Anatomy of Bid-Ask Spread: Empirical Evidence from an Order Driven Market

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Abstract

Under fairly basic rationales, this paper provides a more general microstructure model of price quotation in an order driven market. As an extension of Handa and Schwartz (1996), we decompose the equilibrium of the bid-ask spread, which is derived as a function of the weighted average of three factors including the different valuation of traders and the expected loss of adverse selection from buyers and sellers, respectively, into the implicate components which evolve from the characteristics of traders and market competition. More importantly, we can distinguish the expected loss of adverse selection, which is endogenously formed in our model, between buyers and sellers and investigate the key determinants of the expected loss of adverse selection. The numerical tests clearly show the relationships between the spread and all exogenous parameters. Furthermore, the empirical tests using transaction data on all listed shares in TAIEX provide strong support for our model and show that the asset volatility and the probability of informed trading are positively related to the adverse selection costs. Our results indicate that on average the different valuations account for approximately 26.02% of the bid-ask spread, seller's expected loss of adverse selection account for 36.95% , and buyer's one account for 37.03%..

Key words: Market Microstructure, Order Strategy, Bid-Ask Spread, Adverse Selection Cost, Price Formation, Order Driven Market, Reward-to-Variability Ratio.

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1. Introduction

This article attempts to derive a more general model of price quotation in an order driven market and integrates the several key rationales into the model. We are interested in understanding what are the critical determinants of the bid-ask spread and the adverse selection cost. Furthermore, our model could decompose the bid-ask spread into distinct components which imply the significant implications. This paper presents that the components depends on the characteristics of traders and market competition. Those are contributive to explore the dynamic aspects of order submission strategies. In addition, this study exploits the order and trade data of all listed stocks on the Taiwan Stock Exchange to examine our model. The empirical tests show that the characteristics of traders and market competition are the fundamental elements for the formation of the bid-ask spread indeed, and the numerical tests as well. Order driven system is widespread trading mechanism in the wake of information technology development. Nowadays, order driven markets are essential as quote driven markets in international securities exchanges ;[1] nevertheless throughout the literatures, the related studies of order driven markets are comparatively insufficient until recently. Our study presents a comprehensive perspective on the quotation behavior in the literature body.

In order driven markets, traders can carry out their trades by submitting either limit order that specifies a price for uncertain execution or market order for immediate execution with certainty. Hence, a trader placing limit order has possibility to improve her price to increase payoff but confronts the risk of not being executed and the risk of informed trading. All participants solve this choice problem of limit and market order by submitting the type of order which generates the maximum expected profit. However, in the analysis of the decision process, we should carefully calculate the expected profit in terms of limit order under the price improvement and the risks of non-execution and informed trades, because we focus the order strategy on the estimation of the limit and market orders' expected profits of traders to indirectly infer the equilibrium of price quotation, which is at the quoted price under the indifference of expected profits between limit order and market order.

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[1] For instance, the Australian Stock Exchange, the Helsinki Stock Exchange, the Hong Kong Stock Exchange, the Indian stock market, the Spanish Stock Exchange, the Swiss Stock Exchange, the Taiwan Stock Exchange, the Tokyo Stock Exchange, the Stock Exchange of Thailand, the Paris Bourse, and the Vancouver Stock Exchange etc.

Our ultimate objective is to decompose the bid-ask spread to analyze the implicit causes of the components. We extend the model of Handa and Schwartz (1996) who, according to the original basic rationales, offer a simple prototype of price formation for an order driven market but do not have an explicit model. Notwithstanding Handa, Schwartz, and Tiwari (2003) have explicitly modeled price formation, they do not endogenously incorporate adverse selection cost into the bid-ask spread and discriminate buyers from sellers. The basic rationales of order strategy from previous studies are the valuation of traders and asymmetric information. In this paper, we refine and extend the basic rationales, which include heterogeneous beliefs, adverse selection and the reward-to-variability ratio of investment, into our model.

Since transactions are possible to happen to the heterogeneous beliefs of traders, the expected value of the risky asset reflects the beliefs of traders. Consequently, the market price will collect the expected values of asset from those participants. Other articles have dealt with a dynamic equilibrium model of the limit order. Foucault (1999) suggests that the order placement strategy is related to the valuation of traders' beliefs. Handa, Schwartz, and Tiwari (2003) study that the different valuation among investors is the determinant of the size of the bid-ask spread. As a result, the beliefs of traders determine the direction of market price.[2] Some researches study with an emphasis on the evolution of heterogeneous beliefs. For instance, Foster and Viswanathan (1996) consider a rational expectations model in which heterogeneous beliefs arise among differentially informed traders. Wang (1998) examines a behavioral model in which heterogeneous beliefs arise between the overconfident informed trader and the rational market makers. Therefore, we further conducted an analysis of the heterogeneous beliefs including public information and noisy private signals. In light of the same public information, different traders have different assessments of the risky asset. However, while traders acquire the noisy signals of the asset in private way, they will personally revise their reservation value of the risky asset. So, we incorporate the heterogeneous beliefs of traders, who source information from public and private, into our model of the order strategy.

In addition, traders trade with the informed traders to suffer the loss of adverse selection. Copeland and Galai (1983) show that the spread of market maker who provide liquidity should generate enough returns to cover the cost of trading with informed traders.[3] Glosten (1994) analyses limit order traders' decision which gain from liquidity and lose from information in an open limit order book. They suggest

[2] Hong and stein (1999), Daniel, Hirshleifer, and Subrahmanyam (1998) and Barberis, Shleifer, and Vishny (1998) provide behavior models to analyze that the psychology biases of traders dominate the direction of stock price.

[3] Other related papers include Demsetz (1968), Bagehot (1971), Tinic and West (1972), Branch and Freed (1977), Glosten and Milgrom(1985) and Stoll(1989).

that the open limit order book provides as much liquidity as can be expected in extreme adverse selection environments. As a matter of factor, no matter what kind of trading mechanism, the participants who provide the liquidity to the market must face the risk of adverse selection. Other works on order driven market emphasize the asymmetric information problem, such as Handa and Schwartz (1996) who consider the two kind risks of the limit orders which are the adverse information triggering harmful execution and the favorable news failing execution. Besides, they suggest that the profitability of limit trading from the arrival of liquidity traders sufficiently offset the loss of abovementioned risks is essential to the viability of an order driven market without the intervention of dealers. Handa, Schwartz, and Tiwari (2003) show similarly that the size of the spread is a function of the difference of valuation among investors and asymmetric information costs. Basically, limit order traders resemble dealers in that they provide liquidity and immediacy to the market and encounter the problem of asymmetric information, so that their spread should generate enough return, which is price improvement here, to cover the loss of adverse selection. Furthermore, the size of liquidity that limit order buyers provide is different the one that limit order sellers provide, the result that they should suffer different losses of adverse selection. Even, the buyers compete with the sellers for the demand and the supply of liquidity, and then buyers' adverse selection costs twisted with sellers' melt into the bid-ask spread. Yet, until now, the losses of adverse selection have not been well explored to bring on an incomplete analysis of price formation. The former researches always give exogenously the loss in analyzing the adverse selection problem. Indeed, participants in practice only endogenously estimate the loss rather than to accurately learn the certain loss. However, previous models can not estimate the expected loss of adverse selection and not discriminate the loss what is for buyers from sellers; and further, adverse selection costs of their model are exogenously given that is hardly to analyze the formation causes of spread about informed trades in dynamic market. We try to establish a model which could endogenously forms the expected loss of adverse selection, furthermore, and investigates the magnitude of the expected loss of adverse selection faced by buyers and sellers in an order driven market.

Finally, we suggest that the reward-to-variability ratio of the investment is negatively related to the bid-ask spread. While the risk of the investment increases, traders are likely to suffer huge adverse selection loss. On the contrary, while the expected profit of the investment increases, traders are not likely to suffer huge adverse selection loss. For this reason, limit order traders ask a larger compensation for the risk of informed trades with higher risk of the investment, and they compromise on a smaller compensation for the risk of informed trades with higher expected profit of the investment. Hence, the reward-to-variability ratio of the investment, which is negatively related to the expected loss of adverse selection, is also one of basic rationales for order strategies. Foucault (1999) provides a model of price formation and order placement decisions of the investors who face a risk of non-execution and a winner's curse problem. Their primary finding is that the volatility of risky assets is a key determinant of the order strategy decision. Limit order traders ask for a larger compensation facing the risk of adverse selection with higher volatility of asset. According to the inference, the posted spreads are positively related to asset volatility. Sandas (2001) finds the evidence that the agents face more (less) severe adverse selection risk in order driven markets with higher (lower) stock-specific or market-wide volatility. In spite of those studies considering the volatility of risky assets, that is not complete, because a rational trader generally evaluate her investment decision by two measures, the expected profit and the risk of the investment. Sharpe (1966) introduces the reward-to-variability ratio measure for the performance of mutual funds, which integrated the two measures as return and risk. Hence, we incorporate the concept of the reward-to-variability ratio into the analysis of the adverse selection costs.

