested, we consider the liquidity provider's expected costs and expected revenues. His/her expected losses to informed traders depends on p_I, the probability that the next trader is informed; the liquidity provider's knowledge of the process governing price changes, $f(s)$; and on his/her choice of bid and ask prices, K_B and K_A. Then the expected liquidity provider's loss to an informed trader is,

$$p_I \cdot \left\{ \int_0^{K_B} \left(K_B - s\right) f(s)ds + \int_{K_A}^{\infty} (s - K_A) f(s)ds \right\} \tag{1.1}$$

The symbol s is denoted as the post-trade "true" price of the asset. Not all informed traders who arrive at the marketplace consummate a trade. Non-traders are informed individuals who believe the post-trade will fall between K_A and K_B, the ask and bid prices, respectively. Therefore, the elasticity of demand by informed traders with respect to the bid-ask interval is implicit in the limits of integration of Equation (1.1).

The liquidity provider's revenues come from those uninformed traders who are willing to pay $K_A - S_0$ or $S_0 - K_B$ as a price for immediacy. In order to express the price elasticity of the uninformed trader's demand for immediacy, we follow Copeland and Galai's (1983) setting and partition the fraction of uninformed traders, $p_L = (1 - p_I)$, into two parts. Let p_{TL} and p_{NL} be the probabilities of trading and non-trading, given that a trader is an uninformed trader. In addition, decompose p_{TL} into two parts, p_{BL} and p_{SL} (such that $p_{BL} + p_{SL} = p_{TL}$), which give the probability of buying and selling by an uninformed trader. It is assumed that, given S_0, the probability, p_{TL}, that an uninformed trader will transact falls as the dealer spread increases. Since p_{TL} is decomposed into buying and selling components so that optimal bid and ask prices can be analyzed separately later in the paper,

$$\left.\frac{\partial p_{SL}}{\partial K_B}\right|_{S_0} > 0 \quad \text{and} \quad \left.\frac{\partial p_{BL}}{\partial K_A}\right|_{S_0} < 0 \tag{1.2}$$

The liquidity provider's expected revenue per transaction from uninformed traders is

$$(1 - p_I) \cdot \left\{ p_{SL}(S_0 - K_B) + p_{BL}(K_A - S_0) + p_{NL} \cdot 0 \right\} \tag{1.3}$$

The objective of a risk neutral liquidity provider is to choose the bid and ask prices which maximize his/her expected profit. This can be expressed as

$$\underset{K_A,K_B}{Max}\Big\{(1-p_I)\cdot\big[p_{SL}(S_0-K_B)+p_{BL}(K_A-S_0)\big] \\ -p_I\cdot\left[\int_0^{K_B}(K_B-s)f(s)ds+\int_{K_A}^{\infty}(s-K_A)f(s)ds\right]\Big\} \qquad (1.4)$$

If the liquidity provider is a monopolist, he/she maximizes the difference between the expected revenue and cost function by setting bid and ask prices at first order conditions equal to zero[1]. If there is free entry, the long-run competitive equilibrium is established where the expected costs and revenues are equal and expected long-run profit is zero.

1.3.2 The Case When the Liquidity Provider is Risk Averse

Then, I consider the case when the liquidity provider is risk averse. First, it is assumed that liquidity providers are identical and thus we consider liquidity providers' behaviors as a representative agent's behavior. Second, liquidity provider's expected utility gains or utility losses rather than expected revenues or losses are considered in this extended model. In addition to variables introduced in the previous section, there are two more variables introduced in the extended model: the quantities of the trade, N, and the initial wealth of the liquidity provider, W_0. Liquidity provider's expected utility losses to an informed trader is:

$$p_I\cdot\left\langle\int_0^{K_B}\big\{U[W_0]-U[W_0-N(K_B-s)]\big\}f(s)ds+\int_{K_A}^{\infty}\big\{U[W_0]-U[W_0-N(s-K_A)]\big\}f(s)ds\right\rangle \qquad (1.5)$$

On the other hand, liquidity provider's expected utility gains when the counterparty is an uninformed trader is

[1] Optimal bid and ask prices should be derived from first order conditions with respect to bid and ask prices equal to zero, and second orders conditions with respect to bid and ask prices are negative.

$$(1-p_I)\cdot\left\langle p_{SL}\left\{U[W_0+N(S_0-K_B)]-U[W_0]\right\}+p_{BL}\left\{U[W_0+N(K_A-S_0)]-U[W_0]\right\}+p_{NL}\cdot 0\right\rangle \tag{1.6}$$

where p_{BL}, p_{SL} are the probability of buying and selling by a uninformed trader, and p_{NL} is the probability of non-trading by a uninformed trader

The objective of a risk averse liquidity provider is to choose the bid-ask spread that maximizes his/her expected utility. It is expressed as the following equation,

$$\underset{K_A,K_B}{Max}\left\{(1-p_I)\cdot\left\langle p_{SL}\left\{U[W_0+N(S_0-K_B)]-U[W_0]\right\}+p_{BL}\left\{U[W_0+N(K_A-S_0)]-U[W_0]\right\}+p_{NL}\cdot 0\right\rangle\right.$$
$$\left.-p_I\cdot\left\langle\int_0^{K_B}\left\{U\left[W_0\right]-U\left[W_0-N(K_B-s)\right]\right\}f(s)ds+\int_{K_A}^{\infty}\left\{U\left[W_0\right]-U\left[W_0-N(s-K_A)\right]\right\}f(s)ds\right\rangle\right\} \tag{1.7}$$

If the liquidity provider is a monopolist, he/she maximizes the expected utility by setting bid and ask prices to satisfy the condition that first order conditions equal zero[2]. If there is free entry, the long-run competitive equilibrium is established where the expected utility gains and expected utility losses are equal and expected long-run utility gain is zero.

1.3.3 Optimal Bids and Asks When the Liquidity Provider is a Monopolist

I take first order conditions with respect to K_B or K_A respectively on Equation (1.7) and the following Equation (1.8) and (1.9) are obtained:

$$(1-p_I)\cdot\frac{dp_{SL}}{dK_B}\cdot\left\{U[W_0+N(S_0-K_B)]-U[W_0]\right\}-(1-p_I)\cdot p_{SL}\cdot N\cdot U^{'}[W_0+N(S_0-K_B)]-$$
$$p_I\cdot\frac{\partial}{\partial K_B}\left[\int_0^{K_B}\left\{U\left[W_0\right]-U\left[W_0-N(K_B-s)\right]\right\}f(s)ds\right]=0 \tag{1.8}$$

---

[2] Optimal bid and ask prices should be derived from first order conditions with respect to bid and ask prices equal to zero, and second orders conditions with respect to bid and ask prices are negative.

And

$$(1-p_I)\cdot\frac{dp_{BL}}{dK_A}\cdot\{U[W_0+N(K_A-S_0)]-U[W_0]\}+(1-p_I)\cdot p_{BL}\cdot N\cdot U^{'}[W_0+N(K_A-S_0)]-$$
$$p_I\cdot\frac{\partial}{\partial K_A}\left[\int_{K_A}^{\infty}\{U[W_0]-U[W_0-N(s-K_A)]\}f(s)ds\right]=0 \quad (1.9)$$

Equation (1.8) presents the relationship between trade size N and optimal bid prices K_B, and Equation (1.9) presents the relationship between trade size N and optimal ask prices K_A. In the next section, I propose several propositions and show that how liquidity providers with different risk attitudes set optimal bid and ask prices in response to different trade size in different competitive levels of a market.

1.4 Propositions and Numerical Analysis

Proposition 1.1

A Risk neutral liquidity provider offers horizontal bid curves and horizontal ask curves in response to increasing trade size, whether there exists information asymmetry or not in the market.

I first proof the case when the liquidity provider is a monopolist, and then proof the case when the market is perfectly competitive.

(1) If the Market is a Monopoly

If the liquidity provider is risk neutral, his/her utility function is linear. Without loss of generosity, I assume it can be expressed as $U(x)=x$. Then, I substitute the linear function $U(x)=x$ for the utility function in Equation (1.8) and (1.9), and obtain the following Equation (1.10) and (1.11).

$$N \cdot \left\{ (1-p_I) \cdot \frac{dp_{SL}}{dK_B} \cdot (S_0 - K_B) - (1-p_I) \cdot p_{SL} - p_I \cdot \frac{\partial}{\partial K_B} \left[\int_0^{K_B} (K_B - s) f(s) ds \right] \right\} = 0 \quad (1.10)$$

And

$$N \cdot \left\{ (1-p_I) \cdot \frac{dp_{BL}}{dK_A} \cdot (K_A - S_0) + (1-p_I) \cdot p_{BL} - p_I \cdot \frac{\partial}{\partial K_A} \left[\int_{K_A}^{\infty} (s - K_A) f(s) ds \right] \right\} = 0 \quad (1.11)$$

It is easy to verify that the trade size is irrelevant with first order conditions equal to zero in Equation (1.10) and (1.11). Therefore, the liquidity provider offers horizontal bid curves and horizontal ask curves if the monopolistic liquidity provider is risk neutral.

(2) If the Market is Perfectly Competitive

If there is free entry, long-run expected revenues converge be zero and the long-run competitive equilibrium is established where the expected costs and revenues are equal. Thus, I derive Equation (1.12) and (1.13) from Equation (1.7) and replace the utility function by the linear function $U(x) = x$ in Equation (1.12) and (1.13).

$$N \cdot \left\{ (1-p_I) \cdot p_{SL}(S_0 - K_B) - p_I \cdot \int_0^{K_B} (K_B - s) f(s) ds \right\} = 0 \quad (1.12)$$

And

$$N \cdot \left\{ (1-p_I) \cdot p_{BL}(K_A - S_0) - p_I \cdot \int_{K_A}^{\infty} (s - K_A) f(s) ds \right\} = 0 \quad (1.13)$$

Similarly, it is easy to verify that the trade size *N* is irrelevant with the determination of K_B or K_A in Equation (1.12) and (1.13). Therefore, the risk neutral liquidity provider offers horizontal bid curves and horizontal ask curves when the market is perfectly competitive.

Proposition 1.2

Suppose there exists information asymmetry in the market,

(1) A risk averse liquidity provider offers a negatively-sloped bid curve and a positively-sloped ask curve in response to increasing trade size.

(2) Moreover, the bid curve is convex and the ask curve is concave if the liquidity provider is severely risk averse.

(1) If the Market is a Monopoly

Without loss of generosity, I assume that the liquidity provider has constant absolute risk averse (CARA) utility functions: $U(x) = 1 - e^{-Ax}$, where A is the coefficient of the risk aversion. Then I replace the utility function by the above CARA utility function into Equation (1.8) and Equation (1.9) and obtain the following Equation (1.14) and Equation (1.15)[3].

$$\begin{aligned}&(1-p_I)\cdot\frac{dp_{SL}}{dK_B}\cdot\left[-e^{-A[W_0+N(S_0-K_B)]}+e^{-AW_0}\right]-(1-p_I)\cdot p_{SL}\cdot N\cdot\left[Ae^{-A[W_0+N(S_0-K_B)]}\right]-\\&p_I\cdot A\cdot N\cdot e^{-AW_0+ANK_B}\cdot\int_0^{K_B}e^{-ANs}f(s)ds=0\end{aligned}\tag{1.14}$$

And

$$\begin{aligned}&(1-p_I)\cdot\frac{dp_{BL}}{dK_A}\cdot\left[-e^{-A[W_0+N(K_A-S_0)]}+e^{-AW_0}\right]+(1-p_I)\cdot p_{BL}\cdot N\cdot\left[Ae^{-A[W_0+N(K_A-S_0)]}\right]+\\&p_I ANe^{-AW_0-ANK_A}\int_{K_A}^{\infty}e^{ANs}f(s)ds=0\end{aligned}\tag{1.15}$$

Equation (1.14) and Equation (1.15) express the relationship between the trade size N and optimal bid or ask prices when the risk averse liquidity provider is a monopolist. Then, I do numerical analysis on Equation (1.14) and Equation (1.15) and analyze the results later.

---

[3] I show the detail proofs for deriving Equation (1.14) and (1.15) in the Appendix 1.A

(2) If the Market is Perfectly Competitive

If there is free entry, long-run expected utility gain is next to zero and the long-run competitive equilibrium is established where the expected utility gains and expected utility losses are equal. Hence, I obtain Equation (1.16) and Equation (1.17) from Equation (1.7) and replace the utility function by constant absolute risk averse (CARA) utility functions $U(x) = 1 - e^{-Ax}$ into Equation (1.16) and Equation (1.17).

$$(1 - p_I) \cdot p_{SL} \left\{ e^{-AW_0} - e^{-A[W_0 + N(S_0 - K_B)]} \right\} - p_I \cdot \left\langle \int_0^{K_B} \left\{ e^{-A[W_0 - N(K_B - s)]} - e^{-AW_0} \right\} f(s) ds \right\rangle = 0 \tag{1.16}$$

And

$$(1 - p_I) \cdot p_{BL} \left\{ e^{-AW_0} - e^{-A[W_0 + N(K_A - S_0)]} \right\} - p_I \cdot \left\langle \int_{K_A}^{\infty} \left\{ e^{-A[W_0 - N(s - K_A)]} - e^{-AW_0} \right\} f(s) ds \right\rangle = 0 \tag{1.17}$$

Equation (1.16) and (1.17) express the relationship between the trade size N and optimal bid or ask prices when the liquidity provider is risk averse and the market is perfectly competitive. Then, I perform numerical analysis on Equation (1.14), Equation (1.15), Equation (1.16) and Equation (1.17).

1.4.1 Numerical Analysis

I want to show that how a risk averse liquidity provider set optimal bid or ask prices when the market is a monopoly or perfectly competitive by numerical analysis on Equation (1.14), Equation (1.15), Equation (1.16) and Equation (1.17). Table 1.1 presents the values of the parameters that are applied to perform numerical analysis. Underlying price is assumed to be uniformed distributed with the range from 0 to 20. P_{SL} is assumed to be a linear function with respect to K_B, and P_{BL} is assumed to be a linear function with respect to K_A[4].

<Insert Table 1.1 here>

Table 1.2 reports optimal bid curves offered by a liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market; the results are derived from Equation (1.14) and Equation (1.16). I simulate four cases as liquidity provider's risk aversion coefficient *A* equals 0.067, 0.1, 0.2, and 0.25, respectively. Figure 1.1 contains graphs that are correspondent to the numerical results in Table 1.2. The results show that a liquidity provider with severe risk aversion offers larger bid spreads than a liquidity provider with less risk aversion given the same trade size. Moreover, a liquidity provider with severe risk aversion offers convex negatively-sloped bid curves in a perfectly competitive or monopolistic market.

<Insert Table 1.2 and Figure 1.1 here>

Table 1.3 reports optimal ask curves offered by a liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market; the results are derived from Equation (1.15) and Equation (1.17). Likewise, I simulate four cases as liquidity provider's risk aversion coefficient *A* equals 0.067, 0.1, 0.2, and 0.25, respectively. Figure 1.2 contains graphs that are correspondent to the results in Table 3. The results suggest that a liquidity provider with severe risk aversion offers larger ask spreads than a liquidity provider with less risk aversion given the same trade size. Moreover, a liquidity provider with severe risk aversion offers concave positively-sloped ask curves in a perfectly competitive or monopolistic market. Therefore, according to

[4] I also simulate the cases when P_{SL} and K_B, or P_{BL} and K_A, is assumed to be a concave function. I do not report those results here since the results are quite similar.

Table 1.2 and Table 1.3, we can conclude that *Proposition 1.2* holds.

<Insert Table 1.3 and Figure 1.2 here>

Proposition 1.3

Suppose there exists information asymmetry in the market. The optimal bid-ask spreads that a risk averse liquidity provider offers have the following characteristics:

(1) The bid-ask spreads in a monopolistic market are always larger than those in a perfectly competitive market given the same trade size.

(2) Moreover, the differences of the bid-ask spread between these two types of market decrease in trade size.

Table 1.4 reports the differences of optimal bid-ask spreads that a risk averse liquidity provider offers in a perfectly competitive and a monopolistic market. I simulate four cases as liquidity provider's risk aversion coefficient A equals 0.067, 0.1, 0.2, and 0.25, respectively. Figure 1.3 and Figure 1.4 contain graphs that illustrate optimal bid curves and ask curves that are offered by a liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market. The results suggest that given the same trader size, the liquidity provider with the same risk aversion coefficient offers a larger bid-ask spreads in a monopolistic market than the liquidity provider in a perfectly competitive market. Moreover, the bid-ask spreads between these two types of market narrow as trade size increases.

<Insert Table 1.4, Figure 1.3 and Figure 1.4 here>

Proposition 1.4

Suppose there exists NO information asymmetry in the market.

(1) If a monopolistic risk averse liquidity provider faces different trade size, he/she

offers a positively-sloped bid curves and negatively-sloped ask curves.

(2) Combined with Proposition 1.1, we can conclude that the simultaneous existence of the risk averse liquidity provider and market information asymmetry is the necessary condition that the liquidity provider offers negatively-sloped bid curves and positively-sloped ask curves.

Table 1.5 reports optimal bid and ask curves that a monopolistic liquidity provider offers in response to different levels of market information asymmetry. I simulate four cases as liquidity provider's risk aversion coefficient A equals 0.067, 0.1, 0.2, and 0.25, respectively. Figure 1.5 contains graphs that are correspondent to the results in Table 5. The results indicate that a risk averse liquidity provider offers a positively-sloped bid curves and negatively-sloped ask curves in a monopolistic market with no information asymmetry. Therefore, combined with *Proposition 1.1*, we can conclude that the simultaneous existence of the risk averse liquidity provider and market information asymmetry is the necessary condition that the liquidity provider offers negatively-sloped bid curves and positively-sloped ask curves.

<Insert Table 1.5 and Figure 1.5 here>

I do not consider the case when the market is perfectly competitive under information asymmetry. It is due to the reason that competition may cause long-run expected utility gains disappear and thus bid-ask spreads converge to zero. In addition, if the counterparty is all informed, there is no equilibrium in our model because every trade brings expected utility loss to the liquidity provider and thus Equation (1.14), Equation (1.15), Equation (1.16) and Equation (1.17) cannot be satisfied. Likewise, there is also no equilibrium in Copeland and Galai's (1983) original model as the counterparty is all informed traders.

1.5 Empirical Results

1.5.1 Description of Data and Methodology

I collect the intraday limit order book of Taiwan Index Futures from Taiwan Economic Journal (TEJ) database. The sample period is from January 4th to January 29st, 2010, including all 20 trading days in this month. Moreover, I include all the best five bids and best five offers from the nearby month contracts. Table 1.6 presents the summary statistics for the acquired sample. Panel A presents summary statistics regarding five best adjusted bids and asks[5] with accumulated volumes[6] on January 4th, 2010; Panel B and Panel C present summary statistics for adjusted bids and asks with accumulated volumes each trading day from January 4th to January 29th, 2010. On average, there are 0.3 million observations per trading day for bids or asks with accumulated volumes.

<Insert Table 1.6 here>

Following the methodology proposed by Gabaix et al (2002), adjusted bids (asks) and accumulated volumes are normalized to have zero mean and unit variance. Then, in order to show the relationships between adjusted bids (asks) and accumulated volume, I perform the following regression models for this purpose.

$$B_{n,i} = \beta_0 + \beta_1 V_{n,i} + e_i \tag{1.18}$$

$$A_{n,i} = \beta_0 + \beta_1 V_{n,i} + e_i \tag{1.19}$$

[5] The adjusted quotes are the differences between the original quotes and the middle prices, where the middle price is the mid-price of the best bid and the best ask at each time.

[6] Accumulated volume is the max volume that a trader can liquidate his/her position at a certain price. For example, the accumulated volume for the second best quote is the volume of the first best quote plus that of the second best quote.

$$B_{n,i} = b_0 + b_1 V_{n,i} + b_2 V_{n,i}^2 + e_i \tag{1.20}$$

$$A_{n,i} = b_0 + b_1 V_{n,i} + b_2 V_{n,i}^2 + e_i \tag{1.21}$$

Equation (1.18), Equation (1.19) are linear regression models and Equation (1.20), Equation (1.21) are quadratic models. B_n (A_n) is the normalized adjusted bids (asks) and V_n is the normalized accumulated volume.

1.5.2 Results on the Linear Model and the Quadratic Model

The results are shown is Table 1.7 and Table 1.8. Table 1.7 presents the results of adjusted bid prices and accumulated volumes per trading day on the linear regression model (Equation (1.18)) and the quadratic model (Equation (1.20)). Likewise, Table 1.8 presents the results of adjusted ask prices and accumulated volumes per trading day on the linear regression model (Equation (1.19)) and the quadratic model (Equation (1.21)). Empirical results in Table 1.7 show that β_1 is significantly negative in every linear regression model; b_1 is significantly negative and b_2 is significantly positive in every quadratic model, which implicates that bid curves are negatively-sloped and convex. Moreover, Table 1.8 show that β_1 is significantly positive in linear regression models; b_1 is significantly positive and b_2 is significantly negative in quadratic models, which implicates that ask curves are positively-sloped and concave. Furthermore, all of the parameters are significant at 1% significance level, and most of the R squares for each regression are large and stable[7]. These findings are consistent with the case when the liquidity provider is severe risk averse under information asymmetry.

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[7] The R square in the regression on Jan. 20th is relatively small due to the reason that it is the last trading day for nearby month contracts and many traders rollover their contracts on that day.

<Insert Table 1.7 and Table 1.8 here>

1.5.3 Empirical Results on the Hyperbolic Function tanh(x)

According to Gabaix et al (2002), I also run the regression on the following hyperbolic function tanh(x). Gabaix et al (2002) classify the trading volume as buyer-initiated or seller-initiated, and regard the buyer-initiated (seller-initiated) trading volume as positive (negative) volume imbalance at a certain time period. Following this idea, we may regard the bid (ask) volume as "potential" negative (positive) volume imbalance. The adjusted bids (asks) and trading volumes are normalized to have zero mean and unit variance.

$$Q_{n,i} = c_1 \tanh(c_2 V_{n,i}) + e_i = c_1 \left(\frac{e^{2c_2 V_{n,i}} - 1}{e^{2c_2 V_{n,i}} + 1} \right) + e_i \qquad (1.22)$$

Q_n is the normalized adjusted quote prices (bids or asks) and V_n is the normalized accumulated volume. Table 1.9 presents the results of adjusted bid prices and accumulated volumes per trading day on the hyperbolic regression model (Equation (1.22)). Empirical results show that c_1 and c_2 are significantly positive in every hyperbolic model. All of the parameters are significant at 1% significance level, and all of the R squares for every regression are above 0.9. This finding further shows that bid curves are negatively-sloped and convex and ask curves are positively-sloped and concave, which is consistent with the case when the liquidity provider is severe risk averse under information asymmetry.

<Insert Table 1.9 here>

1.6 Conclusion

In this paper, I extend Copeland and Galai's (1983) model and show that how a risk averse liquidity provider set optimal limit order book under information asymmetry. First of all, this paper shows that a risk neutral liquidity provider offers horizontal bid curves and a horizontal ask curves in response to different trade size, whether there exists information asymmetry or not in the market. Moreover, a severe risk averse liquidity provider offers convex negatively-sloped bid curves and concave positively-sloped ask curves in response to increasing trade size under information asymmetry. Furthermore, Combined *Proposition 1.1* with *Proposition 1.4,* we can conclude that the simultaneous existence of the risk averse liquidity provider and market information asymmetry is the necessary condition that the liquidity provider offers negatively-sloped bid curves and positively-sloped ask curves.