In our model, we set an economical ecology where uninformed traders harbor heterogeneous beliefs of public information and noisy private signals, burden the risks of no-execution and adverse selection, and appraise the adverse selection costs by the reward-to-variability ratio. Comprehensively, multiple parameters that describe the characteristics of distinct traders and market competition mutually determine the static equilibrium of the bid-ask spread. Furthermore, we numerically estimate a variety of static equilibriums based on those related parameters. The main results from the numerical tests are the following:

(i) The heterogeneity of traders' valuation decreases the expected loss of adverse selection and increases the bid-ask spread.

(ii) The maximum of spread is at the most balance proportion of both side traders. In contrast, the minimum of spreads are at the most imbalance proportion.

(iii) The probability of informed trading is positively associated with the expected loss of adverse selection and the bid-ask spread.

(iv) While traders could evaluate true value with a smaller variance, they could pinpoint the true value more precisely. Hence, if traders have no confidence of their calculation of true value accompanying with larger variance, they consider that they will suffer more expected loss from adverse selection.

(v) The precision of private noisy signals decreases the expected loss of adverse selection.

Furthermore, this study exploits the order and trade data of all listed shares on the Taiwan Stock Exchange to examine our model. Firstly, univariate tests show that the bid-ask spreads appear an inverted-U shape as the proportion of sellers to all traders is varied. Secondly, we perform multiple regressions to investigate the influence of the two key determinants including the probability of informed trading and the volatility of assets on the bid-ask spread. All findings are significant consistently with our predictions and the literatures.[4] Besides, our results indicate that on average the different valuations account for approximately 26.02% of the bid-ask spread for TAIEX, seller's expected loss of adverse selection account for approximately 36.95%, and buyer's one account for approximately 37.03%.

This article is organized as follows. In Section 2, we infer the model of order submission strategy and analyze the components of the bid-ask spread. Section 3 contains the inference of the equilibrium price quotation of the model. In Section 4, we examine a variety of numerical tests. The analysis of numerical results summarizes the economical implication. We empirically examine univariate tests and regression tests of our model in Section 5. Our conclusions are presented in Section 6.

2. A Model of Order Strategy

A. The Modeling Framework

A.1 Traders Classification and Noisy Private Signal

It is assumed that there is a single risky asset that be traded only one share each order under sequential trading process in an order driven market. All potential participants can either submit a market order, which trades against the living limit order of best price at its arrival time in the limit order book, or a limit order at a specified price, which enters the book with that price and waits for future market order matching. Consequently, market orders are made sure the execution with being given transaction price from the market, but limit orders are likely to improve their profits and expose to the two risks of the uncertain execution of self-setting price and the trading loss with latent informed traders. In other words, traders face the dilemma of this order choice. We presume that order submission strategy of traders depends completely on the expected profits of the orders. The order which generates the maximum expected profit is the optimal order submission. Furthermore, in a continuous market environment, arrival of investors' order sequentially occurs, so an

[4] Nyholm (2003) and Hong and Wang (2000) show that since the estimated probability of informed trading is larger in the morning than in the afternoon, larger spreads are quoted right after the opening of the exchange as a protection against informed agents. Foucault (1999) and Sandas (2001) find that higher adverse selection risk in markets accompany with higher stock-specific volatility.

understanding of the order dynamics enhances our knowledge of the price formation in the order driven market.

Suppose that investors are classified four groups according to their motivation and information. First two groups are sorted out by their assessment of public information. First group is buyer group where investors with higher reservation value interpret homogeneously that the market price undervalues. Second group is seller group where investors with lower reservation value interpret homogeneously that the market price overvalues. Moreover, the agents of first or second group separately observe noisy private signals on the fundamental value of the risky asset. Clearly, they will have to face the problem of filtering these signals, which they privately obtain, to extract the fundamental value. The perfect informed traders who have exclusively advantageous information belong to the third group only trade by placing market orders. The final group consists of all the traders with liquidity motivation accompanying no trading strategy. Consequently, only the traders of first and second groups have the choice decision of order strategy. Our discussion focus on how those traders decide their orders to max their expected profits that brings to market equilibrium.

Let a random variable $\tilde{X}$ be the fundamental value of the risky asset. The traders of the buyer group obtain the noisy private signal $\tilde{S}_b$. Consider the case in which agents are interested in predicting a random variable $\tilde{X}$. The two variables have the relationship $\tilde{S}_b = \tilde{X} + \tilde{U}_b$, where $\tilde{U}_b$ is an idiosyncratic shock, independent of $\tilde{X}$, with mean 0 and variance $\sigma^2_{b,u}$. Under the assumption that $\tilde{X}$ and $\tilde{S}_b$ have Joint Normal distribution, recognizing that:

$$\begin{pmatrix} \tilde{X} \\ \tilde{S}_b \end{pmatrix} \sim N\left[\begin{pmatrix} \mu_x^H \\ \mu_x^H \end{pmatrix}, \begin{pmatrix} \sigma^2_{b,x} & \sigma^2_{b,x} \\ \sigma^2_{b,x} & \sigma^2_{b,x} + \sigma^2_{b,u} \end{pmatrix}\right]$$

For all agents of the buyer group, μ_x^H and $\sigma^2_{b,x}$ can be viewed as the reservation price and the variance based on public information without any noisy signal. $s_{b,x} = \frac{1}{\sigma^2_{b,x}}$ and $s_{b,u} = \frac{1}{\sigma^2_{b,u}}$ represent the precisions of random variables $\tilde{X}$ and $\tilde{U}_b$, respectively. Therefore, $\rho_b^2 = \frac{\sigma^2_{b,x}}{\sigma^2_{b,x} + \sigma^2_{b,u}}$, that is the determinant coefficient of $\tilde{X}$ and $\tilde{S}_b$, implies the explainable degree of the projection of fundamental value on the private noisy signal.

Similarly, the traders of the seller group hold the noisy private signal $\tilde{S}_s$. They interpret the noisy signal and understand the relationship $\tilde{S}_s = \tilde{X} + \tilde{U}_s$ to deduce the true value. $\tilde{X}$ and $\tilde{S}_s$ are assumed as the Joint Normal distribution:

$$\begin{pmatrix} \tilde{X} \\ \tilde{S}_s \end{pmatrix} \sim N\left[\begin{pmatrix} \mu_x^L \\ \mu_x^L \end{pmatrix}, \begin{pmatrix} \sigma_{s,x}^2 & \sigma_{s,x}^2 \\ \sigma_{s,x}^2 & \sigma_{s,x}^2 + \sigma_{s,u}^2 \end{pmatrix} \right]$$

Likewise, for all agents of the seller group, μ_x^L and $\sigma_{s,x}^2$ can be viewed as the reservation price and the variance based on public information. $s_{s,x} = \frac{1}{\sigma_{s,x}^2}$, $s_{s,u} = \frac{1}{\sigma_{s,u}^2}$ and $\rho_s^2 = \frac{\sigma_{s,x}^2}{\sigma_{s,x}^2 + \sigma_{s,u}^2}$ notate the precision of $\tilde{X}$, $\tilde{U}_s$, and the accountable degree of the sellers' projection, respectively.

A.2 The Core Analysis of Order Strategy

We set up an environment in which all investors, who confront the order decision, deem that a proportion of all participates denoted by k intend to sell and the remainders denoted by $1-k$ intend to buy. The proportion of sellers (buyers) to all traders represents the arrival rate of sellers (buyers) that implies the market competition determined exogenously. Both of traders homogeneously recognize that perfect informed traders arrive with an exogenously specified proportion to all sellers (buyers) p, and that liquidity traders arrive with a proportion to all sellers (buyers) $q\,(=1-p)$.

If buyer group use limit orders, P_B as the bid price of limit order, we can write the expected profits of the buyers as:

$$E(profit_{\lim}^{b} / S_b) = k\left[p \times \int_{-\infty}^{P_B} (X - P_B) f(X / S_b) dX + q \times \int_{-\infty}^{\infty} (X - P_B) f(X / S_b) dX \right] \ldots (1)$$

The subscript b indicates the traders of buyer group. As we know, k is also implicit the seller's arrival rate as the execution probability of the limit buy order. Therefore, the model considers the execution risk that depends on the execution probability, and the lower seller's arrival rate increases the risk.

The first term of (1), $\int_{-\infty}^{P_B}(X-P_B)f(X/S_b)dX$, implies that buyer group expect loss from winner's curse problem which is the adverse information triggering harmful execution and the favorable news failing execution. When buyer group's counterparts are the perfect informed traders, uninformed buyers, even holding noisy signals, have a disadvantage of information suffering these inevitable losses. Hence, if they insist on submitting limit order, they should estimate the expected loss of adverse selection for their investment from being comparatively scanty of information condition on informed trades. Those mean that investor who places a buy limit order has written a free put option of the execution price P_B to the informed trader. Besides, p is the probability for buyer group to confront the perfect informed traders.

The second term of (1), $\int_{-\infty}^{\infty}(X-P_B)f(X/S_b)dX$, implies that buyer group expect profits from their counterparts as liquidity traders with no information and no strategies. Even, contrasting with submitting market order, they have a price improvement due to lower buy price. q is the probability that buyer group meet liquidity traders.

If buyer group use market orders, given the assumption that perfect informed trader trades by submitting market order, they are certain that transactions do not match with perfect informed traders and are executed for sure. Therefore, buyers' market orders are against with the limit sell order at the best ask price as P_A on the limit order book, we can write their expected profit by placing market buy order as:

$$E(profit_{mkt}^{b}/S_b)=\int_{-\infty}^{\infty}(X-P_A)f(X/S_b)dX \text{ ....(2)}$$

Seller group who are similar to buyer group face the risks of no-execution and adverse selection, and price improvement. If seller group uses limit orders, P_A as the ask price of limit sell order, we can write the expected profit as:

$$E(profit_{\lim}^{s}/S_s)$$
$$=(1-k)\left[p\times\int_{P_A}^{\infty}(P_A-X)f(X/S_s)dX+q\times\int_{-\infty}^{\infty}(P_A-X)f(X/S_s)dX\right] \text{ ....(3)}$$

The subscript s indicates the traders of seller group. $1-k$ is viewed as the execution probability of limit sell order. The first term of (3), $\int_{P_A}^{\infty}(P_A - X)f(X/S_s)dX$, is the expected loss from trading with the perfect informed buyer. The second term of (3), $\int_{-\infty}^{\infty}(P_A - X)f(X/S_s)dX$, is the expected profit from liquidity buyer.

If seller group use market orders, P_B as the best bid price on the limit order book, we can write the expected profits as:

$$E(profit_{mkt}^{s}/S_s) = \int_{-\infty}^{\infty}(P_B - X)f(X/S_s)dX \quad \ldots\ldots\ldots(4)$$

In summary, limit order traders resemble dealers in that they provide liquidity and immediacy to the market, but face the problem of the winner’s curse, so both of them have the same behavior that they will use the gain from liquidity trading to compensate for the loss from informed trading. Yet, they have different positions. The limit order trader also as an investor, not a market marker, therefore, has another choice to avoid the two risks for the maximum of expected profits by submitting market order just accompanying with the abandonment of the price improvement.

B. The Model of Order Strategy

B.1 The Expected Profits of Limit order or Market order

Proposition 1

The expected profits of limit buy order:

$$E(profit_{\lim}^{b}/S_b) = k\left[R_b - L_b^{AS}\right]$$

where $L_b^{AS} = p\mathrm{P}(X = P_B/S_b)(\dfrac{1}{R/V_{R_b}})^2$

$$R_b = \mu_x^H + \rho_b^2(S_b - \mu_x^H) - P_B = \overline{V}_b - P_B$$

$$\sigma_{R_b}^2 = \sigma_{b,u}^2\rho_b^2$$

$$R/V_{R_b} = \frac{R_b}{\sigma_{R_b}^2}$$

$$\mathrm{P}(X = P_B/S_b) = \frac{1}{\sqrt{2\pi\sigma_{b,x}^2(1-\rho_b^2)}}e^{\frac{-\left[P_B - \mu_x^H - \rho_b^2(S_b - \mu_x^H)\right]^2}{2\sigma_{b,x}^2(1-\rho_b^2)}}$$

The expected profits of market buy order:

$$E(profit_{mkt}^{b} / S_b) = \mu_x^H + \rho_b^2 (S_b - \mu_x^H) - P_A = \overline{V}_b - P_A$$

Proof: *Appendix 1*

Under the assumption that traders neglect the order submission problem, the traders of buyer group infer the expected value of the risky asset from their heterogeneous beliefs as $\overline{V}_b$, which is a weighted average of μ_x^H (the reservation value of buyers' recognition based on the same public information) and S_b(the reservation value of buyers' procurement based on her private noisy signal), with $1-\rho_b^2$ and ρ_b^2 being the weights placed on these two terms, respectively. ρ_b^2 represents the precision degree of the noisy signal which buyers obtained. As ρ_b^2 approaches its maximum value of unity, $\overline{V}_b$ approaches S_b and the buyer becomes the perfected informed trader. On the other hand, as ρ_b^2 approaches its minimum value of zero, $\overline{V}_b$ approaches μ_x^H and the buyer becomes the pure uninformed trader.

Hence, while buyer group submit limit order without considering the two risk of adverse selection and non-execution, their expected profit is $R_b = \overline{V}_b - P_B$. In contrast, their expected profit of submitting market order is $\overline{V}_b - P_A$. Then adding the first risk that buyers are exposed under adverse selection problem, the expected value of the risky asset, as $\overline{V}_b^{AS} = \overline{V}_b - L_b^{AS}$, consists of the original expected value and the expected loss L_b^{AS} from trading with the perfect informed traders. Again, relax the risk of no-execution into the analysis, buyer's expected profit of limit order is $k\left[R_b - L_b^{AS}\right]$. Besides, the traders submitting market buy order do not burden the risks of adverse selection and non-execution, so their expected profit of market order is $\overline{V}_b - P_A$.

Proposition 2

The expected profits of limit sell order:

$$E(profit^{s}_{\lim} / S_s) = (1-k)\left[R_s - L_s^{AS}\right]$$

where $L_s^{AS} = p\mathrm{P}(X = P_A / S_s)(\frac{1}{R/V_{R_s}})^2$

$$R_s = P_A - \mu_x^L - \rho_s^2 (S_s - \mu_x^L) = P_A - \overline{V}_s$$

$$\sigma_{R_s}^2 = \sigma_{s,u}^2 \rho_s^2$$

$$R/V_{R_s} = \frac{R_s}{\sigma_{R_s}^2}$$

$$\mathrm{P}(X = P_A / S_s) = \frac{1}{\sqrt{2\pi\sigma_{s,x}^2 (1-\rho_s^2)}} e^{\frac{-\left[P_A - \mu_x^L - \rho_s^2 (S_s - \mu_x^L)\right]^2}{2\sigma_{s,x}\sqrt{1-\rho_s^2}}}$$

The expected profit of market sell order:

$$E(profit^{s}_{mkt} / S_s) = P_B - \mu_x^L - \rho_s^2 (S_s - \mu_x^L) = P_B - \overline{V}_s$$

Proof: *Appendix 2*

Similarly, the traders of seller group consider the expected value of the risky asset $\overline{V}_s$ without facing the risk of no-execution and adverse selection. Hence, ρ_s^2 determines that the trader becomes a perfect informed trader or a uninformed trader. $R_s = P_A - \overline{V}_s$ and $P_B - \overline{V}_s$ are the expected profit by submitting the limit order and the market order, respectively. When seller group are exposed under the risks of no-execution and adverse selection, the expected value of the asset as $\overline{V}_s^{AS} = \overline{V}_s - L_s^{AS}$ and the expected profit of limit order as $(1-k)\left[R_s - L_s^{AS}\right]$ involve the expected loss L_s^{AS} from trading with the perfect informed traders.

B.2 The Components of the Expected Profits of Limit order

B.2.1 The Expected Stock Value without Adverse Selection and Non-Execution

Assume that traders have heterogeneous beliefs which are related public information and the private noisy signal. Firstly, the traders of buy group or sell group, according their assessments of the public information, have distinct general reservation values of both sides:

Buy group: $E(X) = \mu_x^H$

Sell group: $E(X) = \mu_x^L$

Secondly, if the traders of buy group hold the noisy private signals, their expected value of the asset is a weighted average of μ_x^H and S_b. ρ_b^2 represents the explainable degree of the noisy signals which buyer obtained. Each trader anticipates the true value by combining public information with private signals. Sell group resemble buyers the same process of expectation:

Buy group: $\overline{V}_b = E(X / S_b) = (1-\rho_b^2)\mu_x^H + \rho_b^2 S_b$

Sell group: $\overline{V}_s = E(X / S_s) = (1-\rho_s^2)\mu_x^L + \rho_s^2 S_s$

The above description is proper to that the traders don't dispose the order choice problem; therefore, they do not consider bearing the risks of adverse selection and non-execution.

B.2.2 The Expected Profits without Adverse Selection and Non-Execution

As abovementioned, the traders who do not burden the risks of adverse selection and non-execution trade at a certain buy or sell price (P_B, P_A), so that they expect the profits of trades based on pure public information as:

Buy group: $E(X - P_B) = \mu_x^H - P_B$

Sell group: $E(P_A - X) = P_A - \mu_x^L$

In addition, the traders of buy (sell) group have acquired extra noisy signals, their expected profit of trade as:

Buy group: $E(X - P_B / S_b) = \overline{V}_b - P_B$

Sell group: $E(P_A - X / S_s) = P_A - \overline{V}_s$

B.2.3 The Reward-to-Variability Ratio of the Investment

Similarly, when the traders are not necessary to deal with the order choice problem, they only bear the fundamental risk of the risky asset. The variance of the investment recognized by traders is derived from Projection Theorem.

$$\text{Buy group: } \begin{cases} \text{Limit Order} \quad : V(\tilde{X} - P_B / S_b) = \dfrac{\sigma_{b,u}^2 \sigma_{b,x}^2}{\sigma_{b,u}^2 + \sigma_{b,x}^2} = \sigma_{R_b}^2 \\ \text{Market Order}: V(\tilde{X} - P_A / S_b) = \dfrac{\sigma_{b,u}^2 \sigma_{b,x}^2}{\sigma_{b,u}^2 + \sigma_{b,x}^2} = \sigma_{R_b}^2 \end{cases}$$

$$\text{Sell group: } \begin{cases} \text{Limit Order} \quad : V(P_A - \tilde{X} / S_s) = \dfrac{\sigma_{s,u}^2 \sigma_{s,x}^2}{\sigma_{s,u}^2 + \sigma_{s,x}^2} = \sigma_{R_s}^2 \\ \text{Market Order}: V(P_B - \tilde{X} / S_s) = \dfrac{\sigma_{s,u}^2 \sigma_{s,x}^2}{\sigma_{s,u}^2 + \sigma_{s,x}^2} = \sigma_{R_s}^2 \end{cases}$$

Consequently, according the aforementioned expected profit of the investment, we infer that the reward-to-variability ratio of the investment considering not the standard deviation but the variance of the investment, as the ratio of the expected profit to the variance of expected profit, represents the standard measure of the performance of trader's specific investment. We can write the reward-to-variability ratio of the investment as:

Buy group: $R / V_{R_b} = \dfrac{R_b}{\sigma_{R_b}^2}$

Sell group: $R / V_{R_s} = \dfrac{R_s}{\sigma_{R_s}^2}$

The reward-to-variability ratio of the investment is easy to compare with other investments of risky assets. The higher reward-to-variability ratio is the higher lucrative investment that is consistently the conventional financial dogma for measuring the performance of an investment.