Empirical evidence from the limit order book of Taiwan Index Futures suggests that bid curves is negatively-sloped and convex, while ask curves are positively-sloped and concave. These findings are consistent with the numerical case when the liquidity provider is severe risk averse under information asymmetry, and thus supports the main proposition in this paper.

This paper has several new implications for the effects of inventory risk and asymmetric information. First, the liquidity provider's risk attitude may affect the shape of the bid-ask spread. If the liquidity provider is risk neutral, different trade size does not affect the bid-ask spread. However, if the liquidity provider is risk averse, increasing trade size enlarges bid-ask spreads, implicating that the inventory risk is correlated with liquidity provider's risk attitude. This finding is the same as Easley and O'Hara (1987), who show that trade size introduces an adverse selection problem into security trading because, given that traders wish to trade, informed traders prefer to trade larger amounts at any given price. Thus, market maker's pricing strategies must also depend on trade size, with large trades being made at less favorable prices. In addition, if there is no information asymmetry in the market, a risk averse liquidity provider sets narrower bid-ask spreads for increasing trade size. These implications show that inventory risk and asymmetric information is not mutually exclusive and is related to the liquidity provider's risk attitude.

Bibliography

Admati, A. R., and P. Pfleiderer, 1988, "A Theory of Intraday Patterns: Volume and Price Variability," *Review of Financial Studies*, 1, 3-40

Alfonsi, A., A. Fruth, and A. Schied, 2008, "Optimal Execution Strategies in Limit Order books with General Shape Functions," *Working Paper*

Amihud, Y., and H. Mendelson, 1980, "Dealership Market: Market Making with Inventory," *Journal of Financial Economics*, 8, 31-53

Bagehot, W., 1971, "The Only Game in Town," *Financial Analyst Journal*, 27, 31-53

Bangia, A., F. X. Diebold, T. Schuermann, and J. D. Stroughair, 1998, "Modeling Liquidity Risk: With Implications for Traditional Market Risk Measurement and Management," *Working Paper*

Bollen, N. P. B., T. Smith, and R. E. Whaley, 2004, "Modeling the Bid/Ask Spread: Measuring the Inventory-Holding Premium," *Journal of Financial Economics*, 72, 97-141

Bondarenko, O., 2001, "Competing Market Makers, Liquidity Provision, and Bid-Ask Spreads," *Journal of Financial Markets*, 4, 269-308

Chaput, J. S., and L. H. Ederington, 2002, "Option Spread and Combination Trading," *Working Paper*

Chen, C. M., 2005, "Security Market Microstructure," *Handout at National Taiwan University*

Chen, R. R., 2002, "Liquidity Quantification and Gamma Risk," *Working Paper*

Chen, R. R., and S. Chung, 2006, "An Option Theory of Bid-Ask Spread," *Working Paper*

Chung, K. H., H. Jo, and H. Shefrin, 2003, "Trading Volume, Information, and Trading Costs: Empirical Evidence," *Working Paper*

Copeland, T. E., and D. Galai, 1983, "Information Effects on the Bid-Ask Spread," *Journal of Finance*, 38, 1457-1469

Demsetz, H., 1968, "The Cost of Transacting," *Quarterly Journal of Economics*, 82, 33-53

Easley, D., and M. O'Hara, 1987, "Price, Trade Size, and Information in Securities Markets," *Journal of Financial Economics*, 19, 69-90

Easley, D., R. F. Engle, M. O'Hara, and L. Wu, 2008, "Time-Varying Arrival Rates of Informed and Uninformed Trades," *Journal of Financial Econometrics*, 171-207

Foucault, T., 1999, "Order Flow Composition and Trading Costs in a Dynamic Limit Order Market," *Journal of Financial Markets*, 2, 99-134

Gabaix, X., P. Gopikrishnan, V. Plerou, and H. E. Stanley, 2002, "Quantifying Stock Price Response to Demand Fluctuations," *Physical Review E*, 66, 027104

Gabaix, X., P. Gopikrishnan, V. Plerou, and H. E. Stanley, 2003, "A Theory of Power Law Distributions in Financial Market Fluctuations," *Nature*, 423, 267-270

Garman, M., 1976, "Market Microstructure," *Journal of Financial Economics*, 3, 257-275

Glosten, L. R., and P. R. Milgrom, 1985, "Bid, Ask and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics*, 14, 71-100

Glosten, L. R., and L. E. Harris, 1988, "Estimating the Components of the Bid-Ask Spread," *Journal of Financial Economics*, 21, 123-142

Handa, P., and R. Schwartz, and A. Tiwari, 2003, "Quote Setting and Price Formation in an Order Driven Market," *Journal of Financial Market*, 6, 461-489

Harris, M., and D. Kreps, 1978, "Speculative Investor Behavior in a Stock Market with Heterogeneous Expectations," *Quarterly Journal of Economics*, 92, 323-336

Hasbrouck, J., 1999, "The Dynamics of Discrete Bid and Ask Quotes," *Journal of Finance*, 54, 2109-2142

Hasbrouck, J., and D. J. Seppi, 2001, "Common Factors in Prices, Order Flows, and Liquidity," *Journal of Financial Economics*, 59, 383-411

He, Z., and W. Xiong, 2009, "Liquidity and Short-Term Debt Crises," *Working Paper*

Heston, S. L., R. A. Korajczyk, and R. Sadka, 2010, "Intraday Patterns in the Cross-Section of Stock Returns," *Working Paper*

Ho, T., and H. R. Stoll, 1981, "Optimal Dealer Pricing under Transactions and Return Uncertainty," *Journal of Financial Economics*, 9, 47-73

Ho, T., and H. R. Stoll, 1983, "The Dynamics of Dealer Markets under Competition," *Journal of Finance*, 38, 1053-1074

Holden, C., and A. Subrahmanyam, 1992, "Long-lived Private Information and

Imperfect Competition," *Journal of Finance*, 47, 247-270

Kreps, D., 1977, "A Note on Fulfilled Expectations Equilibria," *Journal of Economic Theory*, 14, 32-43

Kyle, A. S., 1984, "Market Structure, Information, Futures Markets, and Price Formation," *International Agricultural Trade: Advanced Readings in Price Formation, Market Structure, and Price Instability,* Boulder and London, Westview Press, 45-64

Kyle, A. S., 1985, "Continuous Auctions and Insider Trading," *Econometrica*, 53, 1315-1335

Kyle, A. S., and J. L. Vila, 1991, "Noise Trading and Takeover," *Rand Journal of Economics*, 22, 54-71

Kyle, A. S., and F. K. Wang, 1997, "Speculation Duopoly with Agreement to Disagree: Can Overconfidnece Survive the Market Test?" *Journal of Finance*, 52, 2073-2090

Leland, H., 1998, "Agency Costs, Risk Management, and Capital Structure," *Journal of Finance*, 53, 1213-1243

Lippman, S., and J.J. McCall, 1986, "An Operational Measure of Liquidity," *The American Economic Review*, 76, 43-55

Loderer, C. and L. Roth, 2005, "The Pricing Discount for Limited Liquidity: Evidence from SWX Swiss Exchange and the Nasdaq," *Journal of Empirical Finance*, 12, 239-268

Mercorelli, L. R., D. Michayluk, and A. D. Hall, 2008, "Modeling Adverse Selection on Electronic Order-Driven Markets," *Working Paper*

Morris, S., 1996, "Speculative Investor Behavior and Learning," *Quarterly Journal of Economics*, 111, 1111-1133

Obizhaeva, A. and J. Wang, 2006, "Optimal Trading Strategy and Demand/Supply Dynamics," *Working Paper*

Pasquariello, P., 2000, "The Microstructure of Currency Markets: an Empirical Model of Intraday Return and Bid-Ask Spread Behavior," *Working Paper*

Schwartz, R. A., 2010, "Micro Markets: A Market Structure Approach to Microeconomic Analysis," *John Wiley & Sons*

Schwartz, R. A., G. Sipress and B. Weber, 2010, "Mastering the Art of Equity Trading Through Simulation: The TraderEx Course," *John Wiley & Sons*

Serednyakov, A., 2005, “A Model of the Components of the Bid-Ask Spread,” *Working Paper*

Spiegel, M., 2008, “Patterns in Cross Market Liquidity,” *Finance Research Letters*, 5, 2-10

Spiegel, M., and A. Subrahmanyam, 1992, “Informed Speculation and Hedging in a Noncompetitive Securities Market,” *Review of Financial Studies*, 5, 307-330

Stoll, H. R., 1978, “The Supply of Dealer Services in Securities Markets,” *Journal of Finance*, 33, 1133-1151

Stoll, H. R., 2003, “Market Microstructure,” *Handbook of the Economics of Finance*, 555-600

Theissen, E., 2000, “Market Structure, Informational Efficiency and Liquidity : An Experimental Comparison of Auction and Dealer Markets,” *Journal of Financial Markets*, 3, 333-363

Varian, H., 1985, “Divergence of Opinion in Complete Markets: A Note,” *Journal of Finance*, 40, 309-317

Varian, H., 1986, “Difference of Opinion and Volume of Trade,” *University of Michigan*

Vayanos, D., and J. Wang, 2009, “Liquidity and Asset Pricing: A Unified Framework,” *Working Paper*

Wald, J. K., and H. T. Horrigan, 2005, “Optimal Limit Order Choice,” *Journal of Business*, 78, 597-618

Wang, J., 1993, “A Model of Intertemporal Asset Prices under Asymmetric Information,” *Reviews of Economic Studies*, 60, 249-282

Wang, J., 1994, “A Model of Competitive Stock Trading Volume,” *Journal of Political Economy*, 102, 127-168

Appendix 1.A

1.

$$\frac{d}{dK_B}\int_0^{K_B}\left\{U\left[W_0\right]-U\left[W_0-N(K_B-s)\right]\right\}f(s)ds$$
$$=\frac{d}{dK_B}\int_0^{K_B}\left[1-e^{-AW_0}\right]f(s)ds-\frac{d}{dK_B}\int_0^{K_B}\left[1-e^{-A[W_0-N(K_B-s)]}\right]f(s)ds$$
$$=\frac{d}{dK_B}\left[\int_0^{K_B}f(s)ds-\int_0^{K_B}e^{-AW_0}f(s)ds\right]-\frac{d}{dK_B}\left[\int_0^{K_B}f(s)ds-\int_0^{K_B}e^{-AW_0+AN(K_B-s)}f(s)ds\right]$$
$$=-\frac{d}{dK_B}\left[\int_0^{K_B}e^{-AW_0}f(s)ds\right]+\frac{d}{dK_B}\left[e^{-AW_0+ANK_B}\cdot\int_0^{K_B}e^{-ANs}f(s)ds\right]$$
$$=-e^{-AW_0}f(K_B)+\left[AN\cdot e^{-AW_0+ANK_B}\cdot\int_0^{K_B}e^{-ANs}f(s)ds+e^{-AW_0+ANK_B}e^{-ANK_B}f(K_B)\right]$$
$$=-e^{-AW_0}f(K_B)+\left[AN\cdot e^{-AW_0+ANK_B}\cdot\int_0^{K_B}e^{-ANs}f(s)ds+e^{-AW_0}f(K_B)\right]$$
$$=AN\cdot e^{-AW_0+ANK_B}\cdot\int_0^{K_B}e^{-ANs}f(s)ds$$

2.

$$\frac{d}{dK_A}\int_{K_A}^{\infty}\left\{U\left[W_0\right]-U\left[W_0-N(s-K_A)\right]\right\}f(s)ds$$
$$=\frac{d}{dK_A}\int_{K_A}^{\infty}\left[1-e^{-AW_0}\right]f(s)ds-\frac{d}{dK_A}\int_{K_A}^{\infty}\left[1-e^{-A[W_0-N(s-K_A)]}\right]f(s)ds$$
$$=\frac{d}{dK_A}\left[\int_{K_A}^{\infty}f(s)ds-\int_{K_A}^{\infty}e^{-AW_0}f(s)ds\right]-\frac{d}{dK_A}\left[\int_{K_A}^{\infty}f(s)ds-\int_{K_A}^{\infty}e^{-AW_0+AN(s-K_A)}f(s)ds\right]$$
$$=-\frac{d}{dK_A}\left[\int_{K_A}^{\infty}e^{-AW_0}f(s)ds\right]+\frac{d}{dK_A}\left[e^{-AW_0-ANK_A}\cdot\int_{K_A}^{\infty}e^{ANs}f(s)ds\right]$$
$$=e^{-AW_0}f(K_A)+\left[-AN\cdot e^{-AW_0-ANK_A}\cdot\int_{K_A}^{\infty}e^{ANs}f(s)ds-e^{-AW_0-ANK_A}e^{ANK_A}f(K_A)\right]$$
$$=e^{-AW_0}f(K_B)-\left[AN\cdot e^{-AW_0-ANK_A}\cdot\int_{K_A}^{\infty}e^{ANs}f(s)ds+e^{-AW_0}f(K_A)\right]$$
$$=-AN\cdot e^{-AW_0-ANK_A}\cdot\int_{K_A}^{\infty}e^{ANs}f(s)ds$$

Table 1.1

For the purpose of simulation, Table 1.1 list the value of the parameters in Equation (1.14), (1.15), (1.16), and (1.17). Stock price is assumed to be uniform distributed with the range from 0 to 20. For simplicity, I assume P_{SL} is a linear function with respect to K_B, and P_{BL} is a linear function with respect to K_A [8], as stated below.

Parameter	Value	Parameter	Value
P_I	0.2	W_0	30
S_0	10	A [9]	0.067, 0.1, 0.2, 0.25
$s \sim U[0,20]$			
Linear Function: $P_{SL} = \frac{1}{20} \cdot K_B$, $P_{SL} \in [0,1]$ $P_{BL} = 1 - \frac{1}{20} \cdot K_A$, $P_{BL} \in [0,1]$			

[8] I also simulate the cases as the relationship between P_{SL} and K_B, or P_{BL} and K_A, is a concave quadratic function or concave exponential function. The results are quite similar so I do not report them here.

[9] I simulate four cases with different *A* that equals 0.067, 0.1, 0.2, and 0.25, respectively.

Table 1.2

Table 1.2 reports optimal bid curves that a risk averse liquidity provider offers in a monopoly or a perfectly competitive market, which are derived from Equation (1.14) and Equation (1.16). I denote K_B^{α}, K_B^{β}, K_B^{γ} and K_B^{*} as optimal bid prices in a perfectly competitive market when the risk averse coefficient A equals 0.067, 0.1, 0.2, 0.25, respectively. Similarly, I denote $K_B^{\alpha m}$, $K_B^{\beta m}$, $K_B^{\gamma m}$ and K_B^{*m} as optimal bid prices in a monopolistic market when the risk averse coefficient A equals 0.067, 0.1, 0.2, 0.25, respectively. The values of the other parameters in Equation (1.14) and Equation (1.16) are listed in Table 1.1.

	The Market is Perfectly Competitive				The Market is a Monopoly			
N	K_B^{α}	K_B^{β}	K_B^{γ}	K_B^{*}	$K_B^{\alpha m}$	$K_B^{\beta m}$	$K_B^{\gamma m}$	K_B^{*m}
1	8.621	8.456	7.818	7.415	4.59	4.617	4.508	4.35
2	8.268	7.818	6.011	5.114	4.613	4.508	3.612	3.086
3	7.818	6.967	4.368	3.535	4.508	4.135	2.64	2.138
4	7.27	6.011	3.319	2.66	4.284	3.612	2.007	1.609
5	6.651	5.114	2.66	2.128	3.969	3.086	1.609	1.288
6	6.011	4.368	2.216	1.774	3.612	2.64	1.341	1.073
7	5.398	3.779	1.9	1.52	3.255	2.286	1.15	0.92
8	4.847	3.319	1.663	1.33	2.927	2.007	1.006	0.805
9	4.368	2.954	1.478	1.182	2.64	1.787	0.894	0.715
10	3.96	2.66	1.33	1.064	2.394	1.609	0.805	0.644

Table 1.3

Table 1.3 reports optimal ask curves that a risk averse liquidity provider offers in a monopoly or a perfectly competitive market, which are derived from Equation (1.15) and Equation (1.17). I denote K_A^{α}, K_A^{β}, K_A^{γ} and K_A^{*} as optimal ask prices in a perfectly competitive market when the risk averse coefficient A equals 0.067, 0.1, 0.2, 0.25, respectively. Similarly, I denote $K_A^{\alpha m}$, $K_A^{\beta m}$, $K_A^{\gamma m}$ and K_A^{*m} as optimal ask prices in a monopolistic market when the risk averse coefficient A equals 0.067, 0.1, 0.2, 0.25, respectively. The values of the other parameters in Equation (1.15) and Equation (1.17) are listed in Table 1.1.

	The Market is Perfectly Competitive				The Market is a Monopoly			
N	K_A^{α}	K_A^{β}	K_A^{γ}	K_A^{*}	$K_A^{\alpha m}$	$K_A^{\beta m}$	$K_A^{\gamma m}$	K_A^{*m}
1	11.379	11.544	12.182	12.585	15.41	15.383	15.492	15.65
2	11.732	12.182	13.989	14.886	15.387	15.492	16.388	16.914
3	12.182	13.033	15.632	16.465	15.492	15.865	17.36	17.862
4	12.73	13.989	16.681	17.34	15.716	16.388	17.993	18.391
5	13.349	14.886	17.34	17.872	16.031	16.914	18.391	18.712
6	13.989	15.632	17.784	18.226	16.388	17.36	18.659	18.927
7	14.602	16.221	18.1	18.48	16.745	17.714	18.85	19.08
8	15.153	16.681	18.337	18.67	17.073	17.993	18.994	19.195
9	15.632	17.046	18.522	18.818	17.36	18.213	19.106	19.285
10	16.04	17.34	18.67	18.936	17.605	18.391	19.195	19.356

Table 1.4

Table 1.4 reports the differences of optimal bid-ask spreads that a risk averse liquidity provider offers in a perfectly competitive and a monopolistic market. I simulate four cases as liquidity provider's risk aversion coefficient A equals 0.067, 0.1, 0.2, and 0.25, respectively. Simulations show that bid-ask spreads in a monopolistic market are always larger than those in a perfectly competitive market, given the same trade size. Moreover, the differences of bid-ask spreads in these two types of market will decline as trade size increases.

The Case as Liquidity Provider's Risk Aversion Coefficient A Equals 0.067							
	The Market is Perfectly Competitive			The Market is a Monopoly			Diff of B-A Spreads (#) – (*)
Trade Size	K_B^{α}	K_A^{α}	$K_A^{\alpha} - K_B^{\alpha}$ (*)	$K_B^{\alpha m}$	$K_A^{\alpha m}$	$K_A^{\alpha m} - K_B^{\alpha m}$ (#)	
1	8.621	11.379	2.758	4.59	15.41	10.82	8.062
2	8.268	11.732	3.464	4.613	15.387	10.774	7.31
3	7.818	12.182	4.364	4.508	15.492	10.984	6.62
4	7.27	12.73	5.46	4.284	15.716	11.432	5.972
5	6.651	13.349	6.698	3.969	16.031	12.062	5.364
6	6.011	13.989	7.978	3.612	16.388	12.776	4.798
7	5.398	14.602	9.204	3.255	16.745	13.49	4.286
8	4.847	15.153	10.306	2.927	17.073	14.146	3.84
9	4.368	15.632	11.264	2.64	17.36	14.72	3.456
10	3.96	16.04	12.08	2.394	17.605	15.211	3.131

The Case as Liquidity Provider's Risk Aversion Coefficient A Equals 0.1							
	The Market is Perfectly Competitive			The Market is a Monopoly			Diff of B-A Spreads (#) – (*)
Trade Size	K_B^{β}	K_A^{β}	$K_A^{\beta} - K_B^{\beta}$ (*)	$K_B^{\beta m}$	$K_A^{\beta m}$	$K_A^{\beta m} - K_B^{\beta m}$ (#)	
1	8.456	11.544	3.088	4.617	15.383	10.766	7.678
2	7.818	12.182	4.364	4.508	15.492	10.984	6.62
3	6.967	13.033	6.066	4.135	15.865	11.73	5.664
4	6.011	13.989	7.978	3.612	16.388	12.776	4.798
5	5.114	14.886	9.772	3.086	16.914	13.828	4.056
6	4.368	15.632	11.264	2.64	17.36	14.72	3.456
7	3.779	16.221	12.442	2.286	17.714	15.428	2.986
8	3.319	16.681	13.362	2.007	17.993	15.986	2.624
9	2.954	17.046	14.092	1.787	18.213	16.426	2.334
10	2.66	17.34	14.68	1.609	18.391	16.782	2.102

The Case as Liquidity Provider's Risk Aversion Coefficient *A* Equals 0.2							
	The Market is Perfectly Competitive			The Market is a Monopoly			Diff of B-A Spreads (#) – (*)
Trade Size	K_B^γ	K_A^γ	$K_A^\gamma - K_B^\gamma$ (*)	$K_B^{\gamma m}$	$K_A^{\gamma m}$	$K_A^{\gamma m} - K_B^{\gamma m}$ (#)	
1	7.818	12.182	4.364	4.508	15.492	10.984	6.62
2	6.011	13.989	7.978	3.612	16.388	12.776	4.798
3	4.368	15.632	11.264	2.64	17.36	14.72	3.456
4	3.319	16.681	13.362	2.007	17.993	15.986	2.624
5	2.66	17.34	14.68	1.609	18.391	16.782	2.102
6	2.216	17.784	15.568	1.341	18.659	17.318	1.75
7	1.9	18.1	16.2	1.15	18.85	17.7	1.5
8	1.663	18.337	16.674	1.006	18.994	17.988	1.314
9	1.478	18.522	17.044	0.894	19.106	18.212	1.168
10	1.33	18.67	17.34	0.805	19.195	18.39	1.05

The Case as Liquidity Provider's Risk Aversion Coefficient *A* Equals 0.25							
	The Market is Perfectly Competitive			The Market is a Monopoly			Diff of B-A Spreads (#) – (@)
Trade Size	K_B^*	K_A^*	$K_A^* - K_B^*$ (@)	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$ (#)	
1	7.415	12.585	5.17	4.35	15.65	11.3	6.13
2	5.114	14.886	9.772	3.086	16.914	13.828	4.056
3	3.535	16.465	12.93	2.138	17.862	15.724	2.794
4	2.66	17.34	14.68	1.609	18.391	16.782	2.102
5	2.128	17.872	15.744	1.288	18.712	17.424	1.68
6	1.774	18.226	16.452	1.073	18.927	17.854	1.402
7	1.52	18.48	16.96	0.92	19.08	18.16	1.2
8	1.33	18.67	17.34	0.805	19.195	18.39	1.05
9	1.182	18.818	17.636	0.715	19.285	18.57	0.934
10	1.064	18.936	17.872	0.644	19.356	18.712	0.84

Table 1.5

Table 1.5 reports optimal bid and ask curves that a monopolistic liquidity provider offers in response to different levels of market information asymmetry. The results suggest that a risk averse liquidity provider offers a positively-sloped bid curves and negatively-sloped ask curves in a monopolistic market with no information asymmetry, different from the cases when there is information asymmetry in a market.