B.2.4 The Occurrence Probability of the Setting Limit Price

The traders of buy (sell) group must estimate the occurrence probability of the setting limit price to understand the probability of execution at a specific price. Since traders don't learn the occurrence probability of the setting limit price but can deduce subjectively the occurrence probability of true value at a specific price from the attainable public information and their noisy private signals, the occurrence probability of true value at a specific price is being substituted for the occurrence probability of the setting limit price. The traders of buy (sell) group with the private signal S_b (S_s) set the limit buy (sell) price as P_B (P_A), the below is the occurrence probability of the setting limit price.

Buy group: $\mathrm{P}(X = P_B / S_b)$

Sell group: $\mathrm{P}(X = P_A / S_s)$

B.2.5 The Expected Loss of Adverse Selection

While all traders face the informed trades by submitting limit order, they don't know the loss which the informed traders exploit from them, so must take an expectation of the loss of adverse selection. We derive that the buyers' (sellers') expected loss L_b^{AS} (L_s^{AS}) of adverse selection comprises three factors: the probability of trading with the perfect informed trader, the occurrence probability of the setting limit price P_B (P_A), and the square of the inverse of the reward-to-variability ratio of the investment.

Buy group: $L_b^{AS} = p\mathrm{P}(X = P_B / S_b)(\frac{1}{R / V_{R_b}})^2$

Sell group: $L_s^{AS} = p\mathrm{P}(X = P_A / S_s)(\frac{1}{R / V_{R_s}})^2$

First factor represents the probability that buyer (seller) submits a limit order to meet with the perfect informed traders, so the probability is increasingly easy to trade with the perfect informed traders. Second factor represents the probability that buyer (seller) subjectively estimate the occurrence probability that the setting the bid (ask) price realizes. Therefore, the combination of first and second factor implies that traders calculate the probability of their order execution with perfect informed traders at the setting limit price. Third factor represents the magnitude of the investment loss from informed trades. The reward-to-variability ratio of each investment is negatively related to the expected loss of adverse selection. In other words, although investors face the winner's curse problem, higher expected return of investment could reduce the loss of informed trades.

B.2.6 The Expected Stock Value with Adverse Selection

In an order driven market, all traders, except the perfect informed and liquidity traders, have come up against the winner's curse problem by placing limit orders. As soon as traders consider the order type choice, the expected stock value of limit order should include the expected loss of adverse selection, no matter whether they have noisy private signals. The amendatory expected stock value as:

Buy group: $\overline{V}_b^{AS} = \overline{V}_b - L_b^{AS}$

Sell group: $\overline{V}_s^{AS} = \overline{V}_s + L_s^{AS}$

If traders anticipate that the expected loss of informed trading expand due to the abovementioned three factors changed, buyers (sellers) will reexamine their investment to undervalue (overvalue) the expected stock value lest the winner's curse problems.

B.2.7 The Expected Profits with Adverse Selection and Non-Execution

When submitting limit orders, the expected profits of traders are adjusted to consider the two risks of adverse selection and non-execution.

Buy group: $E(profit_{\lim}^{b} / S_b) = k\left(\overline{V}_b^{AS} - P_B\right)$

Sell group: $E(profit_{\lim}^{s} / S_s) = (1-k)\left(P_A - \overline{V}_s^{AS}\right)$

On the other hand, if traders use market orders which are executed immediately with the limit order of the best price on the order book and never contact with informed traders, they can avoid the two risks.

Buy group: $E(X - P_A / S_b) = \overline{V}_b - P_A$

Sell group: $E(P_B - X / S_s) = P_B - \overline{V}_s$

B.3 The Special Case of the Model

The heterogeneous beliefs of traders include public information and private information. First and Second group are separated by public information, and traders in the same group have the same recognition of public information. Besides, traders have private noisy signals to personally revise their common recognition of public information to a more precise reservation value. Under this discussion, the explainable degree of noisy private signals (ρ_b^2 or ρ_s^2) determines that a trader extremely becomes a perfect informed trader or an uninformed trader. We describe the features of the three classified traders.

B.3.1 The Perfect Informed Trader ($\rho^2 = 1$)

While traders acquire precise private information, they have the absolutely advantage on trades. In order to immediacy, they just submit market order, so that they are not necessary to consider the risk of non-execution and adverse selection. The below item are the features of a perfect informed trader:

The expected stock value:

The perfect informed buyer: $\overline{V}_b^{AS} = \overline{V}_b = S_b$

The perfect informed seller: $\overline{V}_s^{AS} = \overline{V}_s = S_s$

The expected profits of limit order:

The perfect informed traders are not likely to use limit order to fulfill their trades.

The expected profits of market order:

The perfect informed buyer: $E(profit_{mkt}^{b} / S_b) = S_b - P_A$

The perfect informed seller: $E(profit_{mkt}^{s} / S_s) = P_B - S_s$

B.3.2 The Uninformed Trader ($\rho^2 = 0$)

While traders assess the investment only based on pure public information, they have the absolutely disadvantage on information. Therefore, ceteris paribus, they suffer the maximum loss of adverse selection among the classified traders.

The expected stock value:

The uninformed buyer:

$$\begin{cases} \text{Limit Order}: \ \overline{V}_b^{AS} = \mu_x^H - pP(X = P_B)(\dfrac{\sigma_{b,x}^2}{\mu_x^H - P_B})^2 \\ \text{Market Order}: \ E(X) = \mu_x^H \end{cases}$$

The uninformed seller:

$$\begin{cases} \text{Limit Order}: \ \overline{V}_s^{AS} = \mu_x^L + pP(X = P_A)(\dfrac{\sigma_{s,x}^2}{P_A - \mu_x^L})^2 \\ \text{Market Order}: \ E(X) = \mu_x^L \end{cases}$$

The expected profits of limit order:

The uninformed buyer:

$$E(profit_{\lim}^b) = k\left[\mu_x^H - pP(X = P_B)\left(\frac{\sigma_{b,x}^2}{\mu_x^H - P_B}\right)^2 - P_B\right]$$

The uninformed seller:

$$E(profit_{\lim}^s) = (1-k)\left[P_A - \mu_x^L - pP(X = P_A)\left(\frac{\sigma_{s,x}^2}{P_A - \mu_x^L}\right)^2\right]$$

The expected profits of market order:

The uninformed buyer: $E(profit_{mkt}^b) = \mu_x^H - P_A$

The uninformed seller: $E(profit_{mkt}^s) = P_B - \mu_x^L$

B.3.3. The Noisy Uninformed Trader ($0 < \rho^2 < 1$)

Some traders esteem themselves are partially informed traders in terms of their private noisy signals. If the precision of noisy signals are higher, they have more confidences on the expectation, and then expect to suffer smaller loss from adverse selection. So, the precision of noisy signal is the determinant of the type of traders.