The Case as Liquidity Provider's Risk Aversion Coefficient *A* Equals 0.067[10]						
	The Counterparty is Uninformed			The Counterparty is 1% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$
1	5.393	14.607	9.214	5.355	14.645	9.29
2	5.738	14.261	8.523	5.683	14.317	8.634
3	6.04	13.96	7.92	5.959	14.041	8.082
4	6.302	13.698	7.396	6.184	13.816	7.632
5	6.532	13.468	6.936	6.356	13.644	7.288
6	6.734	13.266	6.532	6.473	13.527	7.054
7	6.912	13.088	6.176	6.523	13.477	6.954
8	7.07	12.93	5.86	6.493	13.507	7.014
9	7.212	12.788	5.576	6.373	13.627	7.254
10	7.339	12.66	5.321	6.162	13.838	7.676
	The Counterparty is 10% Informed			The Counterparty is 30% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$
1	5.005	14.995	9.99	4.143	15.857	11.714
2	5.181	14.818	9.637	4.036	15.963	11.927
3	5.252	14.747	9.495	3.808	16.191	12.383
4	5.208	14.792	9.584	3.493	16.506	13.013
5	5.044	14.955	9.911	3.14	16.86	13.72
6	4.776	15.223	10.447	2.793	17.206	14.413
7	4.438	15.561	11.123	2.481	17.52	15.039
8	4.075	15.925	11.85	2.212	17.788	15.576
9	3.721	16.278	12.557	1.985	18.014	16.029
10	3.398	16.601	13.203	1.796	18.203	16.407

[10] The case as *A* equals 0.067 and the counterparty is 20% informed is reported in Table 1.2 and Table 1.3, so I do not report it here.

The Case as Liquidity Provider's Risk Aversion Coefficient *A* Equals 0.1[11]						
	The Counterparty is Uninformed			The Counterparty is 1% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$
1	5.571	14.429	8.858	5.526	14.474	8.948
2	6.04	13.96	7.92	5.959	14.041	8.082
3	6.421	13.579	7.158	6.277	13.723	7.446
4	6.734	13.266	6.532	6.473	13.527	7.054
5	6.993	13.007	6.014	6.519	13.481	6.962
6	7.212	12.788	5.576	6.373	13.627	7.254
7	7.398	12.602	5.204	6.027	13.973	7.946
8	7.559	12.441	4.882	5.549	14.451	8.902
9	7.699	12.301	4.602	5.044	14.956	9.912
10	7.823	12.177	4.354	4.58	15.42	10.84
	The Counterparty is 10% Informed			The Counterparty is 30% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$
1	5.106	14.894	9.788	4.106	15.894	11.788
2	5.253	14.747	9.494	3.808	16.192	12.384
3	5.141	14.859	9.718	3.318	16.682	13.364
4	4.776	15.224	10.448	2.793	17.207	14.414
5	4.258	15.742	11.484	2.341	17.659	15.318
6	3.722	16.278	12.556	1.986	18.014	16.028
7	3.252	16.748	13.496	1.713	18.287	16.574
8	2.866	17.134	14.268	1.503	18.497	16.994
9	2.554	17.446	14.892	1.337	18.663	17.326
10	2.301	17.699	15.398	1.204	18.796	17.592

The Case as Liquidity Provider's Risk Aversion Coefficient *A* Equals 0.2						
	The Counterparty is Uninformed			The Counterparty is 0.01% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$
1	6.04	13.96	7.92	6.039	13.961	7.922
2	6.734	13.266	6.532	6.731	13.269	6.538
3	7.212	12.788	5.576	7.202	12.798	5.596
4	7.559	12.441	4.882	7.514	12.486	4.972

[11] The case as *A* equals 0.1 and the counterparty is 20% informed is reported in Table 1.2 and Table 1.3, so I do not report it here.

5	7.822	12.178	4.356	7.619	12.381	4.762
6	8.03	11.97	3.94	7.284	12.716	5.432
7	8.197	11.803	3.606	6.521	13.479	6.958
8	8.336	11.664	3.328	5.749	14.251	8.502
9	8.452	11.548	3.096	5.116	14.884	9.768
10	8.551	11.449	2.898	4.605	15.395	10.79
	The Counterparty is 1% Informed			The Counterparty is 10% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$
1	5.959	14.041	8.082	5.253	14.747	9.494
2	6.473	13.527	7.054	4.777	15.223	10.446
3	6.373	13.627	7.254	3.722	16.278	12.556
4	5.549	14.451	8.902	2.866	17.134	14.268
5	4.58	15.42	10.84	2.301	17.699	15.398
6	3.835	16.165	12.33	1.919	18.081	16.162
7	3.289	16.711	13.422	1.645	18.355	16.71
8	2.878	17.122	14.244	1.439	18.561	17.122
9	2.558	17.442	14.884	1.279	18.721	17.442
10	2.303	17.697	15.394	1.151	18.849	17.698
	The Counterparty is 20% Informed			The Counterparty is 30% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$
1	12.384	12.384	12.384	12.384	12.384	12.384
2	14.414	14.414	14.414	14.414	14.414	14.414
3	16.028	16.028	16.028	16.028	16.028	16.028
4	16.994	16.994	16.994	16.994	16.994	16.994
5	17.592	17.592	17.592	17.592	17.592	17.592
6	17.994	17.994	17.994	17.994	17.994	17.994
7	18.28	18.28	18.28	18.28	18.28	18.28
8	18.496	18.496	18.496	18.496	18.496	18.496
9	18.662	18.662	18.662	18.662	18.662	18.662
10	18.796	18.796	18.796	18.796	18.796	18.796
The Case as Liquidity Provider’s Risk Aversion Coefficient A Equals 0.25						
	The Counterparty is Uninformed			The Counterparty is 0.0001% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m}-K_B^{*m}$
1	6.24	13.76	7.52	6.24	13.76	7.52

2	6.993	13.007	6.014	6.993	13.007	6.014
3	7.482	12.518	5.036	7.481	12.519	5.038
4	7.823	12.177	4.354	7.82	12.18	4.36
5	8.075	11.925	3.85	8.057	11.943	3.886
6	8.27	11.73	3.46	8.132	11.868	3.736
7	8.425	11.575	3.15	7.717	12.283	4.566
8	8.552	11.448	2.896	6.893	13.107	6.214
9	8.658	11.342	2.684	6.139	13.861	7.722
10	8.748	11.252	2.504	5.526	14.474	8.948
	The Counterparty is 0.01% Informed			The Counterparty is 1% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$
1	6.239	13.761	7.522	6.133	13.867	7.734
2	6.988	13.012	6.024	6.519	13.481	6.962
3	7.45	12.55	5.1	5.798	14.202	8.404
4	7.619	12.381	4.762	4.58	15.42	10.84
5	7.117	12.883	5.766	3.682	16.318	12.636
6	6.12	13.88	7.76	3.07	16.93	13.86
7	5.262	14.738	9.476	2.632	17.368	14.736
8	4.605	15.395	10.79	2.303	17.697	15.394
9	4.093	15.907	11.814	2.047	17.953	15.906
10	3.684	16.316	12.632	1.842	18.158	16.316
	The Counterparty is 10% Informed			The Counterparty is 30% Informed		
N	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$	K_B^{*m}	K_A^{*m}	$K_A^{*m} - K_B^{*m}$
1	5.23	14.77	9.54	3.578	16.422	12.844
2	4.258	15.742	11.484	2.341	17.659	15.318
3	3.048	16.952	13.904	1.602	18.398	16.796
4	2.301	17.699	15.398	1.204	18.796	17.592
5	1.842	18.158	16.316	0.963	19.037	18.074
6	1.535	18.465	16.93	0.803	19.197	18.394
7	1.316	18.684	17.368	0.688	19.312	18.624
8	1.151	18.849	17.698	0.602	19.398	18.796
9	1.023	18.977	17.954	0.535	19.465	18.93
10	0.921	19.079	18.158	0.482	19.518	19.036

Table 1.6

Table 1.6 reports summary statistics for the acquired data from limit order book of Taiwan Index Futures. Panel A presents summary statistics regarding five best adjusted bids and asks[12] with accumulated volume[13] on January 4th, 2010. Panel B and Panel C present summary statistics for adjusted bids and asks with accumulated volumes each trading day from January 4th to January 29th, 2010.

Panel A: Summary Statistics on Jan. 4th, 2010

	Adjusted Quote				Accumulated Volume			
	N	Mean	Median	STD	N	Mean	Median	STD
The Best Bid	57,632	-0.617	-0.5	0.239	57,632	13.341	9	15.015
The 2nd Bid	57,632	-1.623	-1.5	0.251	57,632	40.589	33	29.496
The 3rd Bid	57,632	-2.623	-2.5	0.253	57,632	75.323	66	41.637
The 4th Bid	57,632	-3.623	-3.5	0.254	57,632	114.344	104	54.375
The 5th Bid	57,632	-4.623	-4.5	0.255	57,632	155.974	145	65.824
All Bids	288,160	-2.622	-2.5	1.438	288,160	79.914	64	67.954
The Best Ask	57,632	0.617	0.5	0.239	57,632	13.76	9	16.285
The 2nd Ask	57,632	1.624	1.5	0.255	57,632	39.583	32	29.007
The 3rd Ask	57,632	2.625	2.5	0.256	57,632	72.902	63	41.095
The 4th Ask	57,632	3.625	3.5	0.256	57,632	110.0145	102	52.709
The 5th Ask	57,632	4.625	4.5	0.257	57,632	147.052	138	61.36
All Offers	288,160	2.623	2.5	1.439	288,160	76.662	62	64.423

Panel B: Summary Statistics for Bid Prices from Jan. 4th, 2010 to Jan. 29th, 2010

All Bids	Adjusted Bids				Accumulated Volume			
	N	Mean	Median	STD	N	Mean	Median	STD
Jan. 4th	288,160	-2.622	-2.5	1.438	288,160	79.914	64	67.954
Jan. 5th	306,865	-2.599	-2.5	1.434	306,865	81.237	68	65.549
Jan. 6th	312,265	-2.602	-2.5	1.434	312,265	81.933	67	69.025
Jan. 7th	310,425	-2.625	-2.5	1.44	310,425	75.848	63	62.6
Jan. 8th	303,675	-2.614	-2.5	1.436	303,675	76.458	62	65.903
Jan. 11th	297,645	-2.591	-2.5	1.437	297,645	77.921	60	71.144

[12] The adjusted quotes are the differences between the original quotes and the middle prices, where the middle price is the mid-price of the best bid and the best ask at each time.

[13] The accumulated volume is the max volume that a trader can liquidate his/her position at a certain price. For example, the accumulated volume for the second best quote is the volume of the first best quote plus that of the second best quote.

Jan. 12th	303,950	-2.604	-2.5	1.433	303,950	88.216	71	75.22
Jan. 13th	304,035	-2.612	-2.5	1.435	304,035	93.066	73	83.86
Jan. 14th	293,080	-2.571	-2.5	1.427	293,080	115.197	96	94.411
Jan. 15th	295,360	-2.576	-2.5	1.429	295,360	102.913	84	91.035
Jan. 18th	293,480	-2.577	-2.5	1.429	293,480	110.778	85	105.476
Jan. 19th	306,790	-2.608	-2.5	1.436	306,790	73.201	60	62.603
Jan. 20th	255,985	-2.623	-2.5	1.436	255,985	85.194	55	132.948
Jan. 21st	308,180	-2.604	-2.5	1.435	308,180	86.514	68	75.911
Jan. 22nd	311,135	-2.618	-2.5	1.439	311,135	77.716	60	77.614
Jan. 25th	297,425	-2.605	-2.5	1.434	297,425	77.494	58	75.497
Jan. 26th	313,400	-2.684	-2.5	1.454	313,400	57.629	46	49.743
Jan. 27th	305,885	-2.661	-2.5	1.448	305,885	60.973	50	51
Jan. 28th	311,265	-2.63	-2.5	1.441	311,265	73.858	59	64.257
Jan. 29th	313,970	-2.683	-2.5	1.46	313,970	58.323	47	50.819
Sum	6,032,975	2.616	-2,5	1.443	6,032,975	81.46	68	77.712

Panel C: Summary Statistics for Ask Prices from Jan. 4th, 2010 to Jan. 29th, 2010								
All Asks	Adjusted Asks				Accumulated Volume			
	N	Mean	Median	STD	N	Mean	Median	STD
Jan. 4th	288,160	2.623	2.5	1.439	288,160	76.662	62	64.423
Jan. 5th	306,865	2.6	2.5	1.435	306,865	84.17	68	71.71126
Jan. 6th	312,265	2.602	2.5	1.434	312,265	95.441	71	96.705
Jan. 7th	310,425	2.627	2.5	1.441	310,425	71.791	56	63.108
Jan. 8th	303,675	2.614	2.5	1.436	303,675	84.298	64	79.876
Jan. 11th	297,645	2.618	2.5	1.437	297,645	84.717	62	82.21
Jan. 12th	303,950	2.604	2.5	1.434	303,950	101.496	76	97.28
Jan. 13th	304,035	2.613	2.5	1.436	304,035	90.936	67	83.771
Jan. 14th	293,080	2.572	2.5	1.427	293,080	134.493	107	114.373
Jan. 15th	295,360	2.576	2.5	1.429	295,360	106.424	84	95.12
Jan. 18th	293,480	2.578	2.5	1.43	293,480	92.164	73	79.657
Jan. 19th	306,790	2.609	2.5	1.436	306,790	76.414	59	70.921
Jan. 20th	255,985	2.624	2.5	1.437	255,985	87.803	50	159.72
Jan. 21st	308,180	2.606	2.5	1.436	308,180	77.35	63	65.07
Jan. 22nd	311,135	2.618	2.5	1.439	311,135	81.999	65	70.766
Jan. 25th	297,425	2.606	2.5	1.435	297,425	77.238	59	72.127

Jan. 26th	313,400	2.686	2.5	1.456	313,400	57.875	45	52.346
Jan. 27th	305,885	2.663	2.5	1.45	305,885	62.332	50	54.41
Jan. 28th	311,265	2.629	2.5	1.441	311,265	78.397	60	75.554
Jan. 29th	313,970	2.683	2.5	1.458	313,970	59.62	46	62.896
Sum	6,032,975	2.618	2,5	1.439	6,032,975	83.837	64	84.674

Table 1.7

Table 1.7 presents the results of adjusted bid prices and accumulated volumes per trading day on the linear regression model (Equation (1.18)) and the quadratic model (Equation (1.20)). Following Gabaix et al (2002) techniques, adjusted bid prices and trading volumes are normalized to have zero mean and unit variance. Empirical results show that β_1 is significantly negative in every linear model; b_1 is significantly negative and b_2 is significantly positive in every quadratic model. These findings suggest that bid curves are negatively-sloped and convex, which is consistent with the case when the liquidity provider is severe risk averse under information asymmetry. '***' indicate statistical significance at 1%.

Empirical Results on Linear Regression Model and Quadratic Model						
All Bids	Linear Model		Nonlinear (Quadratic) Model			
	R Square	β_1	R Square	Const	b_1	b_2
Jan. 4th	0.543	-0.737***	0.675	-0.232***	-1.035***	0.232***
Jan. 5th	0.578	-0.761***	0.701	-0.205***	-1.018***	0.205***
Jan. 6th	0.534	-0.731***	0.662	-0.237***	-1.025***	0.237***
Jan. 7th	0.580	-0.762***	0.684	-0.199***	-0.994***	0.199***
Jan. 8th	0.538	-0.733***	0.677	-0.180***	-1.025***	0.180***
Jan. 11th	0.472	-0.687***	0.628	-0.226***	-1.054***	0.226***
Jan. 12th	0.536	-0.732***	0.667	-0.232***	-1.028***	0.232***
Jan. 13th	0.498	-0.706***	0.620	-0.170***	-0.987***	0.170***
Jan. 14th	0.571	-0.756***	0.717	-0.232***	-1.055***	0.232***
Jan. 15th	0.489	-0.699***	0.662	-0.193***	-1.068***	0.193***
Jan. 18th	0.387	-0.622***	0.553	-0.197***	-1.014***	0.197***
Jan. 19th	0.486	-0.697***	0.603	-0.146***	-0.952***	0.146***
Jan. 20th	0.109	-0.331***	0.312	-0.173***	-1.165***	0.173***
Jan. 21st	0.485	-0.697***	0.624	-0.222***	-1.013***	0.222***
Jan. 22nd	0.365	-0.604***	0.555	-0.142***	-1.025***	0.142***
Jan. 25th	0.389	-0.624***	0.536	-0.136***	-0.960***	0.136***
Jan. 26th	0.479	-0.692***	0.597	-0.175***	-0.962***	0.175***
Jan. 27th	0.511	-0.714***	0.637	-0.240***	-1.000***	0.240***
Jan. 28th	0.511	-0.715***	0.651	-0.232***	-1.036***	0.232***
Jan. 29th	0.464	-0.681***	0.599	-0.188***	-0.976***	0.188***

Table 1.8

Table 1.8 presents the results of adjusted ask prices and accumulated volumes per trading day on the linear regression model (Equation (1.19)) and the quadratic model (Equation (1.21)). Following Gabaix et al (2002) techniques, adjusted bid prices and trading volumes are normalized to have zero mean and unit variance. Empirical results show that β_1 is significantly positive in every linear model; b_1 is significantly positive and b_2 is significantly negative in every quadratic model. These findings suggest that bid curves are positively-sloped and concave, which is consistent with the case when the liquidity provider is severe risk averse under information asymmetry. '***' indicate statistical significance at 1%.

Empirical Results on Linear Regression Model and Quadratic Model						
All Asks	Linear Model		Nonlinear (Quadratic) Model			
	R Square	β_1	R Square	Const	b_1	b_2
Jan. 4th	0.532	0.729***	0.641	0.186***	0.969***	-0.186***
Jan. 5th	0.512	0.716***	0.637	0.211***	1.008***	-0.211***
Jan. 6th	0.365	0.604***	0.543	0.149***	1.017***	-0.149***
Jan. 7th	0.531	0.729***	0.659	0.207***	1.030***	-0.207***
Jan. 8th	0.450	0.671***	0.611	0.175***	1.038***	-0.175***
Jan. 11th	0.439	0.662***	0.591	0.232***	1.064***	-0.232***
Jan. 12th	0.459	0.678***	0.621	0.235***	1.085***	-0.235***
Jan. 13th	0.486	0.697***	0.593	0.172***	0.967***	-0.172***
Jan. 14th	0.561	0.749***	0.682	0.264***	1.050***	-0.264***
Jan. 15th	0.471	0.686***	0.632	0.194***	1.034***	-0.194***
Jan. 18th	0.515	0.717***	0.646	0.228***	1.033***	-0.228***
Jan. 19th	0.408	0.639***	0.578	0.214***	1.043***	-0.214***
Jan. 20th	0.076	0.275***	0.218	0.148***	1.037***	-0.148***
Jan. 21st	0.538	0.734***	0.653	0.211***	1.002***	-0.211***
Jan. 22nd	0.511	0.715***	0.636	0.240***	1.024***	-0.240***
Jan. 25th	0.433	0.658***	0.588	0.210***	1.046***	-0.210***
Jan. 26th	0.441	0.664***	0.566	0.167***	0.962***	-0.167***
Jan. 27th	0.487	0.698***	0.626	0.245***	1.027***	-0.245***
Jan. 28th	0.413	0.642***	0.567	0.154***	0.993***	-0.154***
Jan. 29th	0.330	0.574***	0.452	0.025***	0.810***	-0.025***

Table 1.9

Table 1.9 presents the results of adjusted bid/ask prices and accumulated volumes per trading day on the hyperbolic function tanh(x) (Equation (1.22)). Following Gabaix et al (2002) methodology, adjusted bid/ask prices and trading volumes are normalized to have zero mean and unit variance, and the bid volumes are regarded as "negative" volume imbalance. Empirical results show that c_1 and c_2 are significantly positive in every hyperbolic model. These findings further show that bid curves are negatively-sloped and convex and ask curves are positively-sloped and concave, which is consistent with the case when the liquidity provider is severe risk averse under information asymmetry. '***' indicate statistical significance at 1%.

Empirical Results on the Hyperbolic Function tanh(x)			
	The Hyperbolic Function tanh(x)		
	R Square	c_1	c_2
Jan. 4th	0.932	1.361***	1.465***
Jan. 5th	0.925	1.392***	1.348***
Jan. 6th	0.916	1.352***	1.606***
Jan. 7th	0.927	1.379***	1.426***
Jan. 8th	0.925	1.377***	1.502***
Jan. 11th	0.917	1.330***	1.754***
Jan. 12th	0.920	1.350***	1.610***
Jan. 13th	0.919	1.330***	1.703***
Jan. 14th	0.926	1.407***	1.321***
Jan. 15th	0.924	1.380***	1.457***
Jan. 18th	0.908	1.335***	1.618***
Jan. 19th	0.916	1.342***	1.574***
Jan. 20th	0.907	1.273***	3.525***
Jan. 21st	0.920	1.352***	1.513***
Jan. 22nd	0.918	1.338***	1.654***
Jan. 25th	0.916	1.328***	1.749***
Jan. 26th	0.913	1.320***	1.650***
Jan. 27th	0.918	1.327***	1.593***
Jan. 28th	0.921	1.338***	1.661***
Jan. 29th	0.915	1.317***	1.760***

Figure 1.1

Figure 1.1 contains graphs that illustrate optimal bid curves offered by the liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market. The results show that the liquidity provider with severe risk aversion offers larger bid spreads than the liquidity provider with less risk aversion given the same trade size. Moreover, the liquidity provider with severe risk aversion offers convex negatively-sloped bid curves in a perfectly competitive or monopolistic market.

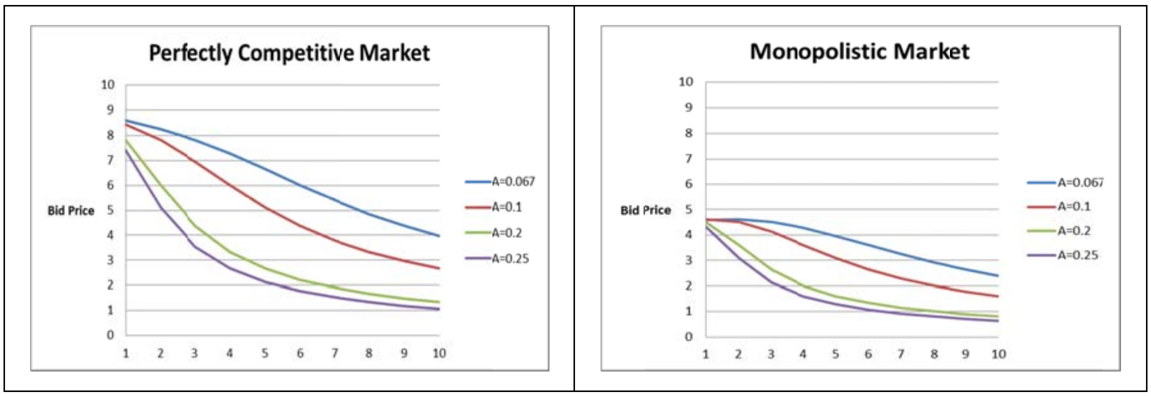


Figure 1.2

Figure 1.2 contains graphs that illustrate optimal ask curves offered by the liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market. The results show that the liquidity provider with severe risk aversion will offer larger ask spreads than the liquidity provider with less risk aversion given the same trade size. Moreover, the liquidity provider with severe risk aversion offers concave positively-sloped ask curves in a perfectly competitive or monopolistic market.

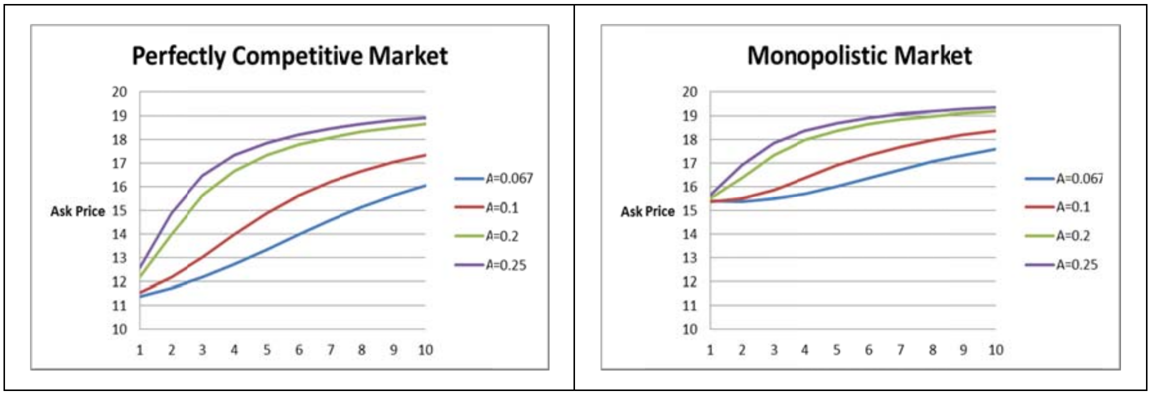


Figure 1.3

Figure 1.3 contains graphs that illustrate optimal bid curves offered by the liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market. The results suggest that given the same trade size, the liquidity provider with the same risk aversion coefficient offers a larger bid spread in a monopolistic market than the liquidity provider in a perfectly competitive market. The spreads between these two curves narrow in increasing trade size.

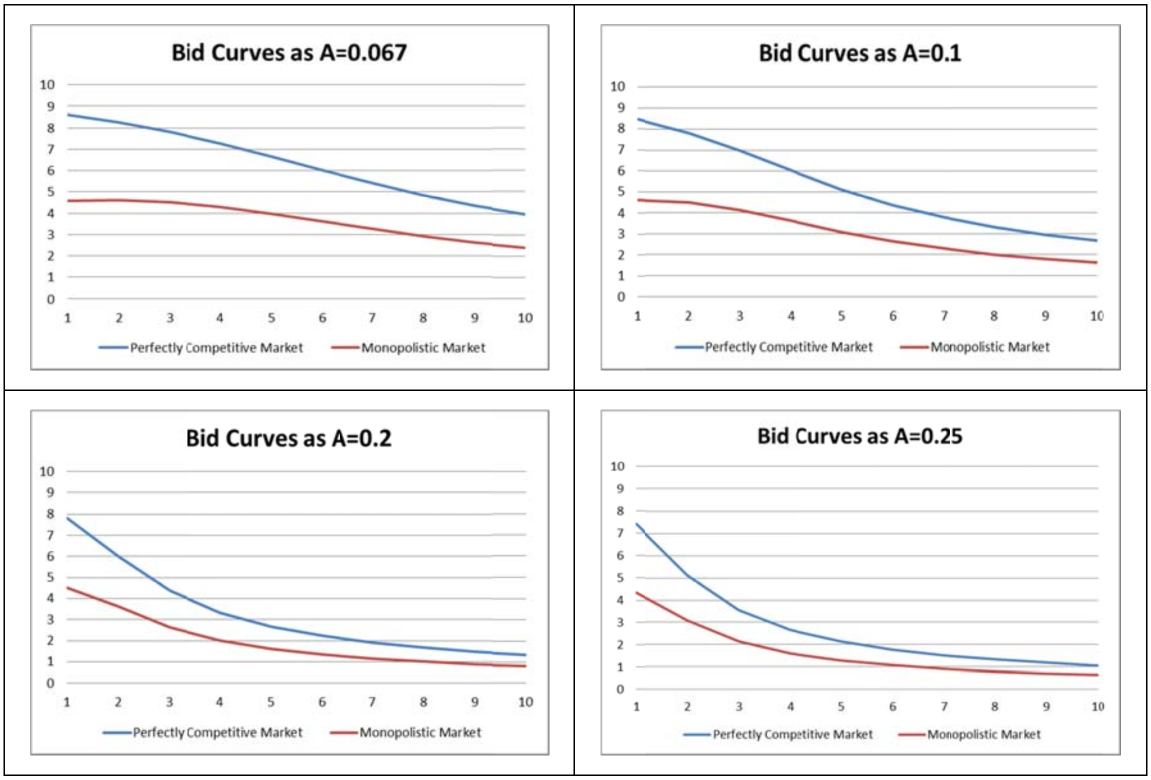


Figure 1.4

Figure 1.4 contains graphs that illustrate optimal ask curves offered by the liquidity provider with different risk aversion coefficients in a perfectly competitive or monopolistic market. The results indicate that given the same trade size, the liquidity provider with the same risk aversion coefficient offers a larger ask spread in a monopolistic market than the liquidity provider in a perfectly competitive market. The spreads between these two curves narrow in increasing trade size.

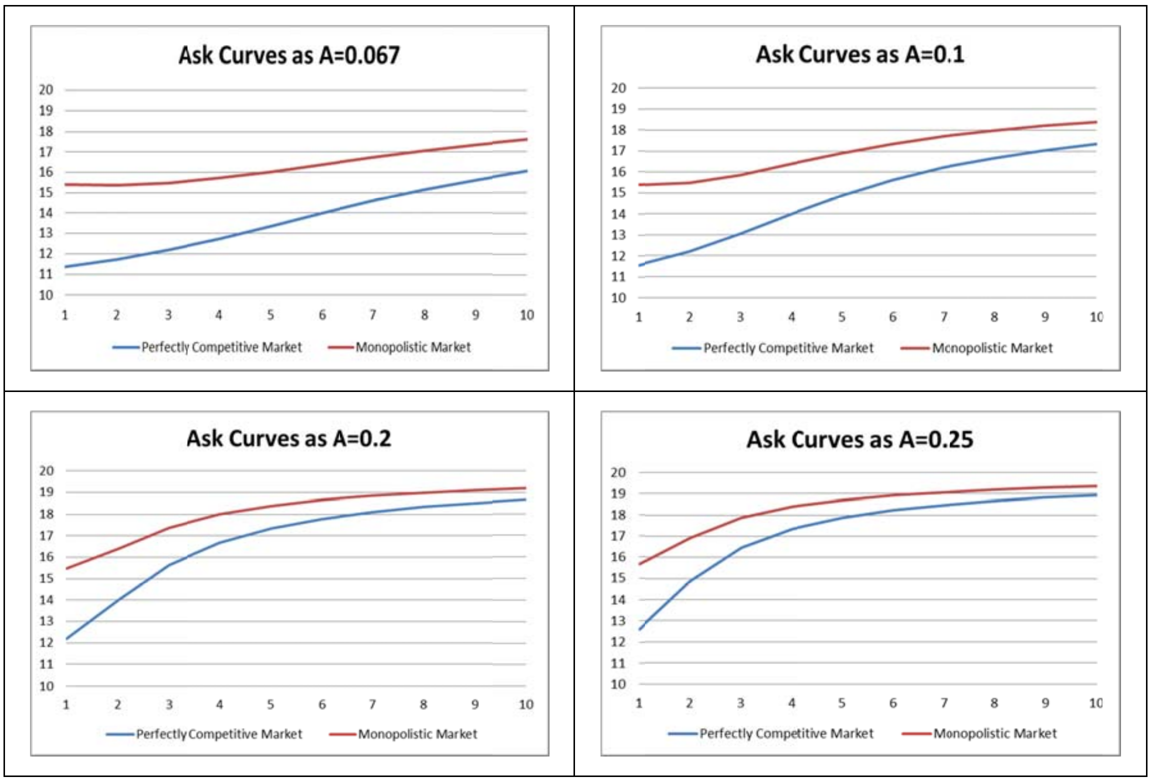
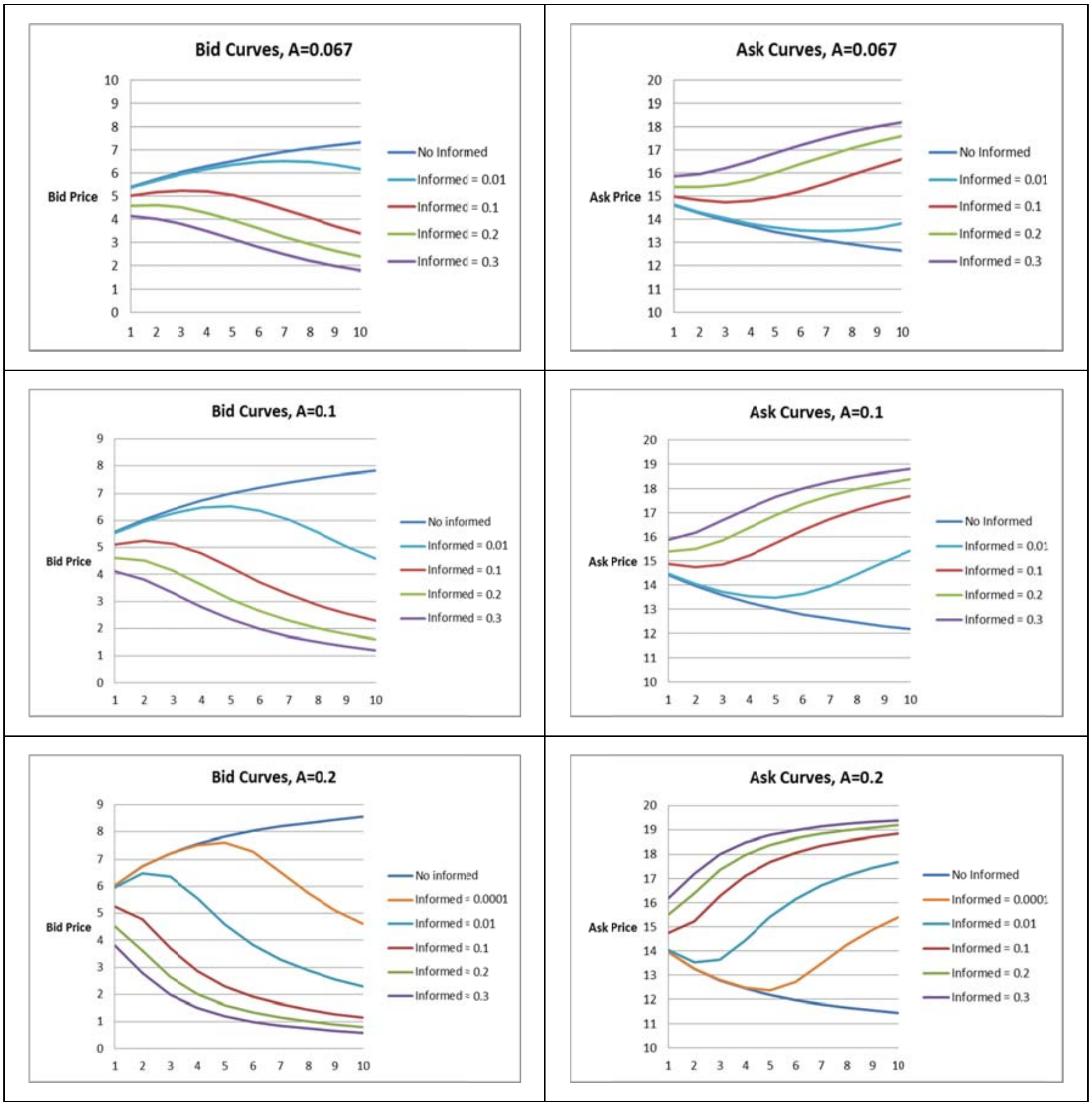
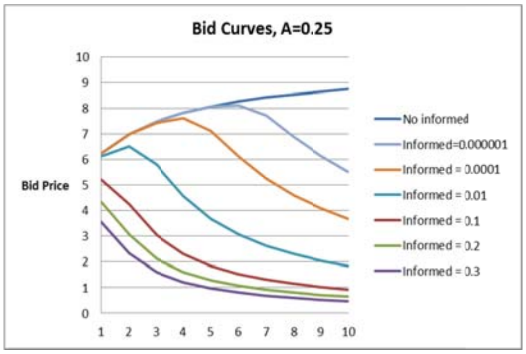
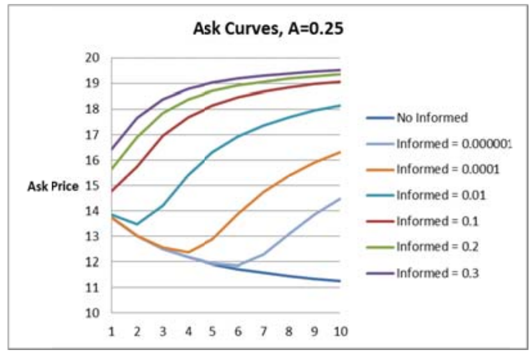


Figure 1.5

Figure 1.5 contains graphs that illustrate optimal bid and ask curves that a monopolistic liquidity provider offers in response to different levels of market information asymmetry. The results show that the risk averse liquidity provider offers a positively-sloped bid curves and negatively-sloped ask curves in a monopolistic market with no information asymmetry, different from the cases when there is information asymmetry in a market.




Bid Curves, A=0.25
Bid Price
No informed
Informed=0.000001
Informed = 0.0001
Informed = 0.01
Informed = 0.1
Informed = 0.2
Informed = 0.3


Ask Curves, A=0.25
Ask Price
No Informed
Informed = 0.000001
Informed = 0.0001
Informed = 0.01
Informed = 0.1
Informed = 0.2
Informed = 0.3

Essay II

Joint Responsibility Policy and Optimal Incentive Contracts

2.1 Introduction

Agency problems have been discussed extensively in the literature on corporate governance. Most issues on corporate governance deal with the ways in which suppliers of finance to corporations assure themselves of earning a return on their investment [Shleifer and Vishny (1997)]. Many researchers focus on how suppliers of finance control executives and make sure that executives do not steal the capital they supply or invest it in bad projects.

Shleifer and Vishny (1997) point out that the agency problem is an essential element of the so-called contractual view of the firm, developed by Coase (1937), Jensen and Meckling (1976), and Fama and Jensen (1983). The essence of the agency problem is the separation of ownership and control, and the agency problem arises when complete, contingent contracts are infeasible. When contracts are incomplete and managers possess more expertise than shareholders, managers typically end up with the residual rights of control, giving them incentives for self-interested behavior. In some cases, this results in managers taking highly inefficient actions, which cost investors far more than the personal benefits to the managers. For instance, the scandals like Enron or WorldCom cause capital markets vulnerable and investors have little confidence on firms' accounting information, and thus the U.S. Government releases The Sarbanes-Oxley Act of 2002, "Public Company Accounting Reform and Investor Protection Act and "Corporate and Auditing Accountability and Responsibility Act," to set a series standards for U.S. public firms' boards, management, and public accounting companies.

Previous studies suggest that a better solution is to grant a manager a highly contingent, long-term incentive contract ex-ante to align his interests with those of the shareholders [Shleifer and Vishny (1997)]. In this way, incentive contracts can induce the manager to act in investors' interest, although such contracts may be expensive if the personal benefits of control are high and there is a lower bound on the manager's compensation in the bad states of the world. Typically, to make such contract feasible, some measure of performance that is highly correlated with the quality of the manager's decision must be verifiable in court. In some cases, the credibility of an implicit threat or promise from the investors to take action based on an observable, but not verifiable, signal may also suffice. Incentive contracts can take a variety of forms, including share ownership, stock options, or a threat of dismissal if income is low [Jensen and Meckling (1976), Fama (1980)]. The optimal incentive contract is determined by the manager's risk aversion, the importance of his decisions, and his/her ability to pay for the cash flow ownership up front [Ross(1973), Stiglitz(1975), Mirrlees (1976), Holmstrom (1979)].

Shleifer and Vishny (1997) indicate that the more serious problem with high-powered incentive contracts is that they create enormous opportunities for self-dealing for the managers, especially if these contracts are negotiated with poorly-motivated boards of directors rather than with large investors. This is a typical two-tiered agency problem since boards of directors are also agents of large investors, and thus boards of directors and larger investors may also have interest conflicts. Scharfstein and Stein (2000) develop a two-tiered agency model to explain how the rent-seeking behavior on the part of division managers can subvert the workings of an internal capital market. In this paper, I propose another two-tiered agency model and want to figure out whether imposing Joint Responsibility between Agent_1 and Agent_2 is a good policy for Principal.

In this paper, the two-tiered agency model describes Principal-Agent relationships among three agents: Principal, Agent_1 and Agent_2. Principal employs Agent_1 as the administrator of the firm and employs Agent_2 as the employee to seek and implement firm's investment projects. Agent_2 has incentives to take on the high risky project that could bring destructive loss to the firm when the bad state of the project occurs. As the agent of Principal, Agent_1 takes responsibility of monitoring Agent_2's behavior and make sure Agent_2 not to take on the high risky project. However, Agents_1 and Agent_2 may collude, making the problem far more complicated than the one-tiered agency issue. Practically, we usually observe the situation that Principal may impose Joint Responsibility policy between Agent_1 and Agent_2. That is, Agent_1 is accused of not identifying in advance Agent_2 who takes on destructive risky projects. Principal believes that Joint Responsibility policy induces more Agent_1's monitoring, and thus mitigates the expected loss of the high risky project. In this paper, I take into account the collusion behavior of Agent_1 and Agent_2, and show that whether imposing Joint Responsibility between Agent_1 and Agent_2 is a good policy for Principal.

Take a general firm for example. There are three agents in a firm: a Shareholder (Principal), a Chief Executive Officer (Agent_1), and a Chief Financial Officer (Agent_2). The CFO has expertise in investing, but he/she has incentives to take on the high risky project[14] due to his/her limited liability. The shareholder employs a CEO to administer the firm and monitor the CFO's behavior. However, when the CEO identifies the CFO

[14] If risky projects always bring higher expected returns than safe projects, the problems I discuss do not exist. I assume that risky projects that the CFO takes on are inefficiently negative NPV projects.

who adopted the high risky project, the CEO may stop the high risky project immediately or let the high risky project go on if the CEO can exploit some rent from the CFO (Or, the CFO may bribe the CEO not to report his/her behavior to the shareholder and let the high risky project go on). Thus, the shareholder needs to design an incentive contract for the CEO ex ante that links CEO's interests with the shareholder's. The two-tiered agency model in this paper focuses on what is the optimal incentive contract for the CEO from the shareholder's perspective: an incentive contact within or without Joint Responsibility policy?

I discuss and compare two cases with different incentive contacts for Agent_1: Case_1 excludes Joint Responsibility while Case_2 includes it, and investigate which incentive contract brings more benefits to Principal. Case_1 illustrates that Principal offers bonus to Agent_1 both at Stage_1 and Stage_2 if Agent_1 catches the Agent_2 who takes on the high risky project at that stage. On the other hand, Case_2 illustrates that Principal offers bonus to Agent_1 at Stage_1 but not at Stage_2 if Agent_1 catches the Agent_2 who takes on the high risky project at that stage. I compare Agent_1's optimal monitoring and Principal's payoffs in these two cases, and figure out which incentive contract brings more benefits to Principal.

Since there are three agents in our model, I adopt backward inductions to solve the model as the finite extensive-form game. First, I find out what is the optimal monitoring for Agent_1 and the optimal probability that Agent_2 takes on the high risky project given any Agent_1's incentive contract. Then, I solve what the optimal incentive contract to Agent_1 should be from Principal's perspective. Moreover, I also investigate what factors are crucial for Principal to determine Agent_1's optimal incentive contracts. Thus, I do static comparative analyses on two exogenous variables in the model: the losses from the bad state of the high risky project L, and the parameter of the monitoring costs a.

Section 2.2 contains literature review on corporate governance. Section 2.3 contains a two-tiered agency model that describes the relationships among Principal, Agent_1, and Agent_2. Section 2.4 contains Case_1 that excludes Joint Responsibility, and Section 2.5 contains Case_2 that includes Joint Responsibility. Section 2.6 compares Case_1 and Case_2 and proposes several propositions. Section 2.7 concludes the paper and some proofs are shown in Appendix.

2.2 Literature Review

Corporate Governance is the essential academic issue and also the subject of enormous practical importance. According to Shleifer and Vishny (1997), the agency problem is one of the most factors that we should pay more attention on corporate governance. Generally, the financiers and the manager sign a contract that specifies what the manager does with the funds, and how the returns are allocated between the manager and the financiers. If they could sign a complete contract to specifies exactly what the manager does in all states of the world, and how the returns are divided, that would be no agency problem. However, the trouble is that most futures states are difficult to describe in advance and thus complete contracts are generally infeasible. Moreover, the manager and the financier need to allocate residual control rights, the rights to make decisions in states not fully foreseen by the contract. The theory of ownership handles the issues about how these residual rights are allocated efficiently.

Shleifer and Vishny (1997) indicate that there exists a contract which specifies that the financiers give funds to the manager but the financiers receive all the residual control rights. However, this kind of contract does not efficient since the financiers may not be qualified or informed to decide what to do. Consequently, the manager may be some residual rights and discretion to allocate funds. Although there may be limits on this discretion in the contract and much of corporate governance deals with these limits, managers practically have significant residual control rights.

Baumol (1959), Marris (1964), Williamson (1964), and Jensen (1986) describe how managers use their control rights to choose projects that benefit them rather than investors. The problem of management discretion arises since managers own control rights over how to allocate investors' funds. Managers might take the money out, or transfer the money to other firms which they own. For example, managers might sell the output or the assets to other manager-owned companies at below market prices. The Economist in June 1995 reports that Korean enterprise groups sometimes sell their subsidiaries to the relatives of the companies at lower market prices. Moreover, greater costs are incurred if managers have interests in expanding the company, overinvesting the free cash flow, and pursuing negative NPV projects. Grossman and Hart (1988) explain these benefits as private benefits of control as well.

According to Grossman and Hart (1986), managerial discretion usually reduces the resources that investors are willing to put up to finance the firm. Thus, most of the issues on corporate governance handle constraints that managers transfer funds on themselves to decrease the misallocation and thus the investors are willing to invest more funds ex ante to the firm. However, even with these constraints, the outcome is usually less efficient than the case when the managers finance the firm with their own money.