The expected stock value:

The noisy uninformed buyer:

$$\begin{cases} \text{Limit} \quad \text{Order}: \quad \overline{V}_b^{AS} = (1-\rho_b^2)\mu_x^H + \rho_b^2 S_b - pP(X = P_B / S_b)\left[\dfrac{\sigma_{b,u}^2 \rho_b^2}{(1\text{-}\rho_{\mathrm{b}}^2)\mu_x^H + \rho_b^2 S_b - P_B}\right] \\ \text{Market} \quad \text{Order}: \quad E(X / S_b) = (1-\rho_b^2)\mu_x^H + \rho_b^2 S_b \end{cases}$$

The noisy uninformed seller:

$$\begin{cases} \text{Limit} \quad \text{Order}: \quad \overline{V}_s^{AS} = (1-\rho_s^2)\mu_x^L + \rho_s^2 S_s + pP(X = P_A / S_s)\left[\dfrac{\sigma_{s,u}^2 \rho_s^2}{P_A \text{ - } (1\text{-}\rho_{\mathrm{s}}^2)\mu_x^L - \rho_s^2 S_s}\right] \\ \text{Market} \quad \text{Order}: \quad E(X / S_s) = (1-\rho_s^2)\mu_x^L + \rho_s^2 S_s \end{cases}$$

The expected profits of limit order:

The noisy uninformed buyer:

$$E(profit_{\lim}^{b} / S_b)$$

$$= k\left[(1-\rho_b^2)\mu_x^H + \rho_b^2 S_b - pP(X = P_B / S_b)\left(\frac{\sigma_{b,u}^2 \rho_b^2}{(1-\rho_b^2)\mu_x^H + \rho_b^2 S_b - P_B}\right)^2 - P_B\right]$$

The noisy uninformed seller:

$$E(profit_{\lim}^{s} / S_s)$$

$$= (1-k)\left[P_A - (1-\rho_s^2)\mu_x^L - \rho_s^2 S_s - pP(X = P_A / S_s)\left(\frac{\sigma_{s,u}^2 \rho_s^2}{P_A - (1-\rho_s^2)\mu_x^L - \rho_s^2 S_s}\right)^2\right]$$

The expected profits of market order:

The noisy informed buyer:

$$E(profit_{mkt}^{b} / S_b) = \left[(1-\rho_x^2)\mu_x^H + \rho_b^2 S_b\right] - P_A$$

The noisy informed seller:

$$E(profit_{mkt}^{s} / S_s) = P_B - \left[(1-\rho_s^2)\mu_x^L + \rho_s^2 S_s\right]$$

3. The Equilibrium of the Model

A. The Optimal Bid and Ask

Proposition 3

$$\begin{cases} P_A^* = \phi \overline{V}_b + (1-\phi)\overline{V}_s^{AS} + \lambda(L_b^{AS} - L_s^{AS}) \\ P_B^* = \lambda \overline{V}_s + (1-\lambda)\overline{V}_b^{AS} + \phi(L_b^{AS} - L_s^{AS}) \end{cases}$$

Where $\lambda = \dfrac{k}{1-k(1-k)}$, $\phi = \dfrac{1-k}{1-k(1-k)}$

Proof: *Appendix 3*

We find that the equilibrium ask price P_A^* (bid price P_B^*) is composed the first part as a weighted average of $\overline{V}_b$ ($\overline{V}_s$) and $\overline{V}_s^{AS}$ ($\overline{V}_b^{AS}$) with ϕ (λ) and $1-\phi$ ($1-\lambda$), and the second part as an adjustment term which is the different expected loss of adverse selection between both side traders $\lambda(L_b^{AS} - L_s^{AS})$ ($\phi(L_b^{AS} - L_s^{AS})$).

To begin with, we discuss the first part. While ϕ approaches its maximum value of unity and λ simultaneously approaches its minimum value of zero, P_A^* approaches $\overline{V}_b$ and P_B^* approaches $\overline{V}_b^{AS}$. On the other hand, while ϕ approaches its minimum value of zero and λ simultaneously approaches its maximum value of unity, P_A^* approaches $\overline{V}_s^{AS}$ and P_B^* approaches $\overline{V}_s$. We have learnt that $\overline{V}_b$ ($\overline{V}_s$) represents the reservation value without the expected loss of adverse selection and $\overline{V}_b^{AS}$ ($\overline{V}_s^{AS}$) represents the reservation value with the expected loss of adverse selection for the buyers (sellers). Based on our afore-discussion, P_A^* which is used by two kind traders, liquidity consumers (as market buy order submitters) and liquidity providers (as limit sell order submitters), reflects the reservation value of both kind users; likewise, P_B^* reflects the reservation values of market sell order submitters and limit buy order submitters. ϕ (λ) determines that the core value of P_A^* (P_B^*) is located between $\overline{V}_b$ ($\overline{V}_s$) and $\overline{V}_s^{AS}$ ($\overline{V}_b^{AS}$), and then the higher (lower) quotation price increases the expected profit of seller (buyer) i.e. ϕ (λ) indirectly determines how the benefits of trading are distributed between the market order buyer (seller) and the limit order seller (buyer).

The second part is related to the difference of the expected loss of adverse selection between buyers and sellers. If buyers' expected loss of adverse selection is larger (smaller) than sellers', the bid and ask price simultaneously increase (decrease). Since the limit order traders of both sides provide liquidity to the market, and they ask compensation from the risk of adverse selection, the result that the ask nose up and the bid nose down. While the ask nose up to originate in seller's expected loss of adverse selection, the buyers are compelled to submit limit buy order, instead market buy order, accompanying that the bid price is guided higher. Similarly, while the bid nose down to originate in buyer's expected loss of adverse selection, the sellers are compelled to submit limit sell order, instead market sell order, accompanying that the ask price is guided lower. Supposing that traders of both sides simultaneously have different degrees of the risk of adverse selection, in the meantime, as buyers are forced to submit limit buy order causing from that seller escalate the ask price to cover the expected loss of adverse selection, if buyers expect that they face higher risk of adverse selection than sellers, they prefer submit market buy order, even that seller escalate the ask price, further to guide the ask price higher and advance to also guide the bid price higher. In the same situation, as sellers are forced to submit limit sell order causing from that buyer descend the bid price to cover the risk of adverse selection, if sellers expect that they face higher risk of adverse selection than buyers, they prefer submit market sell order, even that buyer descend the bid price, further to guide the bid price lower and advance to also guide the ask price lower. Consequently, if buyers' expected loss of adverse selection is larger (smaller) than sellers', the bid and ask price simultaneously increase (decrease). It reflects an adjustment of both sides recognizing the level of winner's curse. While the traders of both sides compete to provide liquidity to the market, one side traders who face lower risk of adverse selection have the advantage of price domination over the other side traders who face higher risk of adverse selection, and then the advantageous side partly transfers the adverse selection costs to the disadvantageous side. In consequence, while one side traders feel the information asymmetric problem larger than the other side, they will suffer more loss from adverse selection.

Furthermore, the exogenously proportion of sellers to all traders k (for buyers as $1-k$) denotes implicitly the seller's (buyer's) arrival rate. Suppose that k approaches zero, and the number of sellers approach zero; most of participates are buyers. The weights are $\lambda \approx 0$, $\phi \approx 1$, so that the bid price is close to $\overline{V}_b - L_s^{AS}$ and the ask price is close to $\overline{V}_b$. As a matter of fact, in an environment that the sellers are few, all buyers compete with each other to lead that they escalate their buy price to induce the execution of trade with thin sellers, and then the bid of limit buy order and the ask of market buy order are both higher. Eventually, while k is close zero, the ask is close to the reservation value of buyers, which is the bottom line of buyers, and the bid is close to the price, that the reservation value of buyers minus sellers' expected loss of adverse selection; in the meanwhile, sellers have an absolute advantage of trade only except the risk of adverse selection.

In the same method, while k approaches unity, sellers enormously outnumber buyers. Therefore, we can obtain the approximation of the related results as $\lambda \approx 1$, $\phi \approx 0$, $P_B^* \approx \overline{V}_s$ and $P_A^* \approx \overline{V}_s + L_b^{AS}$. At this time, in order to execution, all sellers compete with each other to descend the sell price in the environment of rare buyers. The bid and ask are contemporaneously guided down to the seller's reservation value. Similarly, thin buyers have an absolute advantage of trade only except the risk of adverse selection which all uninformed limit trader should consider.

B. The General Equilibrium Spread

Proposition 4

The bid-ask spread as:

$$\pi = \omega_1 \overline{V}_{b-s} + \omega_2 L_s^{AS} + \omega_3 L_b^{AS}$$

Where $\overline{V}_{b-s} = \overline{V}_b - \overline{V}_s$

$$\omega_1 = \frac{k(1-k)}{1-k(1-k)}$$

$$\omega_2 = \frac{(1-k)^2}{1-k(1-k)}$$

$$\omega_3 = \frac{k^2}{1-k(1-k)}$$

$$\omega_1 + \omega_2 + \omega_3 = 1$$

When $k = \frac{1}{2}$**, the maximum spread is:**

$$\pi = \frac{1}{3}(\overline{V}_b - \overline{V}_s) + \frac{1}{3} L_s^{AS} + \frac{1}{3} L_b^{AS}$$

Where $\omega_1 = \omega_2 = \omega_3 = \frac{1}{3}$

When $k = 0$ **(**$k = 1$**), the minimum spread is:**

$$\pi = L_s^{AS} \quad (\pi = L_b^{AS})$$

Where $\omega_1 = \omega_3 = 0, \omega_2 = 1$ $(\omega_1 = \omega_2 = 0, \omega_3 = 1)$

Proof: *Appendix 4*

We can decompose the spread into three factors, first factor related to the difference of valuation among buyers and sellers $\overline{V}_{b-s}$, second factor related to the expected loss of adverse selection of sellers L_s^{AS}, and third factor related to the expected loss of adverse selection of buyers L_b^{AS}. In the order driven market ecology we set up, the spread is a weighted average function of the heterogeneous beliefs of traders and the risks of adverse selection that sellers and buyers face, with ω_1, ω_2 and ω_3 being respectively the weights which are decide by k. On the other hand, when traders change the stock characteristics of their recognitions or market competition shifts, the spread will be fluctuated.