Jensen and Meckling (1976) argue that the manager has incentives to undertake inefficient projects, and thus investors may want to bribe the manager not to undertake those inefficient projects. Walkling and Long (1984), Lambert and Larcker (1985) indicate that we may observe these bribes in practice, such as golden parachutes that induce managers to accept hostile takeover bids. However, in most cases, investors do not pay managers for individual actions and it does not result in efficient outcomes. Empirically, Jensen and Meckling's (1976) prediction is correct and Coase's (1960) argument that investors would bribe the manager does not usually happen. This may be because it is difficult to let numerous investors agree to bribe the manager.

Another reason why we do not observe the case that the manager threatens shareholders and is bribed not to take inefficient projects is that those threats violate the managers' "duty of loyalty" to shareholders. Clark (1985) indicates that it is difficult to describe what this duty obligates the manager to do, but it is obvious that those threats to take value-destroying projects unless managers is bribed is definitely violate "duty of loyalty" to investors. Although this legal duty prevents efficient bargaining between managers and investors, the reason for the duty of loyalty is to avoid the situation where managers constantly threaten shareholders to take inefficient actions unless managers are bribed, especially in the states that are not specified in the contract. Similarly, Shleifer and Vishny (1993) explain why corruption is illegal even if corruption may improve the resource allocation. They suggest that since corruption is prohibited, not all efficient bargains are realized. With the same token, if the duty of loyalty to investors prevents managers from being bribed for not taking self-interested actions, such kind of actions will be taken even if those actions benefit managers less than actions cost investors.

Shleifer and Vishny (1997) suggest that a better solution to the agency problem is to give a manager a highly contingent incentive contract to link his/her interests with investors'. Though such kinds of contracts cost a lot if private benefits of control are high. Generally, in these contracts, measures of performance which is highly correlated with the quality of manager's actions can be verifiable, not only observable. In practice, firms usually pay attention to the design of incentive contracts. Berle and Means (1932) argue that management ownership in large firms is too small to make managers interested in maximizing firm's value. Besides, Murphy (1985), Coughlan and Schmidt (1985), Benston (1985) suggest that pay to managers and firm's performance is positively correlated. Moreover, Jensen and Murphy (1990) investigate the sensitivity of pay of American executives to performance, including executive's salary, bonuses, and stock options. Jensen and Murphy's (1990) finding support Berle and Means' (1932) argument that pay to managers are relatively small compared to firm's revenue.

Yermack (1997) shows that managers tend to receive stock options before good news announcements and delay stock options after bad news announcements, which indicates that one of the serious problems with incentive contracts is that there exist opportunities for self-dealing for the managers, when the contracts are negotiated with boards that are poorly governed instead of investors. Furthermore, managers may even manipulate firm's earnings and investment projects for increasing the pay.

Easterbrook and Fischel (1991) and Romano (1993) are very optimistic about the United States corporate governance system, but Jensen (1993) believes that it is flawed and that a major move from the general corporate form to more highly leveraged organizations, such as LBOs. According to Barca (1995) and Pagano et al (1998), Italian corporate governance mechanisms are undeveloped and the external capitals hesitate to invest in those poor governed companies. Therefore, understanding corporate governance is not only to improve the corporate governance mechanisms, but also to stimulate the institutional changed in emerging markets.

We find more evidence about the issue that managers do not serve the interest of shareholders when we refer to event studies. That is, if the stock price drops when managers announce news, this news may serve the managers' interests rather than the investors'. Fama, Fisher, Jensen, and Roll (1969) propose the first event study in finance area, and we may use this empirical methodology to investigate corporate governance and finance. Jensen (1986) suggests that managers incline to invest the free cash rather than return it to investors. Besides, McConnell and Muscarella (1986) investigate announcement effects of investment projects of oil and other firms, and find that there exist negative returns on the announcements in the oil industry, although not in others.

Acquisitions may provide better evidence on agency costs, since the announcement selection problem does not arise in acquisitions due to the public announcements of all public companies acquisitions. Roll (1986) shows that bidder returns on the announcement of acquisitions are often negative. Lewellen, Loderer, and Rosenfeld (1985) find that negative returns are most common for bidders whose managers own little equity, and suggest that agency problems may exist. Morck, Shleifer, and Vishny (1990) show that bidder returns incline to be the lowest when bidders diversify or when bidders buy rapidly growing firms. Moreover, Bhagat, Shleifer and Vishny (1990), Lang and Stulz (1994), and Comment and Jarrell (1995) suggest that the evidence on stock negative returns of firms' diversification. Furthermore, Kaplan and Weisbach (1992) record the history of diversification by the U.S. firms and most of them have adverse effects on firms' diversification. Lang, Stulz and Walkling (1991) show that bidder returns are the lowest among firms with low Tobin's Q and high cash flows, which provides evidence on Jensen's (1986) free cash flow problem and show that companies with poor investment projects and excess cash may have serious agency problems.

Since both the theory and the empirical studies show that managers have incentives for private benefits and may not do their best for investors, why investors are still willing to borrow their money to firms? The possible reason why managers will not steal money from firms is due to reputation building process by managers. That is, managers are willing to repay investors since they want to raise funds from the capital market in the future, and thus want to build the reputation in order to convince investors to invest them again. Diamond (1989, 1991) shows how companies establish reputations by repaying short term loans, and Gomes (1996) shows how dividend payments create reputations that enable companies to raise money.

Reputation models, such as Diamond (1989, 1991) and Gomes (1996), may also have other problems: the most famous one is the backward recursion problem. That is, if at a certain future state the benefits to managers of raising outside money are lower than the costs of paying to investors, managers may choose to default the repayments to investors. Then, if investors expect that their payment will be defaulted in a certain future state, they will not invest the firm in the beginning. Therefore, although reputation issue is an essential reason why companies can raise outside funds, there may exist other reasons why external financing works.

Another explanation of why investors give their funds to firms without receiving control rights is perhaps excessive investor optimism. DeLong, Shleifer, Summers, and Waldmann (1989, 1990) provide models of external finance based on excessive investor optimism. Their model indicate that investors only care about capital gains in a short run, and they may get back their money from the market shortly. An extreme case is a Ponzi scheme, where promoters raise funds and pay initial investors from the money of latter investors, and thus create an illusion of high returns. Similarly, if investors are optimistic about short run stock rise and will not care about how companies repay their money, external finance without governance can exist.

Some empirical evidence shows the importance of investor optimism for financing in several markets. For instance, Kaplan and Stein (1993) provide evidence to show that high yield bonds that are used to finance takeovers in the U.S. in the 1980s are usually overvalued by investors. Ritter (1991), Loughran, Ritter and Rydqvist (1994), Pagano, Panetta and Zingales (1995) and Teoh, Welch, and Wong (1998) show that the shares of firms issuing initial or secondary offerings are overvalued in the United States and other countries. These findings also suggest that firms' new shares usually issue at times when stock prices are high, and that is why the long run performance of initial public offerings is poor. Moreover, they suggest that managers may manipulate earnings before the offerings and may do inefficient investment policies after the offering.

As we know, the main reason that investors give their money to firms is to obtain control rights of firms. If the investors are shareholders, they have rights to vote on firm's important issues, like mergers and acquisitions, liquidations, and boards of directors' elections. In some countries, shareholders must appear at the shareholders' annual meeting to vote for boards of directors, which usually makes small shareholders choose not to vote. On the other hand, even if shareholders elect boards of directors, directors may not align their interests with shareholders. Weisbach (1988) suggests that boards of directors sometimes fire managers after firms' poor performance in the United States. However, Warner, Watts, and Wruck (1988) suggest that boards of directors need the evidence of firms' poor performance then managers are fired. Besides, Mace (1971) and Jensen (1993) also show that boards of directors are usually controlled by managers in the United States. As for other countries, Kaplan (1994) investigates cases in Japan and Germany and shows that boards of directors are very passive expect the emergency situations.

Generally speaking, if laws do not provide enough control rights to small investors, it is better for larger investors to obtain more control rights. Compared with the control rights are split among many small investors, it is more effective when control rights are concentrated in several large investors. Thus, large investors have incentives to monitor the firm and collect required information, which could avoid free rider problems by small investors. Moreover, Shleifer and Vishny (1986) show that larger investors have enough control rights to change the managers when the firm is under poor performance. However, as long as larger investors have more than half of the total shares of the firm, they can control the assets of the whole firm, which also addresses another agency problem by larger investors.

Larger shareholders in the United States are not common and Roe (1994) suggests that it may be due to the reason that laws restrict high ownership by banks, mutual funds, insurance companies, and other financial institutions. However, Eisenberg (1976), Demsetz (1983), Shleifer and Vishny (1986) suggest that large investors are still common on families investors and wealthy investors. Holderness and Sheehan (1988) also found hundred cases of over 51 percent shareholders in United States public firms. On the other hand, Black and Coffee (1994) show that in United Kingdom the ownership is relatively diversified.

There are some evidence regarding large shareholders and corporate governance. Franks and Mayer (2001) show that larger investors are related to high turnover of boards of directors in Germany. Gorton and Schmid (2000) also find that bank large shareholders improve firms' performance in 1974 sample, and not only bank large shareholders but also nonbank large shareholders improve firms' performance in 1985. Besides, Kaplan and Minton (1994) and Kang and Shivdasani (1995) suggest that companies which own large investors have more opportunities to change the management when the companies have poor performance in Japan. Yafeh and Yosha (2003) show that large investors have more power to reduce firms' unnecessary spending in Japan, for instance, advertising, research and development, entertainment expenses, etc. Shivdasani (1993) also finds that in the United States firms with large outside investors have more changes to be taken over. Denis and Serrano (1996) find that managers have more opportunities to be changed when the firms have poor performance if a takeover is defeated. These findings show that large investors are associated with corporate governance.

Takeover is another mechanism for corporate governance. Hostile takeover, a kind of takeover, is that a bidder makes a tender offer to the target firm's shareholders. If more than 51 percent shareholders of the target firm accept the offer, the bidder acquires the target firm and has the power to change the managers of the target firm. Manne (1965), Jensen (1988), Scharfstein (1988) propose that takeover may be a tool to govern a firm.

Jensen and Ruback (1983) show that takeover often increases the combined value of the target firm the acquired firm. This finding indicates that profits after acquisition are expected to go up. Besides, Palepu (1986), Morck, Shleifer and Vishny (1988, 1989) suggest that firms with poor performance are easy to be target firms, and Martin and McConnell (1991) show that managers in those poorly performing target firms are often replaced after acquisition. As for the free cash flow problem, Jensen (1986, 1988) suggests that takeovers may solve the free cash flow problem because investors may gain profits through mergers and acquisition. Easterbrook and Fischel (1991), Jensen (1993) propose that takeover is an essential corporate governance tool in the United States.

Takeover effective is usually regarded as a useful mechanism for corporate governance, but there are some adverse opinions. First of all, takeovers cost a lot and thus not all of the firms with poor performance will be taken over. Grossman and Hart (1980) show that the bidder may need to pay the expected increase in profits after acquisition to shareholders of the target firm. If the bidder did not do so, the target firm’s shareholder may not accept the offer and hold the shares and if the tender offer succeeds, the shares may become more valuable. Secondly, Shleifer and Vishny (1988) point out that if the bidder may also bring private benefits through overpaying the acquisition, which may also belong to the agency problem. Jensen (1993) suggests that hostile takeovers are only a small part of takeover activities in the United States during the 1980s.

As for large creditors, some researchers also point out that large credits, such as financial institutions, may have power to monitor firms. Smith and Warner (1979) suggest that the power of large creditors comes from a variety of residual rights they receive when firms default or violate debt covenants. If the loan is short-termed, large creditors need to renegotiate with firms in regular, then large creditors may have more control rights over the firms. Furthermore, in some countries, large creditors may also buy equities of the firm and thus have voting rights on firms' affairs. In this case, large creditors may have similar power as large shareholders. Diamond (1984) also presents a model regarding the monitoring power by large creditors.

There may be costs of the existence of large creditors. Demsetz and Lehn (1985) suggest that large creditors may have excessive risk because large loans are not usually diversified. Moreover, creditors may be expropriated by shareholders because large shareholders may not have same interests with other investors in the firm. For example, large shareholders use their control rights to maximize their wealth, but it may cause other investors' interests, such as large creditors', be distorted. Large shareholders may have some private benefits at the expense of other investors and employees. The situation is more serious when large shareholders' control rights are larger than their cash flow rights. Grossman and Hart (1988) and Harris and Raviv (1988) show that if a firm does not follow one-share-one-vote rules or the firm has a pyramid structure, shareholders may have incentives to expropriate other investors. For instance, large investors may prefer paying out cash flows to themselves rather than paying out to all investors fairly. They can pay special dividends to themselves or give a special offer to other firms which they control.

There is some evidence that is related to the benefits of control and expropriation from minor shareholders. On one hand, Demsetz (1983) and Demsetz and Lehn (1985) suggest that there is no relationship between a firm's ownership structure and its performance. On the other hand, Morck, Shleifer and Vishny (1988b) show that there is evidence on the relationship between cash flow ownership of the largest shareholders and profitability of the firms. That is, the profitability of firms rises when the ownership of the largest shareholders is between zero and five percent, and then the profitability of firms drops when the ownership of the largest shareholders is larger than five percent. That is, when investors' ownership increases, the agency problems between large shareholders and total shareholders decrease, so the profitability of firms increases. However, when ownership goes beyond a certain level, large shareholders may have other private benefits so the profitability of firms decreases.

The problem of expropriation by large investors is more serious if other investors have different types, such as different claim rights of cash flows in a firm. For instance, Jensen and Meckling (1976) suggest that a large shareholder may have incentives to take high risky projects since they can share the loss with creditors when the bad state occurs. On the other hand, Myers (1977) suggests that if the large investor is a creditor, he or she may wish the firm not to bear much risk and underinvest the firm's investment projects. Furthermore, Shleifer and Summers (1988) suggest that large investors may even expropriate employees' benefits to themselves.

There are several studies that evidence the expropriation problems in a firm. Asquish and Wizman (1990) show that whether shareholders redistribute rents from creditors in LBOs or leveraged recapitalizations, and they find such transferred rents relatively small. Bhagat, Shleifer, and Vishny (1990), Rossett (1990), and Pontiff, Shleifer and Weisbach (1990) investigate whether takeovers result in large redistributions of wealth from employees' wage reductions, layoffs and pension cutbacks, but they find such transferred rents from employees relatively small as well.

However, expropriation by large investors may be more serious if managers or employees have adverse effect problems. That is, managers or employees may decrease their efforts as they are strictly monitored by outside financiers or easily fired due to the loss of the firm. Schmidt (1996) and Cremer (1995) suggest that even principal gives high powered incentive contracts to agents, agents might reduce their efforts since agents do not bear the risk of bad states.

If expropriation by large investors is expected, external finance for such firms may be difficult. For instance, some countries do not protect minority investor rights very well, but have large investors such as banks or families. In that case, large investors may control managers' behaviors, but small investors are not willing to invest the firm due to lack of protection. It might be the reason why Italy, Germany, or France has relatively small equity markets. However, there is also lack of protection on minority investors in Japan but its equity market is not relatively small. It is also interesting that large investors in Japan are relatively soft. They usually do not take strict actions on monitoring and controlling managers because of their own agency problems, or low powered incentives between large institutions and firms.

2.3 The Model

The two-tiered model features three basic agents: Principal, Agent_1 and Agent_2; all of them are risk-neutral.

Agent_2 has expertise in discovering and implementing investing projects. He/She is capable of seeking two investment projects: one is a safe project and the other is high risky. Investing one dollar in the safe project will generate $1+S$ dollars, and investing one dollar in the high risky project will generate $1+R$ or $1-L$ dollars, with probability of α and $1-\alpha$, respectively[15]. The high risky project is assumed to be a negative NPV project [i.e. $\alpha(1+R)+(1-\alpha)(1-L)<1$], but Agent_2 has incentives to take on it. This is because Agent_2 can share the profit R when the good state $1+R$ realizes, but he/she does not need to suffer a portion of loss $-L$ when the bad state $1-L$ realizes[16]. Agent_2 is characterized by "Limited Responsibility," and he/she prefers taking on the high risky project rather than the safe project.

There are two types of Agent_2: rational and irrational, with probability *r* and $1-r$ respectively. The rational Agent_2 chooses the investment project that brings him/her more expected returns. If two projects bring the rational Agent_2 the same expected returns, he/she may choose one of the projects by random. On the other hand, the irrational Agent takes on risky projects with probability one. Therefore, the probability p that Agent_2 takes on the high risky project is expressed by the following Equation (2.1),

$$p = r \cdot p_r + (1-r) \cdot 1 = rp_r + 1 - r \tag{2.1}$$

Agent_1 takes the responsibility of monitoring Agent_2. Agent_1 determines his/her efforts in monitoring $m \in [0,1]$, which brings the monitoring costs am^2 to Agent_1; *a* is a constant. As *m* is determined, Agent_1 will be able to identify Agent_2 taking on the high risky project with probability *m*. When Agent_1 identifies the risky Agent_2, Agent_1 have the following two options: fire Agent_2 and stop the high risky project, or collude with Agent_2 and continue the risky project. If Agent_1 collude with Agent_2,

[15] Principal is assumed not to be able to verify whether the investment project is risky or safe by the project's outcome. Therefore, Principal cannot accuse Agent_1 and Agent_2 if the outcome 1+R realizes, which means Agent_2 takes on risky projects but the good state of the world occurs.

[16] It is assumed that $\alpha R > S$. Thus, Agent_2 prefers taking the risky project rather than the safe project.

Agent_1 can exploit a bribe[17] T from Agent_2 as when the good state *1+R* realizes. The agency problem in this model lies in the situation that Agent_1 may not do utmost efforts to monitor Agent_2. Furthermore, Agent_1 may even collude with Agent_2 for exploiting the bribe *T*.

Principal employs Agent_1 to administrate the firm and monitor Agent_2; Principal employs Agent_2 to seek and implement firm's investment projects. Principal offers Agent_1 and Agent_2 a proportion of the profit from the outcome, denoted by W_1 and W_2, respectively[18]. In order to induce more efforts of monitoring from Agent_1, Principal designs an incentive contract (B_1, B_2) for Agent_1[19]: Agent_1 obtains the bonus B_1 as long as he/she stops the risky Agent_2 at Stage_1, and obtains the bonus B_2 as long as he/she stops the risky Agent_2 at Stage_2.

There are four stages in the model, shown in Figure 2.1. At Stage_0 Principal determines the incentive contract (B_1, B_2) for Agent_1. After knowing the bonus compensation (B_1, B_2), Agent_1 determines his/her efforts in monitoring m, and Agent_2 determines the probability of taking risky projects p (or p_r [20]). At Stage_1, Agent_1 knows whether he/she identifies the risky Agent_2 with probability m. If Agent_1 identifies the risky Agent_2, Agent_1 chooses to stop the high risky project or collude with Agent_2, letting risky projects go on. If Agent_1 fails to identify the risky

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[17] The bribe T should be larger than zero and do not exceed the total income of the risky Agent_2 when the good state occurs; That is, $0 \le T \le W_2 R$.

[18] W_1 and W_2 are exogenous variables.

[19] The bonus compensation (B_1, B_2) are endogenous variables in the model.

[20] Equation (2.1) indicates that $p = \gamma p_r + 1 - \gamma$. That is, p can be derived once p_r is determined. Thus, I focus on the equilibrium of p_r and m rather than p and m.

Agent_2 at Stage_1, Agent_1 has another chance to identify the risky Agent_2 at Stage_2 with probability 0.5. At Stage_3, the outcome of the project realizes. If the good state of the high risky project $1+R$ realizes, Agent_1 obtains the bribe T from Agent_2. On the other hand, if the bad state $1-L$ realizes, Agent_1 and Agent_2 obtain nothing but they do not share the loss $-L$, either. In addition, Principal suffers a little loss $-\ell$ if the high risky project is stopped at Stage_2[21].

<Insert Figure 2.1 here>

Figure 2.2 contains the decision tree graph for the model, which can be also regarded as an extensive-form in the game theory. At each node, Agent_1 or Agent_2 maximizes his/her own benefits when he/she is in charge. Decision tree methodology is usually observed in capital budgeting, and we can use backward induction to solve the decision tree and find out what optimal strategies are for Principal, Agent_1 and Agent_2.

<Insert Figure 2.2 here>

2.4 Case_1: Principal Offers Bonus to Agent_1 both at Stage_1 and Stage_2 if Agent_1 Catches the Risky Agent_2 at that Stage (Joint Responsibility Excluded)

To solve the finite extensive-form game, the technique of backward induction is applied. First of all, I find optimal actions for Agent_1 to determine m and Agent_2 to determine p_r given any incentive contract (B_1, B_2). Then, I solve what Principal's optimal action to offer (B_1, B_2) should be.

[21] It is assumed that $-\ell > \alpha R + (1-\alpha)(-L)$. The little loss $-\ell$ is less than the expected NPV of the high risky project.

2.4.1 Optimal Actions of Agent_1 and Agent_2 in Case_1

First of all, incentive compatibility (IC) constraints for Agent_1 to stop the risky Agent_2 both at Stage_1 and Stage_2 are listed as Equation (2.2) and Equation (2.3):

$$\alpha(W_1R + T - am^2) + (1-\alpha)(-am^2) \leq B_2 - am^2$$

$$\Rightarrow B_2 \geq \alpha W_1 R + \alpha T \tag{2.2}$$

And

$$B_1 \geq B_2 \tag{2.3}$$

Then, Agent_1's expected payoff function is expressed in Equation (2.4):

$$V_1 = mpB_1 + m(1-p)W_1S + (1-m)p \cdot \frac{1}{2} \cdot B_2 + (1-m)p \cdot \frac{1}{2} \cdot \alpha W_1 R + (1-m)(1-p)W_1S - am^2 + K$$

$$\Rightarrow V_1 = mpB_1 + (1-m)p \cdot \frac{1}{2} \cdot (B_2 + \alpha W_1 R) + (1-p)W_1S - am^2 + K \tag{2.4}$$

In Equation (2.4), K is the transfer between Principal and Agent_1, which is introduced to make sure that Agent_1's retention constraint is always binding when I solve optimal actions for Principal later in Section 2.4.2.

Given p_r, Agent_1's optimal action for the monitoring m is shown in Equation (2.5)[22], which is the first order condition on Equation (2.4) with respect to m:

$$pB_1 - \frac{1}{2}pB_2 - \frac{1}{2}p\alpha W_1 R - 2am = 0$$

$$\Rightarrow m = \frac{[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)]}{2a} p = \frac{[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)]}{2a}[rp_r + (1-r)]$$

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[22] Given p_r, p is also decided due to Equation (2.1): $p = rp_r + 1 - r$

$$\Rightarrow m = \frac{[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)]}{2a}(1-r) + \frac{[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)]}{2a} r p_r \qquad (2.5)$$

On the other hand, Agent_2's expected payoff function when he/she takes on the high risky project is

$$V_2^R = (1-m)\cdot\frac{1}{2}\cdot\alpha W_2 R \qquad (2.6)$$

Agent_2's payoff function when he/she takes on the safe project is

$$V_2^S = W_2 S \qquad (2.7)$$

The condition that Agent_2 is indifferent to taking on the high risky project or the safe project (i.e. $V_2^R = V_2^S$), shall be expressed in Equation (2.8) [23]

$$m^* = 1 - \frac{2S}{\alpha R}, \quad \alpha R > 2S \qquad (2.8)$$

From Equation (2.6), Equation (2.7), and Equation (2.8), we can obtain the following Equation (2.9). That is, the rational Agent_2 does not take on the high risky project if $m > m^*$; he/she takes on it if $m < m^*$, and he/she is indifferent to the high risky project and the safe project if $m = m^*$.

$$\begin{aligned} p_r &= 0, && if \;\; m > m^* \\ p_r &\in [0,1], && if \;\; m = m^* \\ p_r &= 1, && if \;\; m < m^* \end{aligned} \qquad (2.9)$$

Equation (2.5) and Equation (2.9) are described on the graph in Figure 2.3. Figure 2.3 contains one example of the equilibrium m and p_r by Agent_1 and the rational Agent_2 given an incentive contract (B_1, B_2). The black line, expressed by Equation (2.5),

[23] The inequality $\alpha R > 2S$ holds due to the reason that m should not be negative

is Agent_1's reaction function given Agent_2's probability of taking on the high risky project; the dotted line, expressed by Equation (2.9), is Agent_2's reaction function given Agent_1's monitoring *m*. The crossover point of these two lines is the equilibrium *m* and p_r by Agent_1 and the rational Agent_2, which is determined by the value of the incentive contract[24] (B_1, B_2).