In particularly, we find out that the weights of the three factors imply the economical meaning. The proportion of sellers to all traders k also represents the market competition of both sides. k determines the probability of traders arrival states which are illustrated in Figure 1. We have realized that there are three states for the simultaneous arrival of two traders. Actually, a trade is executed while a buyer and a seller contemporaneously arrive. Hence, ω_1 which implies the arrival rate of a buyer and a seller in sequence represents the probability of trade execution. Since the price of a successful trade should reflect the valuation of both sides from their beliefs, the weight of the difference of valuation is the probability of trade execution. Next, the concurrent arrival of the same side traders is unable to achieve execution. When two buyers (sellers) arrive coincidentally, the probability of the arrivals is ω_2 (ω_3). As we know, all sellers (buyers) must worry that their counterparts are likely to be informed traders to necessarily burden the expected loss of adverse selection L_s^{AS} (L_b^{AS}). While the probability of two buyers (sellers) arrival is higher, sellers (buyers) estimate that the probability of their counterparts as informed traders is higher, and then they enhance the weights of the expected loss of adverse selection to protect themselves.

In addition, we analyze how the extreme market competition influences the bid-ask spread. For instance $k = 0$, the number of buyers outnumbers severely the number of sellers. Consequently, $\omega_1 = \omega_3 = 0$, $\omega_2 = 1$, the spread which only cover the expected loss of adverse selection of sellers reflects that too much buyers eagerly chase the sellers' order to induce that buyers' offer price of market and limit buy order enormously and successively raise and the spread being relatively tight. The buyers eventually offer the buy price of quotation as $\overline{V}_b$, where this highly competition deprive all the expected profits of buyers, so sellers exploit the maximum profit of the difference valuation between sellers and the market price $\overline{V}_b - \overline{V}_s$ but should nearly burden the risk of adverse selection. At this time, the expected profit of limit and market order for buyer and sellers is $E(profit^{b}_{\lim,mkt} / S_b) \approx 0$ and $E(profit^{s}_{\lim,mkt} / S_s) \approx \overline{V}_b - \overline{V}_s - L^{AS}_s$, respectively.

For $k = 1$, sellers enormously outnumber buyers, $\omega_1 = \omega_2 = 0, \omega_3 = 1$, so that buyers take all profits away and the spread only cover the expected loss of adverse selection of buyers. As a result, ceteris paribus, under the extreme market competition the spread which only involve the expected loss of adverse selection of one side is the minimum spread. For $k = \frac{1}{2}$, the number of sellers equals the number of buyers. According our model ω_1 varies from 0 to $\frac{1}{3}$. At this time, $\omega_1 = \omega_2 = \omega_3 = \frac{1}{3}$, the spread which is the equal-average of the three factors is at the largest value of the weight of the different valuations to reflect traders' heterogeneous beliefs. Therefore, other things being equal, the well-balance competition brings to the maximum spread. In summary, the proportion of both sides, as the market competition measure, dominates how to distribute the bid-ask spread into the three factors, meanwhile dominates how to allocate the benefit of the investment to traders.

4. The Numerical Test of the Model

Although our model has a complete analysis of price quotation and find out the significant meaningful components of the spread, the optimal solution of our model is not a linear closed form. In this section, we discuss the implications of the model using the numerical results from independently tuning the parameters which include the characteristics of traders and market competition (μ^H_x, μ^L_x, k, p, $\sigma_{b,x}$, $\sigma_{s,x}$, ρ_b, ρ_s, S_b, S_s). Under other things being equal, we analyze the influences of the specific parameter upon the meaningful economical terms and, for robustness, the same effects while another parameter alters a unit. To simplify the ecology of the model, we set up the basic values of the parameters for the analysis of our model, as μ_x^H =120, μ_x^L =80, k =0.5, p =0.25, $\sigma_{b,x}$ =20, $\sigma_{s,x}$ =20, ρ_b =0, ρ_s =0, S_b =130, S_s =70. We generate the numerical results with tuning each parameter by the same calibration. The below context is separated into several sub-sections in light of different parameters to discuss the numerical tests.

A. The Valuations of Traders (μ_x^H, μ_x^L)

Table 1 presents the numerical tests related to the tuning the valuations of buyers and sellers. Under other parameters being equal, in Table 1 first penal is about the effects of the tuning the valuation and, for robustness, the remainder penal is about the same effects while another parameter alters a unit. The second column displays the values of all parameters in our model. The remainder columns are distinct implicate terms of our research from the numerical tests, which cover the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profit, the components of bid-ask spread, and the ratios of the three factors to the spread.

We find that widening the different valuation between buyers and sellers raises the reward-to-variability ratio and then reduces the expected loss of adverse selection. It provides support to shows that the reward-to-variability ratio is negatively related to the expected loss of adverse selection. Furthermore, the different valuation of traders, which is one of factors of bid-ask spread, increase the bid-ask spread. Eventually, the influence of first factor is larger than the summary effects of the second and third factors, the result that the higher heterogeneity of traders' beliefs increases the spread, although the expected loss of adverse selection is lower.

B. The Proportion of Sellers to All Traders (k)

Table 2 profiles the numerical test results according to calibrate the parameter of the proportion of sellers to all traders. Given the aforementioned inference, as k approaches zero, $P_B^* \approx \overline{V}_b - L_s^{AS}$, $P_A^* \approx \overline{V}_b$, $\pi \approx L_s^{AS}$, $E(profit_{\lim,mkt}^b / S_b) \approx 0$ and $E(profit_{\lim,mkt}^s / S_s) \approx \overline{V}_b - \overline{V}_s - L_s^{AS}$ are consistently with our numerical tests; in addition, k approach unity as well. Moreover, the numerical results show that the minimum spreads occur at $k =$ 0 or 1 and the maximum spreads occur at $k = 1/2$, that coincide with the discussion of proposition 4. Furthermore, we can find out that the bid-ask spreads display the inverse U-shape.

C. The Probability of informed trading (p)

The informed trades, which generate the adverse selection costs for uninformed traders, mainly depend on the probability of trading with informed traders. Table 3 shows the related results of change the probability of trading with informed traders. We detect that as p approaches zero, the expected loss of adverse selection approaches zero and the bid-ask spread gradually shrink. Therefore, the probability of informed trading monotonically increases with the bid-ask spread.

D. The Variance of True Value Recognized by All Traders (σ_x)

Suppose that the traders of both groups have the same variance of true value based on the same public information. The numerical tests about the tuning this variance are reported in Table 4. If traders evaluate the smaller variance of true value, they could pinpoint the true value more precise. Thus given a zero value for the variance, traders have an infinite value of the reward-to-variability ratio and no expected loss of adverse selection. At this stage, traders esteem themselves as the perfect informed traders, i.e., their preservation value based on public information are view by them as the true value. In contrast, traders are not confident of their calculation of true value accompanying with a larger variance, so they consider that they will suffer more expected loss from adverse selection. Consequently, while making more vague explanation of public information for true value, the expected loss of adverse selection and bid-ask spreads are persistently swollen.

E. The Variance of True Value Recognized by The Buyers ($\sigma_{b,x}$)

The heterogeneous beliefs of traders involve not only the preservation value but also the variance. Now consider the case where only the variance of true value recognized by the buyers fluctuates and pin down one of the sellers, which of results are shown in Table 5. When buyers recognize that $\sigma_{b,x}$ approaches zero, the expected loss of adverse selection of buyers approaches zero, yet those of sellers almost retain static; in the meantime, the expected loss of adverse selection in bid-ask spread nearly reflects the sellers' recognition of winner's curse. This deduction is correspondent with that traders could benefit from the precise assessment of true value. In contrast, while buyers have recognized a larger volatility of risky asset, they estimate a higher expected loss of adverse selection, so that the fluctuation of the optimal spread almost reflects that the expected loss of AS coming from buyers varied.

F. The Precision of Traders' Private Noisy Signals (ρ)

We assume that traders measure the true value of assets from not only public information but noisy signals in private access way. Because of being noisy signals, traders appraise the true value depending on the precision of the signals. To simplify, we set the buyers' private signal as S_b =130 and Table 6 compares the revision of the precision of buyers' noisy signals. Intuitively, while the precision of noisy signals increases, the bias price of noisy signals is more accurate, and buyers' reward-to-variability ratio increases that bring to the expected loss of adverse selection lower; nevertheless, the size of bid-ask spread, which depend not only on the expected loss of adverse selection but also on the heterogeneous valuation from the price of private noisy signal, is uncertain. In a brief, Table 6 shows that the precision of noisy signals is negatively related to the expected loss of adverse selection.

G. The Price of Traders' Private Noisy Signals (S_b)

In contrast, in Table 7 given the precision of buyers' private noisy signals as ρ_b =0.25, we examine a variety price of private noisy signals under the certain degree of noisy signal. The larger price of buyers' private signals increases the reward-to-variability of buyers and sellers, and it causes the expected loss of adverse selection of buyer and seller lower. In the contrary, the smaller price of buyer's private signals decreases the expected loss of adverse selection for both sides. Likewise, since the price of traders' private signals influence the heterogeneous valuation and the expected loss of adverse selection, the size of the bid-ask spread is uncertain.

5. The Empirical Analysis of the Model

In this section, we develop various important testable implications based on our theoretical model and the numerical tests in the previous section. First, the proportion of sellers to all traders, which represents the market competition measure during a given period, is the vital role of bid-ask spread in our model due to that it is the key determinant of the weights for the three factors of spread. The interesting feature of proposition 4 is that the minimum spreads appear at the extremely imbalance and the maximum spreads appear at the most well balance of market force. We design several experiments to examine the relation between the bid-ask spread and market competition.

Otherwise, we also conduct experiments that investigate other determinants of bid-ask spread. Our model would suggest that the expected loss of adverse selection depend on the characteristics of traders. Finally, regression experiments for all the listed firms of the Taiwan Stock Exchanges are employed to test whether our model is fitted in a pure order-driven market, so as to estimate the magnitude of three core factors.

For robustness of our analysis, we create a great number of artificial data which are calculated by the parameters from our model. Table 8 presents the all possible values of six parameters that we set. Thereby, we obtain 113,625 artificial bid-ask spreads, but only 57,136 could converge. Based on the convergent data, we attempt to apply the linear analysis for the non-linear equilibrium of price quotation from our model. The purpose of the analysis of simulation data is to verify that univariate tests and regression tests are feasible analyzing the empirical data for our non-linear model.

A. Description of the Market and the Dataset

A. 1 Structure of the Taiwan Stock Exchange

This section describes the dataset details about the Taiwan Stock Exchange (hereafter abbreviated as TAIEX) and some stylized facts of the data help motivate our subsequent analysis. The centralized trading system of the Exchange is very similar to other electronic limit order markets, such as the Paris Bourse and the Tokyo Stock Exchange, where limit orders are cumulated in a computerized order book and automatically crossed with market orders under price and time priorities. Besides, to enhance the liquidity, transparency and efficiency of securities trading, apart from providing the computer system for stock trading and matching, the mechanism develops market information closure systems. During trading hours, investors may obtain real-time trading information—the bid and ask price, the last trade price, cumulative traded volume of individual stock, and a collection of market statistics—from the electronic quotation display in board rooms of the securities brokers.

In TAIEX, there are no specialists or dealers; hence investors must place orders in the computerized market through brokers. The consolidated limit order book environment accepted only limit orders. The orders are stored and executed in sequence that they are received by the market. Transactions occur when a trader on the opposite side of the market hits the quote. Orders can be entered half an hour before the trading session starts at 9:00 a.m. and the opening price is determined by a batch auction. Trading is continuous in the regular trading session from 9:00 a.m. to 1:30 p.m., Monday through Friday, buy and sell orders can interact to determine the executed price subject to applicable auto-matching rules by computerization via brokers directly routing to the system. Buy (sell) orders are in standard unit or multiples of standard units. One trading unit is 1,000 shares to all listed stocks.

A.2 Dataset

The TAIEX data used in this study are drawn from the Taiwan Economics Journal database. All the information in our dataset is available to market participants in real time through computerized information dissemination systems and all brokers are directly connected to the system. The dataset contains the history of the order book for all listed stocks in the TAIEX, for the 254 trading days from April 1 2003 to March 31 2004. For each transaction, the dataset reports stock code, the execution price, the time of execution ,the quantity exchanged, while for each order revision, the dataset reports the time, the best five bid and ask prices and the number of shares demanded or offered at each of the five bid and ask quotes. According the database, in each observations we generate the variables which we need to examine our model.

The following definitions of the variables are constructed in our analysis:

1. Quoted spread = Best Ask Price － Best Bid Price

2. Percentage spread = $\frac{\text{Quoted Spread}}{1/2\,(\text{Best Ask Price} + \text{Best Bid Price})} \times 100\%$

3. The proportion of sellers to all traders ($k\%$) =

$$\frac{\text{Trades Volume} + \text{Limit Sell Orders at the Best Ask}}{\text{Trades Volume} + \text{Limit Sell Orders at the Best Ask} + \text{Limit Buy Orders at the Best Bid}} \times 100\%$$

4. The weight of the different valuation ($W_1\%$)

$$= \frac{k(1-k)}{1-k(1-k)} \times 100\%$$

5. The weight of the seller's expected loss of adverse selection ($W_2\%$)

$$= \frac{(1-k)^2}{1-k(1-k)} \times 100\%$$

6. The weight of the buyer's expected loss of adverse selection ($W_3\%$)

$$= \frac{k^2}{1-k(1-k)} \times 100\%$$

Table 9 presents monthly summary statistics about our dataset during the 12 subperiods from Apr 20003 to Mar 2004. We observe that the market activities during the spread period of the severe acute respiratory syndrome (SARS) among Apr 2003 to Jun 2003 are very low and dramatically increased after the epidemic disease contained. The mean quoted spread, which ranges from NT$0.12 to NT$0.15, seems smaller in the SARS period than post-SARS period. Interestingly, we didn't find the same phenomena about the mean percentage spread which ranges extending from 0.51% to 0.57%, probably due to bullish market in post-SARS period. The mean market competition measure ($k\%$) not larger than 50% in our sample means that buy side force is a little bit over than sell side. While the market competition measure ($k\%$) varies between 0 and 100%, $\omega_1\%$ varies from 0 to $100/3\%$, $\omega_2\%$ varies from 100% to 0, and $\omega_3\%$ varies from 0 to 100%, respectively. The final column is the description of simulation data which we create from different values of parameters associated with the characteristics of traders and market competition.

B. Market Competition Measure, Weight of the Different Valuations and Bid-Ask Spread

We have defined market competition measure as the proportion of sellers to all traders that can capture which side market force dominates the other side. Firstly, we follow Handa, Swartz, and Taiwari (2003) experiments that examine the relations between the spread and the market competition measure. In the beginning, our samples are divided into two parts where the first part sample is $k\%$ larger than 50% and the second part is $k\%$ smaller than 50%. The quoted spread of each stock are classified by quintiles of $k\%$ respectively in two parts samples. Table 10 presents the results of the relations between the quoted spreads and the market competition measures, and the weight of the different valuations. Penal A of Table 10 which represents the results of the first part sample shows that quoted spreads are highest for the smallest $k\%$ quintiles 5, ranged from 0.19 to 0.48 among months, and gradually decrease advance to larger $k\%$ quintile. The results appear that, in Panel B, the largest $k\%$ quintiles 6 in second part samples accompany with the highest spread values ranged from 0.15 to 0.38 among months. All F-statistics confirm that the quoted spread are statistically significant across quintiles in both parts samples. The combining the results of Panel A and B displays an inverted U-shaped quoted spread, that is consistent with the proposition 4 and Handa, Swartz, and Taiwari (2003) who indicate spread high when the order flow is relatively well-balanced.

We have shown that $\omega_1\%$, as composed of $k\%$, is the determinant of the magnitude of the discrepancy of traders' opinion to the whole spread. While the market competition measure is 50%, that implies the maximum discrepancy of traders' beliefs, the spread reflects the biggest percentage from the different valuation factor. In other words, when $k\%$ close to 50%, $\omega_1\%$ close to the maximum value of $1/3$, and when k% close to 0% or 100%, $\omega_1\%$ close to the minimum value of zero. For that reason, we suggest that the weight of different valuations is more convenient than the market competition measure for the analysis of the relation between the heterogeneous beliefs and the bid-ask spread. In the same method, the quoted spreads of each stock are classified by the quintiles of $\omega_1\%$. Panel C of Table 3 shows that the largest $\omega_1\%$ quintiles have the maximum quoted spread ranged from 0.16 to 0.42 among months. This presents the monotonically increasing relation between spreads and quintiles $\omega_1\%$, which is consistent with the prediction of Proposition 4 and the inverted U-shaped relation from the combining Panel A and B. For robustness, the final column of Table 10 provides that using simulation data we could still obtain the same inverted U-shaped relation and monotonically increasing relation for quoted spreads.

In the same way, we examine the relation between the percentage spreads and the market competition measures. Overall, k% quintiles 5 and 6 have the highest percentage spreads from 0.65% to 0.83%, which are displayed in Panel A and B of Table 11, and $\omega_1\%$ quintiles 1 have the highest percentage spread from 0.67% to 0.83% in Panel C of Table 11. No matter empirical data or simulation data, percentage spreads also have the same patterns, the inverted U-shaped relation and the monotonically increasing relation, which are plotted in Figure 2 and Figure 3.

C. Probability of Informed Trading, Asset Volatility, Adverse selection Cost and Bid-Ask Spread

We have derived the expected loss of adverse selection in previous section. It consists of three factors which are the probability of informed trading, the occurrence probability of the setting limit price, and the square of the inverse of the reward-to-variability ratio of the investment. We try to analyze the two key determinants of adverse selection costs, as the probability of informed trading and the asset volatility. According our model, the probability of informed trading is positively related to the expected loss of adverse selection and the bid-ask spread. Copeland and Galai (1983) suggest adverse information as the sole source for the existence of a spread. Despite the large body of literature [5] related to market microstructure, little is known about the order-driven market.