<Insert Figure 2.3 here>

Table 2.1 lists the range of the incentive contact (B_1, B_2) and the correspondent values of the equilibrium *m* and p_r. Note that the correspondent values of the equilibrium *m* and p_r are derived from Equation (2.5) and Equation (2.9). Consequently, Table 2.1 presents the equilibrium *m* and p_r determined by Agent_1 and Agent_2 given any incentive contract (B_1, B_2). In Section 2.4.2, I discuss what the optimal incentive contract (B_1, B_2) is from Principal's perspective.

<Insert Table 2.1 here>

2.4.2 Optimal Incentive Contracts for Principal in Case_1

Principal would like to maximize his/her expected payoff function with several constraints, such as Equation (2.1), Equation (2.2), and Equation (2.3). Moreover, Agent_1's opportunity costs for this job, denoted by U_1, should be satisfied[25] as well. Thus, Principal's maximization problem can be expressed as below:

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[24] The value of the incentive contract (B_1, B_2) affects Agent_1's reaction function, the black line in Figure 3.

[25] This is called "retention constraint," which satisfies Agent_1's individual rationality constraint

$$\underset{B_1,B_2}{Max} \quad \pi = mp(-B_1) + (1-m)p\left\{\frac{1}{2}(-\ell - B_2) + \frac{1}{2}\left[\alpha(1-W_1-W_2)R + (1-\alpha)(-L)\right]\right\}$$

$$+(1-p)(1-W_1-W_2)S - K$$

Subject to

$p = rp_r + 1 - r$, $0 \le p_r \le 1$

$B_1 \ge B_2 \ge \alpha W_1 R + \alpha T$

$$V_1 = mpB_1 + (1-m)p \cdot \frac{1}{2} \cdot (B_2 + \alpha W_1 R) + (1-p)W_1 S - am^2 + K = U_1$$

Figure 2.4 presents possible values of the incentive contract (B_1,B_2) in Case_1. The possible values of the incentive contract (B_1,B_2) should be located in Zone A, Zone B, Zone C, or Zone D, in Figure 2.4, which is classified by the range of the incentive contract (B_1,B_2) in Table 2.1. Then, I compare Principal's expected payoffs when the values of the incentive contract (B_1,B_2) are located in each zone, and investigate what zone should optimal incentive contracts (B_1,B_2) be located in from Principal's perspective.

<Insert Figure 2.4 here>

Table 2.2 presents Principal's expected payoff functions under Zone A, Zone B, Zone C, Zone D in Figure 4, and the correspondent optimal incentive contract (B_1,B_2); in Zone B, the optimal incentive contract (B_1,B_2) is specified in Table 2.3. The optimal incentive contract (B_1,B_2) in Zone A and Zone C is located in the corner solution shared with Zone B, and thus they can be included in the optimal incentive contract (B_1,B_2) of Zone B as well. Besides, there is no optimal incentive contract (B_1,B_2) in Zone D,

where the equilibrium $m < m^*$ and $p_r = 1$. This is due to the reason that as the optimal incentive contract (B_1, B_2) is located in Zone D, Agent_1's monitoring m is low and Agent_2 takes on the high risky project with probability one. Therefore, Principal's expected payoff is negative in Zone D and thus the optimal incentive contract (B_1, B_2) cannot be located in Zone D.

<Insert Table 2.2 here>

Table 2.3 presents three conditions regarding Principal's expected payoffs under Zone B, and the correspondent optimal incentive contract (B_1, B_2). It is interesting that the optimal incentive contract (B_1, B_2) in Zone B depends on Principal's expected loss when Agent_1 does not identify the risky Agent_2 at Stage_1. If the expected loss is greater than $-2a/(1-r)$, the optimal incentive contract (B_1, B_2) is the same as that in Zone A, which implicates that the expected loss is so great that Principal is willing to offer the highest B_1 to Agent_1 and thus the equilibrium $m = 1$, $p_r = 0$; If the expected loss is less than $-2a(\alpha R - 2S)/\alpha R(1-r)$, the optimal incentive contract (B_1, B_2) is the same as that in Zone C, which implicates that the expected loss is not great so Principal offers enough B_1 to induce the equilibrium $m = m^*$, $p_r = 0$; if the expected loss is between $-2a/(1-r)$ and $-2a(\alpha R - 2S)/\alpha R(1-r)$, the optimal incentive contract B_1 is the function of the expected loss, which implicates that the expected loss causes Principal to offer enough B_1 to Agent_1 and the equilibrium $m \in (m^*, 1)$, $p_r = 0$.

<Insert Table 2.3 here>

From Table 2.2, Table 2.3 and the previous analysis, we can conclude that the optimal incentive contract (B_1, B_2) from Principal's perspective is located in Zone B, where Principal's payoff function is maximized and the equilibrium $m \in [m^*, 1]$, $p_r = 0$. The optimal B_2 is fixed to $\alpha W_1 R + \alpha T$, which satisfies Equation (2.2) regarding Agent_1's incentive compatible condition.

2.5 Case_2: Principal Offers Bonus to Agent_1 at Stage_1 but not at Stage_2 if Agent_1 Catches the Risky Agent_2 at that Stage (Joint Responsibility Included)

I apply the backward induction to solve Case_2, which is the same as that in Case_1. First of all, I solve Agent_1's optimal action on the monitoring m and Agent_2's optimal action on the probability p_r given any incentive contract (B_1, B_2). Then, I solve what Principal's optimal action to offer (B_1, B_2) should be.

2.5.1 Optimal Actions of Agent_1 and Agent_2 in Case_2

First of all, incentive compatibility (IC) constraints for Agent_1 to stop the risky Agent_2 at Stage_1 but not at Stage_2 are listed as Equation (2.10) and Equation (2.11):

$$\alpha(W_1 R + T - am^2) + (1-\alpha)(-am^2) \le B_1 - am^2$$

$$\Rightarrow B_1 \ge \alpha W_1 R + \alpha T \tag{2.10}$$

and

$$\alpha(W_1 R + T - am^2) + (1-\alpha)(-am^2) > B_2 - am^2$$

$$\Rightarrow B_2 < \alpha W_1 R + \alpha T \tag{2.11}$$

Equation (2.11) implies that B_2 can be set to be zero in Case_2. As for Agent_1's action. Besides, Agent_1's expected payoff function can be expressed by Equation (2.12),

$$V_1 = mpB_1 + m(1-p)W_1S + (1-m)p \cdot \frac{1}{2} \cdot (\alpha W_1R + \alpha T) + (1-m)p \cdot \frac{1}{2} \cdot \alpha W_1R + (1-m)(1-p)W_1S - am^2 + K$$

$$\Rightarrow V_1 = mpB_1 + (1-m)p(\alpha W_1R + \frac{1}{2}\alpha T) + (1-p)W_1S - am^2 + K \qquad (2.12)$$

In Equation (2.12), K is the transfer between Principal and Agent_1, which is introduced to make sure that Agent_1's retention constraint is always binding when I solve optimal actions for Principal later in Section 2.5.2.

Agent_1's optimal action for the monitoring m is expressed by Equation (2.13), which is the first order condition on Equation (2.12) with respect to m:

$$pB_1 - p\alpha W_1R - \frac{1}{2}p\alpha T - 2am = 0$$

$$\Rightarrow m = \frac{\left(B_1 - \alpha W_1R - \frac{1}{2}\alpha T\right)}{2a}p = \frac{\left(B_1 - \alpha W_1R - \frac{1}{2}\alpha T\right)}{2a}\left[rp_r + (1-r)\right]$$

$$\Rightarrow m = \frac{\left(B_1 - \alpha W_1R - \frac{1}{2}\alpha T\right)}{2a}(1-r) + \frac{\left(B_1 - \alpha W_1R - \frac{1}{2}\alpha T\right)}{2a}rp_r \qquad (2.13)$$

On the other hand, Agent_2's expected payoff function if he/she takes on the high risky project is

$$V_2^R = (1-m)\alpha(W_2R - \frac{1}{2}T) \qquad (2.14)$$

Agent_2's payoff function if he/she takes on the safe project is

$$V_2^S = W_2S \qquad (2.15)$$

The condition that Agent_2 is indifferent to taking on the high risky project or the safe project (i.e. $V_2^R = V_2^S$), shall be expressed in Equation (2.16)[26]

$$m^{**} = 1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T} \quad , \alpha W_2 R - \frac{1}{2}\alpha T > W_2 S \tag{2.16}$$

From Equation (2.14), Equation (2.15), and Equation (2.16), we can obtain the following Equation (2.17). Similar to Case_1, the rational Agent_2 does not take on the high risky project if $m > m^{**}$; he/she takes on it if $m < m^{**}$, and he/she is indifferent to the high risky project and the safe project if $m = m^{**}$.

$$\begin{aligned} p_r &= 0, && \text{if } m > m^{**} \\ p_r &\in [0,1], && \text{if } m = m^{**} \\ p_r &= 1, && \text{if } m < m^{**} \end{aligned} \tag{2.17}$$

Equation (2.13) and Equation (2.17) are described on the graph in Figure 2.5. Figure 2.5 contains one example of the equilibrium *m* and p_r by Agent_1 and the rational Agent_2 given an incentive contract[27] B_1. The black line, expressed in Equation (2.13), is Agent_1's reaction function given Agent_2's probability of taking on the high risky project. There are two dotted lines: they are Agent_2's reaction function given Agent_1's monitoring *m* in Case_2 and Case_1[28], respectively. The crossover point of the black line and the dotted lines is the equilibrium *m* and p_r by Agent_1 and the rational Agent_2, which is determined by the value of the incentive contract B_1.

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[26] $\alpha W_2 R - \alpha T / 2 > W_2 S$ holds because *m* should not be negative

[27] I do not consider B_2 since B_2 can be set to be zero in Case_2 by Equation (2.11)

[28] In order to compare Case_1 and Case_2 in the next section, Figure 2.5 also contains Agent_2's reaction function given Agent_1's monitoring in Case_1

<Insert Figure 2.5 here>

Table 2.4 lists the range of the incentive contact B_1 and the correspondent values of the equilibrium *m* and p_r. Note that the correspondent values of the equilibrium *m* and p_r are derived from Equation (2.13) and Equation (2.17). Consequently, Table 2.4 presents the equilibrium *m* and p_r determined by Agent_1 and Agent_2 given any incentive contract B_1. In Section 2.5.2, I discuss what the optimal incentive contract B_1 is from Principal's perspective.

<Insert Table 2.4 here>

2.5.2 Optimal Incentive Contracts for Principal in Case_2

Principal would like to maximize his/her expected payoff function with several constraints, such as Equation (2.10), Equation (2.11), and Equation (2.12). Similarly to Case_1, Agent_1's opportunity costs for this job, denoted by U_1, should be satisfied. Thus, Principal's maximization problem can be expressed as below:

$$\underset{B_1}{Max} \quad \pi = mp(-B_1) + (1-m)p\left[\alpha(1-W_1-W_2)R + (1-\alpha)(-L)\right] + (1-p)(1-W_1-W_2)S - K$$

Subject to

$$p = rp_r + 1 - r, \quad 0 \le p_r \le 1$$

$$V_1 = mpB_1 + (1-m)p(\alpha W_1 R + \frac{1}{2}\alpha T) + (1-p)W_1 S - am^2 + K = U_1$$

$$B_1 \ge \alpha(W_1 R + T) > B_2 \ge 0$$

Figure 2.6 present possible values of the incentive contract B_1 in Case_2. The possible values of the incentive contract B_1 should be located in Segment A, Segment B, Segment C, or Segment D, in Figure 2.6, which is classified by the range of the incentive contract B_1 in Table 2.4. Note that the range of Segments depends on the value of *T*. If $T = W_2 R$, the range of Segments depends on Line L_1, L_2, L_3, L_4, which are the same as Case_1; If $W_2 R > T \geq 0$, the range of Segments is determined by Line L_1, L_2', L_3', L_4. Then, I compare Principal's expected payoffs when the values of the incentive contract B_1 are located in each segment, and investigate what segment should optimal incentive contracts B_1 be located in from Principal's perspective.

<Insert Figure 2.6 here>

Table 2.5 presents Principal's expected payoff functions under Segment A, Segment B, Segment C, Segment D in Figure 2.6, and the correspondent optimal incentive contract B_1; in Segment B, the optimal incentive contract B_1 is specified in Table 2.6. The optimal incentive contract B_1 in Segment A and Segment C is located in the corner solution shared with Segment B, and thus they can be included in the optimal incentive contract B_1 of Segment B as well. Besides, there is no optimal incentive contract B_1 in Segment D, where the equilibrium $m < m^{**}$ and $p_r = 1$. This is because as the optimal incentive contract B_1 is located in Segment D, Agent_1's monitoring *m* is low and Agent_2 takes on the high risky project with probability one. Therefore, Principal's expected payoff is negative in Segment D and thus the optimal incentive contract B_1 cannot be located in Segment D.

<Insert Table 2.5 here>

Table 2.6 presents three conditions regarding Principal's expected payoffs under

Segment B, and the correspondent optimal incentive contract B_1. It is interesting that the optimal incentive contract B_1 in Segment B depends on Principal's expected loss when Agent_1 does not identify the risky Agent_2 at Stage_1. If the expected loss is greater than $-2a/(1-r)$, the optimal incentive contract B_1 is the same as that in Segment A, which implicates that the expected loss is so great that Principal is willing to offer the highest B_1 to Agent_1 and thus the equilibrium $m=1$, $p_r=0$; If the expected loss is less than $-2a\left[\alpha W_2 R-(0.5)S-W_2 S\right]/(1-r)\left[\alpha W_2 R-(0.5)S\right]$, the optimal incentive contract B_1 is the same as that in Segment C, which implicates that the expected loss is not great so Principal offers enough B_1 to induce the equilibrium $m=m^{**}$, $p_r=0$. Last but not least, if the expected loss is between $-2a/(1-r)$ and $-2a\left[\alpha W_2 R-(0.5)S-W_2 S\right]/(1-r)\left[\alpha W_2 R-(0.5)S\right]$, the optimal incentive contract B_1 is the function of the expected loss, which implicates that the expected loss causes Principal to offer enough B_1 to Agent_1 and the equilibrium $m\in(m^{**},1)$, $p_r=0$.

<Insert Table 2.6 here>

From Table 2.5, Table 2.6 and the previous analysis, we can conclude that the optimal incentive contract B_1 from Principal's perspective is located in Segment B, where Principal's payoff function is maximized and the equilibrium $m\in[m^{*},1]$, $p_r=0$. In Section 2.6, I compare the equilibrium m and p_r, and Principal's payoffs in Case_1 and Case_2.

2.6 The Comparison of Case_1 and Case_2

In this section, I discuss Principal's payoffs in Case_1 and Case_2, and Agent_1 and Agent_2's optimal actions on the equilibrium *m* and p_r. I also do static comparative analysis on two exogenous variables: the loss from the bad state of the high risky project *L* and the parameter of monitoring costs *a*, and show that how these variables change Agent_1's monitoring and Principal's payoff in equilibrium.

Proposition 2.1

The monitoring in Case_2 is no less than that in Case_1 in equilibrium

This is one of the most important propositions in the model. Due to Joint Responsibility policy in Case_2, Principal does not give bonus to Agent_1 if Agent_1 identifies the risky Agent_1 at Stage_2. The model shows that the monitoring in Case_2 is no less than that in Case_1. Proposition 1 is consistent with the intuition that Joint Responsibility induces more Agent_1's monitoring. Lemma 2.1 and Lemma 2.2 are introduced to prove Proposition 2.1.

Lemma 2.1

In equilibrium, the range of Agent_1's monitoring both in Case_1 and Case_2 is $[1-\frac{2S}{\alpha R},1]$**.**

From Section 2.4 and Section 2.5 we conclude that the optimal incentive contract is located in Zone B in Figure 2.4 and Segment B in Figure 2.6. In Case_1, the range of Agent_1's monitoring in equilibrium is $[1-2S/\alpha R,1]$; In Case_2, the range of Agent_1's monitoring in equilibrium is $\left[1-W_2S/\left[\alpha W_2R-(0.5)\alpha T\right],1\right]$. It is assumed that $T\in\left[0,W_2R\right]$, the range of Agent_1's monitoring in Case_2 is $[1-2S/\alpha R,1]$ as well.

Lemma 2.2

Principal's expected cost when Agent_1 does not identify the risky Agent_2 at Stage_1 determines the optimal B_1, and the optimal B_1 determines Agent_1's monitoring in equilibrium.

Tables 2.3 and Table 2.6 indicate that the greater Principal's expected cost[29] when Agent_1 does not identify the risky Agent_2 at Stage_1, the larger the optimal incentive contract B_1 for inducing Agent_1's monitoring. If Principal's expected cost is greater than $-2a/1-r$, Principal offers the maximum B_1, which induces Agent_1's monitoring to be one.

According to Lemma 2.1 and Lemma 2.2, we can conclude that Proposition 2.1 holds. Lemma 2.1 presents that the range of Agent_1's monitoring in Case_2 is the same as that in Case_1. Lemma 2.2 shows that the greater Principal's expected loss when Agent_1 does not identify the risky Agent_2 at Stage_1, the larger Agent_1's monitoring in equilibrium both in Case_1 and Case_2. Since Principal's expected cost when Agent_1 does not identify the risky Agent_2 at Stage_1 in Case_2 is always larger than that in Case_1, Agent_1's monitoring in Case_2 is no less than that in Case_1 in equilibrium.

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[29] In Case_1, the expected cost is $\frac{1}{2}(-\ell)+\frac{1}{2}\left\{-\alpha W_2R+[\alpha R+(1-\alpha)(-L)]\right\}$; In Case_2, the expected cost is $\frac{1}{2}\alpha T-\alpha W_2R+[\alpha R+(1-\alpha)(-L)]$

Proposition 2.2

In equilibrium, the probability that Agent_2 takes on the high risky project is 1-r.

From the analysis of Section 2.4 and Section 2.5, we can conclude that the optimal incentive contract is located in Zone B in Case_1 and Segment B in Case_2. In equilibrium, the probability p_r that the rational Agent_2 takes the high risky project is zero. Accordingly, the probability p that Agent_2 takes on the high risky project is 1-*r*.

Why not the probability of the risky Agent_2 would be higher than *1-r* in equilibrium? In Case_1, the incentive contract that results in $1\text{-}r<p<1$ is located in Zone C. Given the same $m = m^*$, Principal would like to make *p* as small as possible, so Principal sets the incentive contract to make the equilibrium *p* be 1-*r*. Following the same analysis, we can conclude the identical result in Case_2.

Proposition 2.2 shows that Principal does his/her best to decrease the probability of Agent_2 taking on the high risky project. The following Propositions 2.3 and Proposition 2.4 present the static comparative analysis of two exogenous variables: the loss from the bad state of the high risky project *L* and the parameter of monitoring costs *a*, and show that how these variables change Agent_1's monitoring and Principal's payoffs in equilibrium.

Proposition 2.3

Agent_1's monitoring is weakly increasing and Principal's payoff is weakly decreasing in the loss from the bad state of the high risky project.

Proof: Please see Appendix.

Tables 2.3 and Table 2.6 indicate that as the loss from the bad state of the high risky project L increases, Principal increases the incentive contract B_1 to induce higher Agent_1's monitoring. Proposition 2.3 presents that although Agent_1's monitoring increases, Principal's payoff goes down. This is because increasing m causes the monitoring cost (am^2) to be much larger than the decrease of Principal's expected cost. In addition, the little loss ℓ and Agent_2's payment (W_2) lead to the same effect as well. Higher Agent_1's monitoring results from more Principal's expected loss, and thus it does not bring Principal more benefit.

Proposition 2.4

Agent_1's monitoring is weakly decreasing and Principal's payoffs are also weakly decreasing in the parameter of the monitoring cost.

Proof: Please see Appendix.

Proposition 2.4 indicates that as the parameter of the monitoring cost increases, the equilibrium m and π are weakly decreasing. This is due to the reason that increasing the parameter of the monitoring cost decreases the incentive effect of B_1 and thus the equilibrium m decreases. Furthermore, decreasing the monitoring m leads to the increase of Principal's expected cost when Agent_1 does not identify the risky Agent_2 at Stage_1, and thus Principal's payoff decreases as well.

Proposition 2.5

For Principal, Case_1 weakly dominates Case_2; that is, Principal's payoff in Case_1 is no less than that in Case_2

Proof: Please see Appendix.

Proposition 2.5 shows that Joint Responsibility is not a good policy for Principal. From Table 2.3 and Table 2.6, Principal's expected cost in Case_2 is no less than that in Case_1. Accordingly, Principal's payoff in Case_1 weakly dominates that in Case_2.

Proposition 2.5 implicates that if Agent_1 has an opportunity to stop the risky Agent_2 at Stage_2, Principal should offer the incentive contract B_2 to Agent_1. In that way, once Agent_1 identify the risky Agent_2 at State_2, he/she does not collude with the risky Agent_2 and stop the high risky project, and thus Principal's expected cost may decrease.[30]

2.7 Concluding Remarks

In this paper, I propose a two-tiered agency model and show that Joint Responsibility between Agent_1 and Agent_2 is not a good policy for Principal. A two-tiered agency model describes Principal-Agent relationships among three agents: Principal, Agent_1 and Agent_2. Principal employs Agent_1 to administer the firm and monitor Agent_2's behavior, and Principal employs Agent_2 as the employee to seek and implement firm's investment project. Joint Responsibility policy states that Agent_1 may be accused of not identifying in advance Agent_2 who takes on destructive risky projects. Principal believes that Joint Responsibility policy induces more Agent_1's efforts in monitoring, and thus mitigates expected loss of the high risky project. The model in this paper takes into account the collusion behavior of Agent_1 and Agent_2 and show that imposing Joint Responsibility between Agent_1 and Agent_2 may cause the decrease of Principal's payoff in equilibrium.

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[30] $\because -\ell > \alpha R + (1-\alpha)(-L)$

I discuss and compare two different incentive contacts for Agent_1: the incentive contract in Case_1 is without Joint Responsibility and that in Case_2 is within Joint Responsibility. The incentive contact is Case_1 is that Principal still offers B_2 for Agent_1 even if Agent_1 does not to identify the risky Agent_2 at Stage_1 but identify the risky Agent_2 at Stage_2. On the other hand, the incentive contact in Case_2 is that Principal does not offer B_2 for Agent_1 if Agent_1 does not identify the risky Agent_2 at Stage_1.

After comparing Agent_1's monitoring and Principal's payoff in these two cases, we conclude that although Agent_1's monitoring in Case_2 is larger than that in Case_1, Principal's payoff in Case_1 weakly dominates that in Case_2. Therefore, Principal's optimal action is to offer the incentive contract to Agent_1 to stop the risky Agent_2 both at Stage_1 and Stage_2. This result suggests that Joint Responsibility is not a good policy for Principal. As long as Principal may suffer less if the high risky project is stopped, Principal should provide the incentive contract (B_1, B_2) to Agent_1 both at Stage_1 and Stage_2.

I also do static comparative analysis on the following two exogenous variables: the loss from the bad state of the high risky project, and the parameter of monitoring costs. Consistent with our intuition, increasing the loss from the bad state of the high risky project increases Agent_1's monitoring but decrease Principal's payoff; Moreover, increasing the parameter of monitoring costs decreases both Agent_1's monitoring and Principal's payoff in equilibrium.

Bibliography

Aron, D., 1991, "Using the Capital Market as a Monitor: Corporate Spinoffs in an Agency Framework," *Rand Journal of Economics*," 22, 505-518

Barca, F., 1995, "On Corporate Governance in Italy: Issues, Facts, and Agency," *Bank of Italy, Rome*

Baumol, W., 1959, "Business Behavior, Value and Growth," *Macmillan, New York*

Bekaert, G., and C. R. Harvey, 2003, "Emerging Market Finance," *Journal of Empirical Finance*, 10, 3-57

Benston, G., 1985, "The Self-Serving Management Hypothesis: Some Evidence," *Journal of Finance*, 7, 67-83

Berle, A., and G. Means, 1932, "The Modern Corporation and Private Property," *Macmillan, New York*

Bhagat, S., A. Shleifer, and R. Vishny, 1990, "Hostile Takeovers in the 1980s: The Return to Corporate Specialization," *Brookings Papers on Economic Activity: Microeconomics, Special Issue*, 1-72

Black, B., and J. Coffee, 1994, "Hail Britannia? Institutional Investor Behavior under Limited Regulation," *Michigan Law Review*, 92, 1997-2087

Bolton, P., and D. S. Scharfstein, 1990, "A Theory of Predation Based on Agency Problems in Financial Contracting," *American Economic Review*, 80, 94-106

Claessens, S., and J. P. Fan, 2002, "Corporate Governance in Asia: A Survey," *International Review of Finance*, 3, 71-103

Clark, R., 1985, "Agency Costs versus Fiduciary Duties, in Principals and Agents: The Structure of Business," *Harvard Business School Press, Cambridge, Mass*

Coase, R., 1937, "The Nature of the Firm," *Economica*, 4, 386-405

Coase, R., 1960, "The Problem of Social Cost," *Journal of Law and Economics*, 3, 1-44

Comment, R., and G. Jarrell, 1985, "Corporate Focus and Stock Returns," *Journal of Financial Economics*, 37, 67-87

Coughlan, A., and R. Schmidt, 1985, "Executive Compensation, Management Turnover, and Firm Performance: An Empirical Investigation," *Journal of Accounting and Economics*, 7, 43-66

Cremer, J., 1995, "Arm's Length Relationships," *Quarterly Journal of Economics*, 110, 275-296

DeLong, J. B., A. Shleifer, L. Summers, and R. Waldmann, 1989, "The Size and Incidence of the Loss from Noise Trading," *Journal of Finance*, 44, 681-696

DeLong, J. B., A. Shleifer, L. Summers, and R. Waldmann, 1990, "Noise Trader Risk in Financial Markets," *Journal of Political Economy*, 98, 703-738

Demsetz, H., 1983, "The Structure of Ownership and the Theory of the Firm," *Journal of Law and Economics*, 26, 375-390

Demsetz, H. and K. Lehn, 1985, "The Structure of Corporate Ownership: Causes and Consequences," *Journal of Political Economy*, 93, 1155-1177

Denis, D., and J. McConnell, 2003, "International Corporate Governance," *Journal of Financial and Quantitative Analysis*, 38, 1-36

Denis, D., and J. Serrano, 1996, "Active Investors and Management Turnover following Unsuccessful Control Contests," *Journal of Financial Economics*, 40, 239-266

Diamond, D., 1984, "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies*, 51, 393-414

Diamond, D., 1989, "Reputation Acquisition in Debt Market," *Journal of Political Economy*, 97, 828-862

Diamond, D., 1991, "Debt Maturity Structure and Liquidity Risk," *Quarterly Journal of Economics*, 106, 1027-1054

Easterbrook, F., and D. Fischel, 1991, "The Economic Structure of Corporate Law," *Harvard University Press, Cambridge, Mass*

Eisenberg, M., 1976, "The Structure of the Corporation: A Legal Analysis," *Little, Brown and Co., Boston*

Fama, E., 1980, "Agency Problems and the Theory of the Firm," *Journal of Political Economy*, 88, 288-307

Fama, E., L. Fisher, M. Jensen, and R. Roll, 1969, "The Adjustment of Stock Prices to New Information," *International Economic Review*, 10, 1-21

Fama, E., and M. Jensen, 1983, "Agency problems and Residuals Claims," *Journal of Law and Economics*, 26, 327-349

Frank, J., and C. Mayer, 1990, "Takeovers: Capital Markets and Corporate Control: A

Study of France, Germany, and the UK" *Economic Policy: A European Forum*, 10, 189-231

Frank, J., and C. Mayer, 2001, "The Ownership and Control of German Corporations" *Review of Financial Studies*, 14, 943-977

Fulghieri, P., and L. S. Hodrick, 2006, "Synergies and Internal Agency Conflicts: The Double-Edged Sword of Mergers," *Journal of Economics and Management Strategy*, 15, 549-576

Gomes, A., 1996, "Dynamics of Stock Prices, Manager Ownership, and Private Benefits of Control," *Harvard University*

Gorton, G., and F. Schmid, 2000, "The Universal Banking and the Performance of German Firms," *Journal of Financial Economy*, 58, 29-80

Grossman, S., and O. Hart, 1980, "Takeover Bids, the Free-Rider Problem, and the Theory of the Corporation," *Bell Journal of Economics*, 11, 42-64

Grossman, S., and O. Hart, 1986, "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy*, 94, 691-719

Grossman, S., and O. Hart, 1988, "One Share-One Vote and the Market for Corporate Control," *Journal of Financial Economics*, 20, 175-202

Harris, M., and A. Raviv, 1988, "Corporate Governance: Voting Rights and Majority Rules," *Journal of Financial Economics*, 20, 203-235

Holdrness, C., and D. Sheehan, 1988, "The Role of Majority Shareholders in Publicly Held Corporations: An Exploratory Analysis," *Journal of Financial Economics*, 20, 317-346

Holmstrom, B., 1979, "Moral Hazard and Observability," *Bell Journal of Economics*, 10, 4-29

Holmstrom, B., and P. Milgrom, 1990, "Regulating Trade among Agents," *Journal of Institutional and Theoretical Economics*, 146, 85-105

Jensen, M., 1986, "Agency Costs and Free Cash Flow, Corporate Finance, and Takeover," *American Economic Review*, 76, 323-329

Jensen, M., 1988, "Takeover: Their Causes and Consequences," *Journal of Economic Perspectives*, 2, 21-48

Jensen, M., 1993, "The Modern Industrial Revolution, Exit, and the Failure of Internal Control Systems," *Journal of Finance*, 48, 831-880

Jensen, M., and W. Meckling, 1976, “Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure,” *Journal of Financial Economics*, 3, 305-360

Jensen, M., and K. Murphy, 1990, “Performance Pay and Top Management Incentives,” *Journal of Political Economy*, 98, 225-263

Jensen, M., and R. Ruback, 1983, “The Market for Corporate Control: The Scientific Evidence,” *Journal of Financial Economics*, 11, 5-50

Kang, J., and A. Shivdasani, 1995, “Firm Performance, Corporate Governance, and Top Executive Turnover in Japan,” *Journal of Financial Economy*, 38, 29-58

Kaplan, S., 1994, “Top Executive Rewards and Firm Performance: A Comparison of Japan and the United States,” *Journal of Political Economy*, 102, 510-546

Kaplan, S., and B. Minton, 1994, “Appointments of Outsiders to Japanese Boards: Determinants and Implications for Managers,” *Journal of Financial Economics*, 36, 225-257

Kaplan, S., and J. Stein, 1993, “The Evolution of Buy Out Pricing and Financial Structure in the 1980s,” *Quarterly Journal of Economics*, 108, 313-357

Kaplan, S., and M. Weisbach, 1992, “The Success of Acquisitions: Evidence from Divestitures,” *Journal of Finance*, 47, 107-138

Kreps, D., 1990, “A Course in Microeconomic Theory,” *Princeton University Press*

Kreps, D., 1990, “Game Theory and Economic Modeling,” *Oxford University Press*

Lambert, R., and D. Larcker, 1985, “Golden Parachutes, Executive Decision-Making and Shareholder Wealth,” *Journal of Accounting and Economics*, 7, 179-203

Lang, L., and R. Stulz, 1994, “Tobin’s Q, Corporate Diversification, and Firm Performance,” *Journal of Political Economy*, 102, 1248-1280

Lang, L., R. Stulz, and R. Walking, 1991, “A Test of the Free Cash Flow Hypothesis: The Case of Bidder Returns,” *Journal of Financial Economics*, 29, 315-336

Lewellen, W., C. Loderer, and A. Rosenfeld, 1985, “Merger Decisions and Executive Stock Ownership in Acquiring Firms,” *Journal of Accounting and Economics*, 7, 209-231

Loughran, T., J. Ritter, and K. Rydqvist, 1994, “Initial Public Offerings: International Insights,” *Pacific Basin Financial Journal*, 2, 165-199

Mace, M., 1971, “Directors, Myth, and Reality,” *Harvard Business School Press, Boston*

Manne, H., 1965, "Mergers and the Market for Corporate Control," *Journal of Political Economy*, 75, 110-126

Marris, R., 1964, "The Economic Theory of Managerial Capitalism," *Free Press of Glencoe, Illinois*

Martin, K., and J. McConnell, 1991, "Corporate Performance, Corporate Takeovers, and Management Takeover," *Journal of Finance*, 46, 671-688

McConnell, J., and C. Muscarella, 1986, "Corporate Capital Expenditure Decisions and the Market Value of the Firm," *Journal of Financial Economics*, 14, 399-422

Mirrlees, J., 1976, "The Optimal Structure of Incentives and Authority within an Organization," *Bell Journal of Economics*, 7, 105-131

Morck, R., A. Shleifer, and R. Vishny, 1988, "Characteristics of Targets of Hostile and Friendly Takeovers, in A. Auerbach, Ed.," *Corporate Takeovers: Cause and Consequences, university of Chicago Press, Chicago*

Morck, R., A. Shleifer, and R. Vishny, 1988b, "Management Ownership and Market Valuation: An Empirical Analysis," *Journal of Financial Economics*, 20, 293-315

Morck, R., A. Shleifer, and R. Vishny, 1989, "Alternative Mechanisms of Corporate Control" *American Economic Review*, 79, 842-852

Morck, R., A. Shleifer, and R. Vishny, 1990, "Do Managerial Objectives Drive Bad Acquisitions?" *Journal of Finance,* 45, 31-48

Murphy, K., 1985, "Corporate Performance and Managerial Remuneration: An Empirical Analysis," *Journal of Accounting and Economics*, 7, 11-41

Myers, S., 1977, "Determinants of Corporate Borrowing," *Journal of Financial Economics*, 5, 147-175

Pagano, M., F. Panetta, and L. Zingales, 1998, "Why Do Companies Go Public? An Empirical Analysis," *Journal of Finance,* 53, 27-64

Palepu, K., 1986, "Predicting Takeover Targets: A Methodological and Empirical Analysis," *Journal of Accounting and Economics,* 8, 3-35

Pontiff, J., A. Shleifer, and M. Weisbach, 1990, "Reversions of Excess Pension Assets after Takeovers," *Rand Journal of Economics,* 21, 600-613

Ritter, J., 1991, "The Long Run Performance of IPOs," *Journal of Finance*, 46, 3-27

Roe, M., 1994, "Strong Managers Weak Owners: The Political roots of American

Corporate Finance," *University Press, Princeton, N.J.*

Roll, R., 1986, "The Hubris Hypothesis of Corporate Takeovers," *Journal of Business*, 59, 197-216

Rossett, J., 1990, "Do Union Wealth Concessions Explain Takeover Premiums?" *Journal of Financial Economics*, 27, 263-282

Romano, R., 1993, "The Genius of American Corporate Law," *American Enterprise Institute Press, Washington, D.C.*

Ross, S., 1973, "The Economic Theory of Agency: The Principal's Problem," *American Economic Review*, 63, 134-139

Scharfstein, D., 1988, "The Disciplinary Role of Takeovers," *Review of Economic Studies*, 55, 185-199

Scharfstein, D. S., and J. C. Stein, 2000, "The Dark Side of Internal Capital Market: Divisional Rent-Seeking and Inefficient Investment," *Journal of Finance,* 55, 2537-2564

Schmidt, K., 1996, "The Costs and Benefits of Privatization," *The Journal of Law, Economics and Organization*, 12, 1-24

Shivdasani, A., 1993, "Board Composition, Ownership Structure, and Hostile Takeovers," *Journal of Accounting and Economy*, 16, 167-198

Shleifer, A., and L. Summers, 1988, "Breach of Trust in Hostile Takeover," in A. J. Auerbach, Ed., *Corporate Takeovers: Causes and Consequence, University of Chicaro Press, Chicago,* 65-88

Shleifer, A., R. W. Vishny, 1986, "Larger Shareholders and Corporate Control," *Journal of Political Economy*, 94, 461-488

Shleifer, A., R. W. Vishny, 1988, "Value Maximization and the Acquisition Process," *Journal of Economic Perspectives*, 2, 7-20

Shleifer, A., R. W. Vishny, 1989, "Management Entrenchment: The Case of Manager-Specific Investment," *Journal of Financial Economics,* 25, 123-140

Shleifer, A., R. W. Vishny, 1993, "Corruption," *Quarterly Journal of Economics*, 108, 599-618

Shleifer, A., R. W. Vishny, 1997, "A Survey of Corporate Governance," *Journal of Finance*, 52, 737-783

Smith, C., and J. Warner, 1979, “On Financial Contracting: An Analysis of Bond Covenants,” *Journal of Financial Economics*, 7, 117-161

Stiglitz, J., 1975, “Incentives, risk, and Information: Notes toward a Theory of Hierarchy,” *Bell Journal of Economics*, 6, 552-579

Teoh, S. H., I. Welch, and T. J. Wang, 1998, “Earning Management and the Underperformance of Seasoned Equity Offerings,” *Journal of Financial Economics*, 50, 63-99

Warner, J., and R. Watts, and K. Wruck, 1988, “Stock Prices and Top Management Changes,” *Journal of Financial Economics*, 20, 461-492

Walkling, R., and M. Long, 1984, “Agency Theory, Managerial Welfare, and Takeover Bid Resistance,” *Bell Journal of Economics*, 15, 54-68

Weisbach, M., 1988, “Outside Directors and CEO Turnover,” *Journal of Financial Economics*, 20, 431-460

Williamson, O., 1964, “The Economics of Discretionary Behavior: Managerial Objectives in a Theory of the Firm,” *Prentice Hall, Englewood Cliffs, N.J.*

Williamson, O., 1985, “The Economic Institutions of Capitalism,” *Free Press, New York*

Yafeh, Y., and O. Yosha, 2003, “Large Shareholders and Banks: Who Monitors and How?” *The Economic Journal*, 113, 128-146

Appendix 2.A

Proofs of Proposition 1 and Proposition 2 have been discussed in the context

Proof of Proposition 3

(1) In Case 1,

$$\frac{\partial m}{\partial L}=\frac{\partial\left\{\dfrac{[B_1-\frac{1}{2}(B_2+\alpha W_1R)]}{2a}(1-r)\right\}}{\partial L}=\frac{\partial\left\{\dfrac{\{\alpha W_2R+\ell-[\alpha R+(1-\alpha)(-L)]\}}{4a}(1-r)\right\}}{\partial L}=\frac{(1-\alpha)(1-r)}{4a}>0$$

$$\frac{\partial\pi}{\partial L}=-\frac{1}{2}(1-m)(1-r)(1-\alpha)-\frac{(1-r)(1-\alpha)}{4a}(1-r)\cdot\left\{\frac{1}{2}\big[(-\ell)+\alpha(1-W_2)R+(1-\alpha)(-L)\big]\right\}$$

$$-2am\frac{(1-r)(1-\alpha)}{4a}$$

$$\leq-\frac{1}{2}(1-r)(1-\alpha)+\frac{(1-r)(1-\alpha)}{4a}(1-r)\cdot\frac{2a}{1-r}=0$$

(2) In Case 2,

$$\frac{\partial m}{\partial L}=\frac{\partial\left\{\dfrac{B_1-\alpha W_1R-\frac{1}{2}\alpha T}{2a}(1-r)\right\}}{\partial L}=\frac{\partial\left\{\dfrac{\alpha W_2R-[\alpha R+(1-\alpha)(-L)]-\frac{1}{2}\alpha T}{2a}(1-r)\right\}}{\partial L}=\frac{(1-\alpha)(1-r)}{2a}>0$$

$$\frac{\partial\pi}{\partial L}=-(1-m)(1-r)(1-\alpha)-\frac{(1-r)(1-\alpha)}{2a}(1-r)\cdot\big\{-\alpha W_2R+[\alpha R+(1-\alpha)(-L)]\big\}$$

$$-2am\frac{(1-\alpha)(1-r)}{2a}$$

$$\leq-(1-r)(1-\alpha)+\frac{(1-r)(1-\alpha)}{2a}(1-r)\frac{2a}{1-r}=0$$

Proof of Proposition 4

(1) In Case 1,

$$\frac{\partial m}{\partial a}=\frac{-2(1-r)\left(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R\right)}{4a^2}=-\frac{(1-r)}{2a^2}\left(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R\right)<0$$

$$\frac{\partial \pi}{\partial a}=\frac{(1-r)^2}{2a^2}(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R)\left\{\frac{1}{2}\left[(-\ell)+\alpha(1-W_2)R+(1-\alpha)(-L)\right]\right\}$$

$$-\frac{(1-r)^2}{4a^2}(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R)^2+\frac{(1-r)^2}{2a^2}(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R)^2$$

$$=\frac{(1-r)^2}{4a^2}(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R)\left\{(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R)+2\left\{\frac{1}{2}\left[(-\ell)+\alpha(1-W_2)R+(1-\alpha)(-L)\right]\right\}\right\}$$

$$=\frac{(1-r)^2}{4a^2}(B_1-\frac{1}{2}B_2-\frac{1}{2}\alpha W_1 R)\left\{\frac{1}{2}\{\ell-\alpha(1-W_2R)-(1-\alpha)(-L)\}\right\}(1-2)<0$$

(2) In Case 2,

$$\frac{\partial m}{\partial a}=\frac{-2(1-r)(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)}{4a^2}=-\frac{(1-r)}{2a^2}(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)<0$$

$$\frac{\partial \pi}{\partial a}=\frac{(1-r)^2}{2a^2}(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)\left\{\frac{1}{2}\alpha T-\alpha W_2 R+[\alpha R+(1-\alpha)(-L)]\right\}$$

$$-\frac{(1-r)^2}{4a^2}(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)^2+\frac{(1-r)^2}{2a^2}(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)^2$$

$$=\frac{(1-r)^2}{4a^2}(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)\left\{(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)+2\left\{\frac{1}{2}\alpha T-\alpha W_2 R+[\alpha R+(1-\alpha)(-L)]\right\}\right\}$$

$$=\frac{(1-r)^2}{4a^2}(B_1-\alpha W_1 R-\frac{1}{2}\alpha T)\left\{-\frac{1}{2}\alpha T+\alpha W_2 R-[\alpha R+(1-\alpha)(-L)]\right\}(1-2)<0$$

Proof of Proposition 5

$$\pi_2 = (1-m_2)(1-r)\left\{\frac{1}{2}\{\alpha(T - W_2R) + [\alpha R + (1-\alpha)(-L)\} + \frac{1}{2}\{-\alpha W_2 R + [\alpha R + (1-\alpha)(-L)]\}\right\}$$

$$+ r(1-W_2)S - U_1 - a(m_2)^2$$

$$\leq (1-m_2)(1-r)\left\{\frac{1}{2}(-\ell) + \frac{1}{2}\{-\alpha W_2 R + [\alpha R + (1-\alpha)(-L)]\}\right\} + r(1-W_2)S - U_1 - a(m_2)^2$$

$$\leq (1-m_1)(1-r)\left\{\frac{1}{2}(-\ell) + \frac{1}{2}\{-\alpha W_2 R + [\alpha R + (1-\alpha)(-L)]\}\right\} + r(1-W_2)S - U_1 - a(m_1)^2 = \pi_1$$

$$\therefore \pi_1 \geq \pi_2$$

Table 2.1

Table 2.1 presents the equilibrium m and p_r determined by Agent_1 and Agent_2 given any incentive contract (B_1, B_2). The ranges of the incentive contact (B_1, B_2) for Zone A, Zone B, Zone C, Zone D are also specified in Figure 2.4. The correspondent values of the equilibrium m and p_r are derived from Equation (2.5) and Equation (2.9).

Zone	The Range of the Incentive Contract (B_1, B_2)	The Equilibrium m and p_r
A	$B_1 - \frac{1}{2}B_2 \geq \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}$	$m = 1$, $p_r = 0$
B	$\frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}\left(1 - \frac{2S}{\alpha R}\right) \leq B_1 - \frac{1}{2}B_2 \leq \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}$	$m = \frac{\left[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)\right]}{2a}(1-r) \in \left[1 - \frac{2S}{\alpha R}, 1\right]$, $p_r = 0$
C	$\frac{1}{2}\alpha W_1 R + 2a\left(1 - \frac{2S}{\alpha R}\right) \leq B_1 - \frac{1}{2}B_2 \leq \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}\left(1 - \frac{2S}{\alpha R}\right)$	$m = 1 - \frac{2S}{\alpha R}$, $p_r = 1 - \frac{B_1 - \frac{1}{2}(B_2 + \alpha W_1 R) - 2a\left(1 - \frac{2S}{\alpha R}\right)}{r\left[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)\right]} \in [0,1]$
D	$B_1 - \frac{1}{2}B_2 < \frac{1}{2}\alpha W_1 R + 2a\left(1 - \frac{2S}{\alpha R}\right)$	$m = \frac{\left[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)\right]}{2a} \in \left[0, 1 - \frac{2S}{\alpha R}\right)$, $p_r = 1$

Table 2.2

Table 2.2 presents Principal's expected payoff functions under Zone A, Zone B, Zone C, Zone D in Figure 2.4, and the correspondent optimal incentive contract (B_1, B_2); in Zone B, the optimal incentive contract (B_1, B_2) is specified in Table 3. The optimal incentive contract (B_1, B_2) in Zone A and Zone C is located in the corner solution shared with Zone B, and thus they can be included in the optimal incentive contract (B_1, B_2) of Zone B as well. Besides, there is no optimal incentive contract (B_1, B_2) in Zone D, where the equilibrium $m < m^*$ and $p_r = 1$. This is because as the optimal incentive contract (B_1, B_2) is located in Zone D, Agent_1's monitoring *m* is low and Agent_2 takes on the high risky project with probability one. Therefore, Principal's expected payoff is negative in Zone D and thus the optimal incentive contract (B_1, B_2) cannot be located in Zone D.

Zone	Principal's Payoff Function	The Optimal Incentive Contract (B_1, B_2)
A	$\pi = r(1-W_2)S - U_1 - a$	$B_1 = \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}$ $B_2 = \alpha W_1 R + \alpha T$
B	$\pi = (1-m)(1-r)\cdot\left\{\frac{1}{2}\left[(-\ell) + \alpha(1-W_2)R + (1-\alpha)(-L)\right]\right\}$ $+ r(1-W_2)S - U_1 - am^2$	See Table 3
C	$\pi = \frac{2S}{\alpha R}(rp_r + 1 - r)\left\{\frac{1}{2}(-\ell) + \frac{1}{2}\left[\alpha(1-W_2)R + (1-\alpha)(-L)\right]\right\}$ $+ r(1-p_r)(1-W_2)S - U_1 - a\left(1 - \frac{2S}{\alpha R}\right)^2$	$B_1 = \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}\left(1 - \frac{2S}{\alpha R}\right)$ $B_2 = \alpha W_1 R + \alpha T$
D	$\pi = (1-m)\left\{\frac{1}{2}(-\ell) + \frac{1}{2}\left[\alpha(1-W_2)R + (1-\alpha)(-L)\right]\right\}$ $-U_1 - am^2 < 0$	No optimal (B_1, B_2)

Table 2.3

Table 2.3 presents three conditions regarding Principal's expected payoffs under Zone B, and the correspondent optimal incentive contract (B_1,B_2). We conclude that the optimal incentive contract (B_1,B_2) in Zone B depends on Principal's expected loss when Agent_1 does not identify the risky Agent_2 at Stage_1.

Zone	The Condition	The Optimal Incentive Contract (B_1,B_2)
B	$\frac{1}{2}(-\ell)+\frac{1}{2}[-\alpha W_2 R+\alpha R+(1-\alpha)(-L)]\le -\frac{2a}{1-r}$	$B_1=\alpha W_1 R+\frac{1}{2}\alpha T+\frac{2a}{1-r}$, $B_2=\alpha W_1 R+\alpha T$
	$-\frac{2a}{1-r}<\frac{1}{2}(-\ell)+\frac{1}{2}[-\alpha W_2 R+\alpha R+(1-\alpha)(-L)]<$ $-\frac{2a}{1-r}(1-\frac{2S}{\alpha R})$	$B_1=\alpha W_1 R+\frac{1}{2}\alpha T+\frac{1}{2}\{\ell+\alpha W_2 R$ $-[\alpha R+(1-\alpha)(-L)]\}$ $B_2=\alpha W_1 R+\alpha T$
	$-\frac{2a}{1-r}(1-\frac{2S}{\alpha R})\le\frac{1}{2}(-\ell)+\frac{1}{2}[-\alpha W_2 R+\alpha R+(1-\alpha)(-L)]$	$B_1=\alpha W_1 R+\frac{1}{2}\alpha T+\frac{2a}{1-r}\left(1-\frac{2S}{\alpha R}\right)$ $B_2=\alpha W_1 R+\alpha T$

Table 2.4

Table 2.4 presents the equilibrium m and p_r determined by Agent_1 and Agent_2 given any incentive contract B_1. The range of the incentive contact B_1 for Segment A, Segment B, Segment C, Segment D are also specified in Figure 2.6. The correspondent values of the equilibrium m and p_r are derived from Equation (2.13) and Equation (2.17).

Segment	The Range of the Incentive Contract B_1	The Equilibrium m and p_r
A	$B_1 \geq \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}$	$m = 1$, $p_r = 0$
B	$\alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right) \leq$ $B_1 \leq \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}$	$m = \frac{B_1 - \alpha W_1 R - \frac{1}{2}\alpha T}{2a}(1-r) \in \left[1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}, 1\right]$ $p_r = 0$
C	$\alpha W_1 R + \frac{1}{2}\alpha T + 2a\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right) \leq$ $B_1 \leq \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$	$m = 1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}$, $p_r = 1 - \frac{1 - \frac{2a}{B_1 - \alpha W_1 R - \frac{1}{2}\alpha T}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)}{r}$ $\in [0,1]$
D	$B_1 < \alpha W_1 R + \frac{1}{2}\alpha T + 2a\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$	$m = \frac{B_1 - \alpha W_1 R - \frac{1}{2}\alpha T}{2a} \in \left[0, 1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$, $p_r = 1$

Table 2.5

Table 2.5 presents Principal's expected payoff functions under Segment A, Segment B, Segment C, Segment D in Figure 2.6, and the correspondent optimal incentive contract B_1; in Segment B, the incentive contract B_1 is specified in Table 2.6. The optimal incentive contract B_1 in Segment A and Segment C is located in the corner solution shared with Segment B, and thus they can be included in the optimal incentive contract B_1 of Segment B as well. Besides, there is no optimal incentive contract B_1 in Segment D, where the equilibrium $m < m^{**}$ and $p_r = 1$. This is because as the optimal incentive contract B_1 is located in Segment D, Agent_1's monitoring m is low and Agent_2 takes on the high risky project with probability one. Therefore, Principal's expected payoff is negative in Segment D and thus the optimal incentive contract B_1 cannot be located in Segment D.

Seg-ment	Principal's Payoff Function	The Optimal Incentive Contract B_1
A	$\pi = r(1-W_2)S - U_1 - a$	$B_1 = \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}$
B	$\pi = (1-m)(1-r)\cdot\left[\frac{1}{2}\alpha T + \alpha(1-W_2)R + (1-\alpha)(-L)\right] + r(1-W_2)S - U_1 - am^2$	See Table 6
C	$\pi = \left(\frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)(rp_r + 1 - r)\left[(1/2)\alpha T + \alpha(1-W_2)R + (1-\alpha)(-L)\right] + r(1-p_r)(1-W_2)S - U_1 - a\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)^2$	$B_1 = \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$
D	$\pi = (1-m)\left[\frac{1}{2}\alpha T + \alpha(1-W_2)R + (1-\alpha)(-L)\right] - U_1 - am^2 < 0$	No optimal B_1

Table 2.6

Table 2.6 presents three conditions regarding Principal's expected payoffs under Segment B, and the correspondent optimal incentive contract B_1. We conclude that the optimal incentive contract B_1 in Segment B depends on Principal's expected loss when Agent_1 does not identify the risky Agent_2 at Stage_1.

Segment	The Condition	The Optimal Incentive Contract B_1
B	$\frac{1}{2}\alpha T - \alpha W_2 R + \alpha R + (1-\alpha)(-L) \le -\frac{2a}{1-r}$	$B_1 = \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}$
	$-\frac{2a}{1-r} < \frac{1}{2}\alpha T - \alpha W_2 R + \alpha R + (1-\alpha)(-L) < -\frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$	$B_1 = \alpha W_1 R + \alpha W_2 R - [\alpha R + (1-\alpha)(-L)]$
	$-\frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right) \le \frac{1}{2}\alpha T - \alpha W_2 R + \alpha R + (1-\alpha)(-L)$	$B_1 = \alpha W_1 R + \frac{1}{2}\alpha T + \frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$

Figure 2.1

Figure 2.1 presents that there are four stages in the model. The endogenous variables are the incentive contract (B_1, B_2), Agent_1's monitoring and the probability of the rational Agent_2's taking on the high risky project.

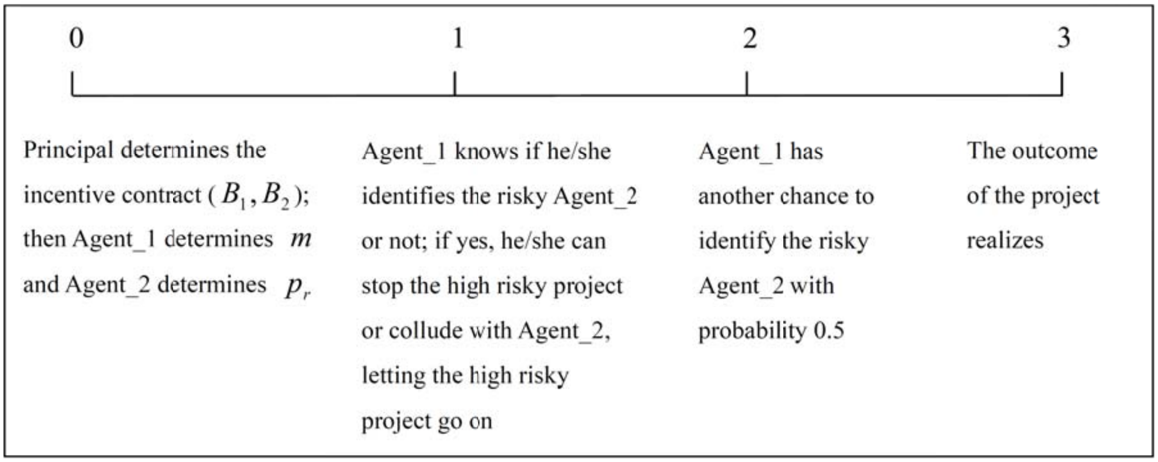


Figure 2.2

Figure 2.2 contains the decision tree graph for Agent_1 and Agent_2, which is also the extensive game form in the model. In the graph, Agent_1 is denoted by "I" and Agent_2 is denoted by "II"; Nature is denoted by "N". Agent_1's and Agent_2's payoffs are included in the parenthesis at the terminal node. Besides, the probability that Agent_2 takes on the high risky project is equal to the ratio of the rational and irrational Agent_2 times the probability of taking on the high risky project.

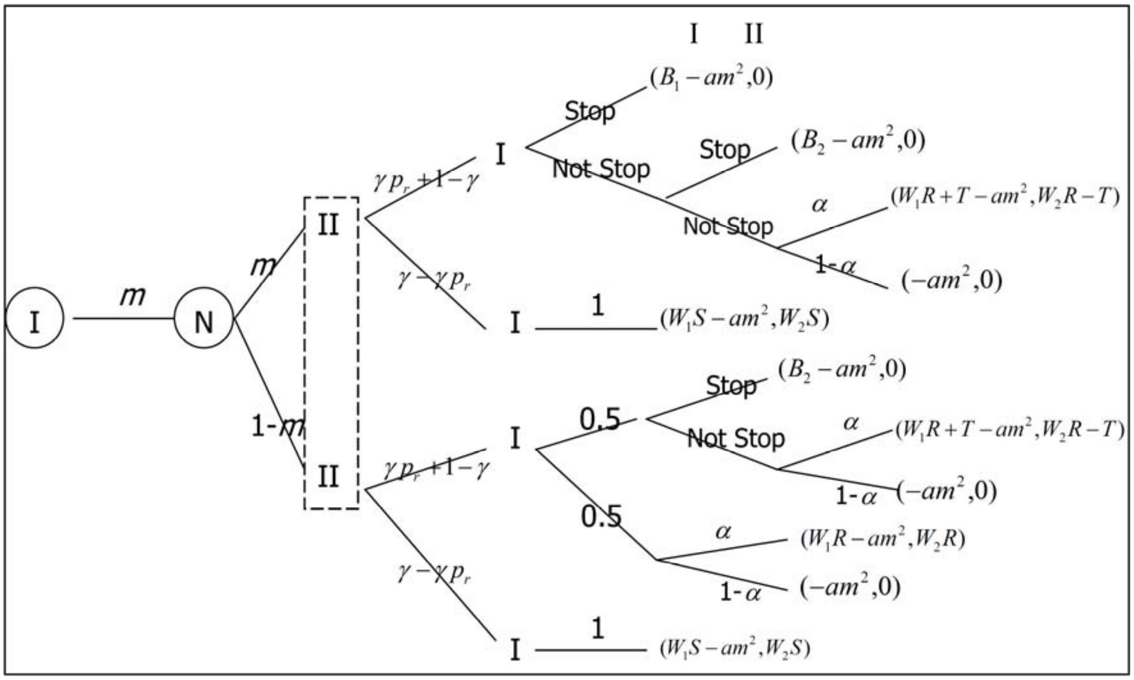
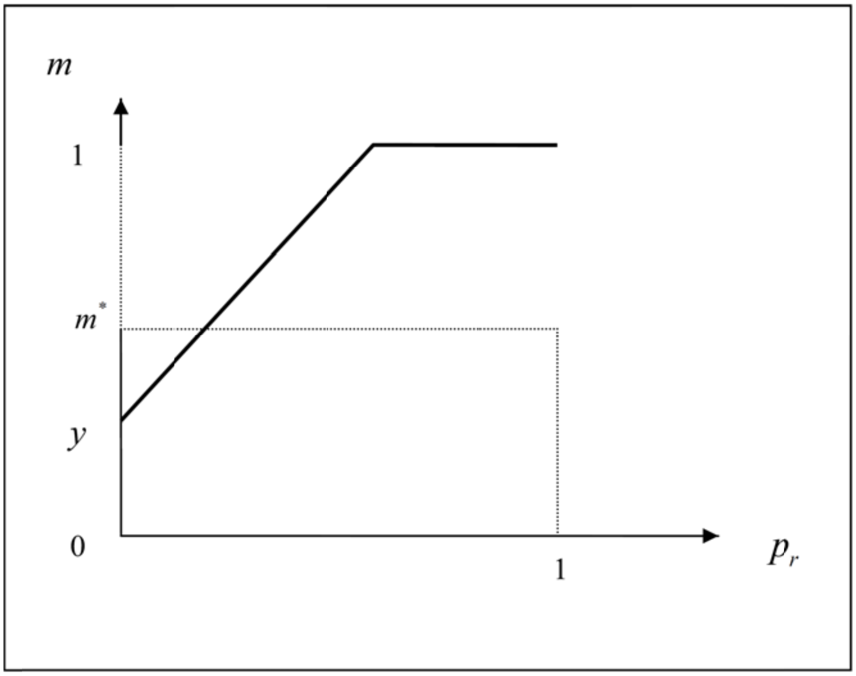


Figure 2.3

Figure 2.3 contains one example of the equilibrium *m* and p_r by Agent_1 and the rational Agent_2 given an incentive contract (B_1, B_2). The black line, expressed in Equation (2.5), is Agent_1's reaction function given Agent_2's probability of taking on the high risky project; the dotted line, showed in Equation (2.9), is Agent_2's reaction function given Agent_1's monitoring *m*. The crossover point of these two lines is the equilibrium *m* and p_r by Agent_1 and the rational Agent_2, which is determined by the value of the incentive contract (B_1, B_2).

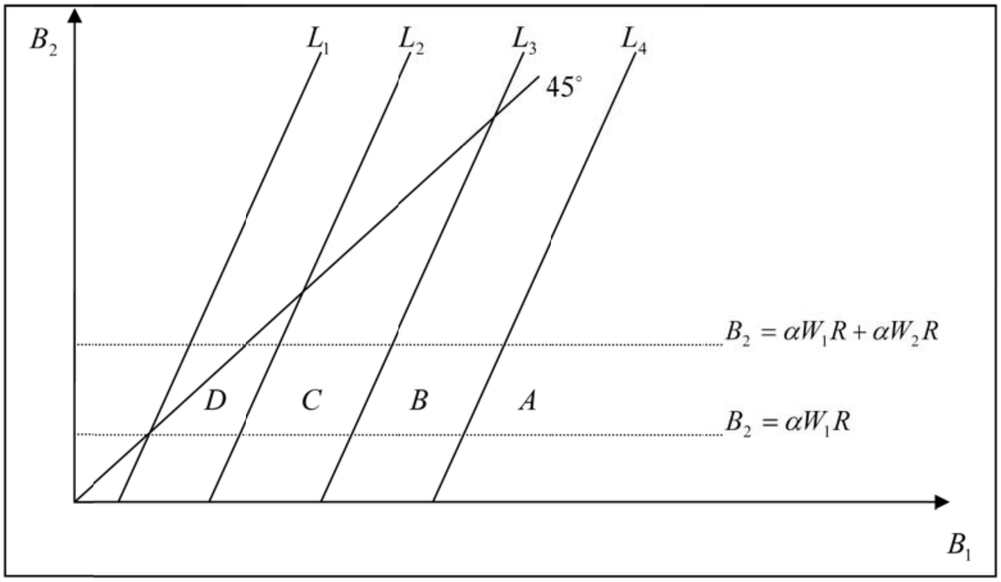


$$m^* = 1 - \frac{2S}{\alpha R}, \quad y = \frac{\left[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)\right]}{2a}(1-r),$$

The slope of the black line: $\dfrac{\left[B_1 - \frac{1}{2}(B_2 + \alpha W_1 R)\right]}{2a} r$

Figure 2.4

Figure 2.4 present possible values of the incentive contract (B_1, B_2) in Case_1. The possible values of the incentive contract (B_1, B_2) should be located in Zone A, Zone B, Zone C, or Zone D, in Figure 4, which is classified by the range of incentive contract (B_1, B_2) in Table 2.1.



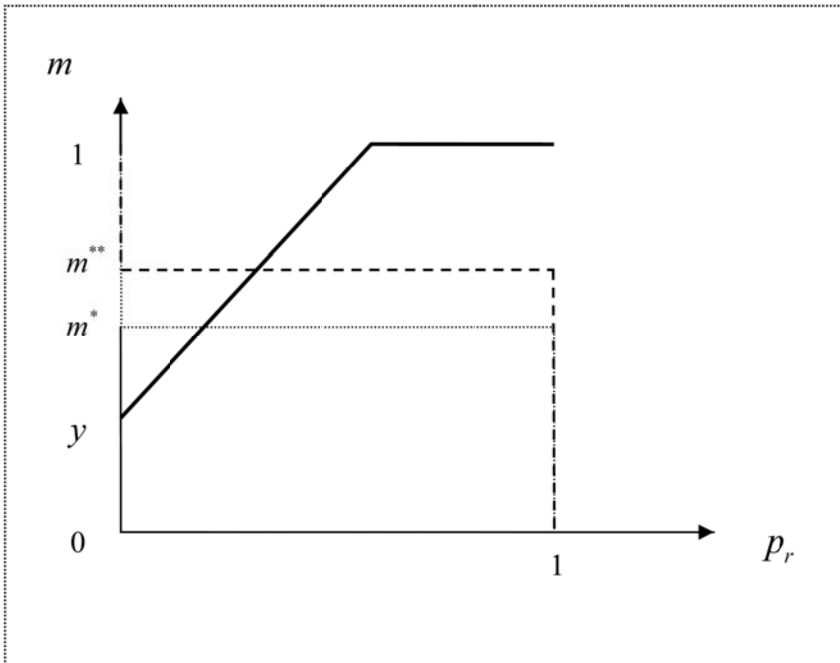
$$L_1 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R\,, \quad L_2 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + 2a(1 - \frac{2S}{\alpha R})$$

$$L_3 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}(1 - \frac{2S}{\alpha R})$$

$$L_4 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}$$

Figure 2.5

Figure 2.5 presents one example of the equilibrium m and p_r by Agent_1 and the rational Agent_2 given an incentive contract B_1. The black line, expressed in Equation (2.13), is Agent_1's reaction function given Agent_2's probability of taking on the high risky project. There are two dotted lines: The thick dotted line is Agent_2's reaction function given Agent_1's monitoring m in Case_2; and the thin dotted line is Agent_2's reaction function given Agent_1's monitoring m in Case_1. The crossover point of the black line and the dotted line is the equilibrium m and p_r by Agent_1 and the rational Agent_2, which is determined by the value of the incentive contract B_1.



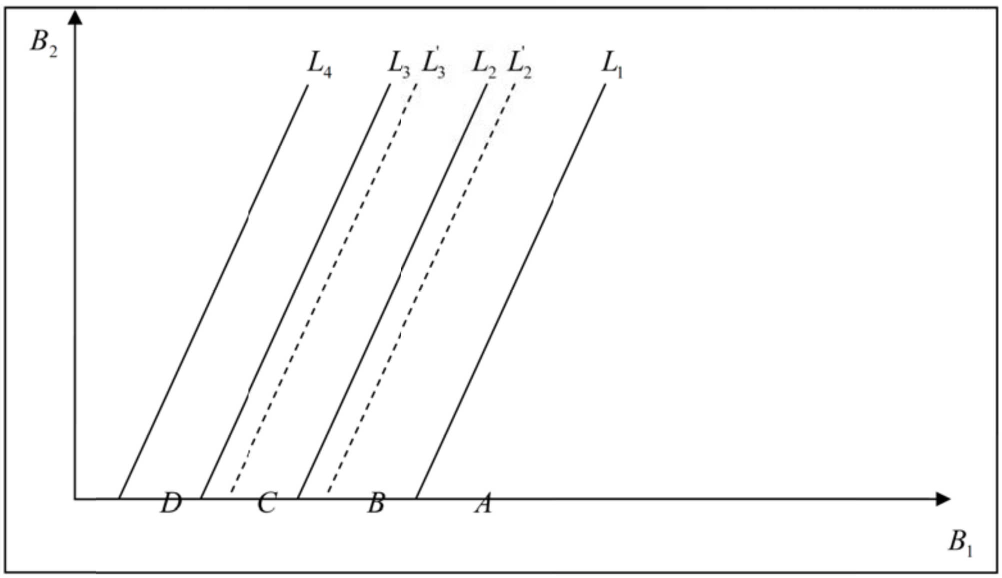
$$m^* = 1 - \frac{2S}{\alpha R}, \quad m^{**} = 1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}$$

$$y = \frac{\left(B_1 - \alpha W_1 R - \frac{1}{2}\alpha T\right)}{2a}(1-r),$$

The slope of the black line: $\frac{\left(B_1 - \alpha W_1 R - \frac{1}{2}\alpha T\right)}{2a} r$

Figure 2.6

Figure 2.6 present possible values of the incentive contract B_1 in Case_2. The possible values of the incentive contract B_1 should be located in Segment A, Segment B, Segment C, or Segment D, which is classified by the range of incentive contract B_1 in Table 4. Note that the range of Segments depends on the value of *T*. If $T = W_2 R$, the range of Segments depends on Line L_1, L_2, L_3, L_4, which are the same as Case_1; If $W_2 R > T \geq 0$, the range of Segments is determined by Line L_1, $L_2^{'}$, $L_3^{'}$, L_4.



$$L_1 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}, \quad L_2 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}(1 - \frac{2S}{\alpha R})$$

$$L_3 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + 2a(1 - \frac{2S}{\alpha R}), \quad L_4 : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R,$$

$$L_2^{'} : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + \frac{2a}{1-r}\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right),$$

$$L_3^{'} : B_1 - \frac{1}{2}B_2 = \frac{1}{2}\alpha W_1 R + 2a\left(1 - \frac{W_2 S}{\alpha W_2 R - \frac{1}{2}\alpha T}\right)$$

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Working Papers

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