Extant studies related adverse selection focus on the order-driven market, such as Glosten (1994) who analyzes the adverse selection problem of the limit order market. Handa and Schwartz (1996) explicitly derive a model of investor's order decision, which consider the probability of informed trading. As we know, the probability of informed trading is a difficulty observed variable in a limit order market. Therefore, we try to seek a measurable proxy for the probability of informed trading to examine the bid-ask spreads. Nyholm (2003) show empirically that the estimated probability of informed trading is larger in the morning than in the afternoon. Hong and Wang (2000) extend the literature on private information to explain why trading is clustered at the open and the close. Madhavan (1992) considers traders with diverse information concerning the value of an asset at the onset of trading. As trading continues, private information is impounded into prices, and specialists narrow their spreads as their informational handicap declines. Besides, various articles have been proposed information-based factor to explain the intraday pattern of bid-ask spreads.[6] We attempt to treat time intervals of a trading day as the proxy variable for the probability of informed trading. During the sample period, trading on the TAIEX was conducted from 9:00 A.M. to 1:30 P.M. Taipei time. A time series of percentage bid-ask spreads over the trading day in the market is constructed. For the analysis of the probability of informed trading described below, we partition each trading day into one 54-minutes interval and five successive 54-minutes intervals.

To compare spreads cross stocks, we just examine the percentage spread that quoted spreads are transformed to standardized variables. The distribution of the percentage spread for five time-intervals samples is reported in Table 12. The percentage spreads are highest at the beginning of the day, gradually declining before

[5] Bagehot (1971), Easley and O'Hara (1987), Glosten and Milgrom(1985) show market maker will tend to sustain losses on trades with informed traders , and therefore must adjust the spread until these losses are offset by gains from trades with liquidity traders.

[6] McInish and Wood (1992) show information can explain partially the reverse J-shape. Admati and Pfleiderer (1988) suggest

that diverse private information caused trading clusters around the trading of privately informed traders, which offers an explanation for the observed reverse-J pattern. Cyree and Winters (2001) suggest private information may have a role in the size and shape of the observed reverse-J patterns. Brock and Kleidon(1992), and Lee, Mucklow, and Ready (1993) document that spreads are widest immediately after the open and immediately preceding the close. Chung, Van Ness, Van Ness (1999) suggest that intraday pattern largely reflects the intraday variation in spreads established by limit-order traders.

they increase during the close. This confirms that Nyholm (2003) and Hong and Wang (2000) documented that the probability of informed trading is larger at the open and the close, and larger spreads are quoted right after the opening of the exchange as a protection against informed agents. The familiar picture of a reverse J-shaped pattern emerges in Figure 4. Besides, we also classified quoted spreads of the simulation data by quintiles of the probability of informed trading; quintile 1 as the smallest probability group and quintile 5 as the largest probability group. The result of simulation data also show that the probability of informed trading is positively related to the quoted spread.

In previous section, the expected loss of adverse selection is formed from the characteristics of traders; therefore, we find the reward-to-variability ratio is the most critical determinant of adverse selection costs. Sharpe (1966, 1975, and 1994) introduced a measure for the performance of mutual funds and proposed the term reward-to-variability ratio. The contribution is simply to integrate two measures mean and standard deviation into the Sharpe Ratio. The reward-to-variability ratio, as the ratio of the mean to the standard deviation of the investment, is an indicator to measure the risk-adjusted performance of the investment. Yet, the reward-to-variability ratio is a ratio of the mean to the variance of investment in our model, so that it considers the influence of the square of standard deviation. Although our theoretical model recommend the reward-to-variability ratio better than the asset volatility to the analysis of the adverse selection, our reward-to-variability ratio, which have already joined the influence of expected return, lay much stress on the asset volatility. Therefore, in below context, we focus on the asset volatility for analyzing the expected loss of adverse selection. Foucault (1999) suggests that the volatility of assets is a main determinant of the mix between market and limit orders. Limit order traders ask for a larger compensation for the risk of being picked off in markets with high volatility.[7] For this reason, posted spreads are positively related to asset volatility. Sandas (2001) finds evidence consistent with more severe adverse selection risk in markets with high stock-specific volatility.

Likewise, we try to seek a measurable proxy for the asset volatility to examine posted bid-ask spread. Hasbrouck (1991) and Foucault (1999) document that asset volatility decreases with equity capitalization. The Fama-French (FF) factors SMB contain systematic risk[8] Besides, Vassalou and Xing (2004) find that default risk is intimately related the size characteristics of a firm. As a result of that small (big) firms should have higher (lower) standard deviation of asset accompanying with

[7] Harris (1998) shows that higher fundamental volatility makes limit orders less attractive since volatility increases free limit order option values.

[8] Fama and French (1996) argue that the SMB factors of the Fama-French (1993) model proxy for financial distress.

higher (lower) expected profit of asset, but the influence of the variance in our reward-to-variability ratio is bigger than the influence of the expected profit; we tend to treat firm size as the proxy variable for asset volatility or our reward-to-variability ratio. For comparison, the percentage spread is proper spread variable to compare between stocks. We classify all stocks of TAIEX into quintiles of firm size on a daily basis to examine whether the smallest firm size quintile have the highest mean percentage spread. Table 13 presents the distribution of the percentage spread for firm size quintile-daily sorted samples of the TAIEX securities. The mean percentage spreads of firm size quintiles are statistically different, and those clearly have a monotonically positive relation as asset volatility in Figure 5. In addition, we also classified quoted spreads of the simulation data by quintiles of the asset volatility recognized by buyers and sellers, respectively; quintile 1 as the smallest volatility group and quintile 5 as the largest volatility group. Both show the same monotonically positive relation. The results of univariate tests and numerical tests are consistent with Foucault (1999) and Sandas (2001).

D. Regression Tests of the Model

Our theoretical model considers that bid-ask spread is a function of the weighted average of three factors including the different valuations $\overline{V}_{b-s}$ and the expected loss of adverse selection for buyers and sellers (L_b^{AS}, L_s^{AS}), respectively. Therefore, the below equation decomposes the spread into three terms as:

$$\pi = \omega_1 \overline{V}_{b-s} + \omega_2 L_s^{AS} + \omega_3 L_b^{AS}$$

In previous section, we offer the univariate tests of percentage spread related the market competition measure ($k\%$) and the weight of different valuations ($\omega_1\%$) both reflecting the traders' heterogeneous beliefs. Nevertheless, the market competition measure also generates the weights of the other two factors as the expected loss of adverse selection of sellers and buyers. So, we need to simultaneously consider $\omega_1\%$, $\omega_2\%$ and $\omega_3\%$ to comprehensively capture the variation of spreads, not just $k\%$. In this section, we use multiple regression tests to examine whether the equilibrium of our model is empirically valid. However, the model has proven $\omega_1 + \omega_2 + \omega_3 = 1$; to avoid the multicollinearity, we eliminate ω_1% variable for the regression models. A panel data regression is estimated with the following empirical model rewritten from the original equation:

$$\pi = \overline{V}_{b-s} + \omega_2(L_s^{AS} - \overline{V}_{b-s}) + \omega_3(L_b^{AS} - \overline{V}_{b-s}) + \varepsilon$$

where $\overline{V}_{b-s}$ denotes the different valuations between buys and sellers, and L_s^{AS} (L_b^{AS}) is the expected loss of adverse selection of the sellers (buyers). The equation can be estimated by using multiple regressions on two independent variables: (i) the weight of the sellers' expected loss of adverse selection (ω_2), and (ii) the weight of the buyers' expected loss of adverse selection (ω_3). We performed panel data regressions of all listed stocks in TAIEX market for each month. The results in Panel A of Table 14 indicate that the three coefficients in all regressions turn out to be significant. The coefficient of ω_2 (ω_3) represents $L_s^{AS} - \overline{V}_{b-s}$ ($L_b^{AS} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, and then L_s^{AS} (L_b^{AS}) is obtained by the coefficient of ω_2 (ω_3) plus the intercept term. For instance, L_s^{AS} of April 2003 is equal to 0.6012% as the coefficient of ω_2 (0.027%) plus the intercept term (0.574%). Likewise, L_b^{AS} of April 2003 is equal to 0.5335% as the coefficient of ω_3 (-0.04%) plus the intercept term (0.574%). Based on this method, we further investigate monthly the size of the three factors for market in Panel B of Table 14 and the results show that the different valuations averages 0.473%; sellers' expected loss of adverse selection averages 0.54%; buyers' expected loss of adverse selection averages 0.583%. Next, for each month, we estimate separately the values and percentages of spread coming from the three different factors according to the means of ω_1, ω_2, and ω_3. The Panel C of Table 14 provides the anatomy of the percentage spread for each month in our samples period. Our results indicate that on average the different valuations account for approximately 26.02% of the percentage bid-ask spread, seller's expected loss of adverse selection account for approximately 36.95% of the percentage bid-ask spread, and buyer's one account for approximately 37.03%. In summary, all adverse selection costs account for approximately 74% of the percentage spread, then it reflect whoever submitting limit order mostly concerns the informed trading. In addition, we also examine the quoted spreads of the simulation data by panel regression. The last column presents the related results that show the linear regression fitted the analysis of our non-linear equilibrium model.

In fact, the characteristics of traders seems to have important influences on the bid-ask spread, like the asset volatility, the expected profit, the probability of informed trading and so forth. As a result, we focus on the two most critical characteristics of traders as the probability of informed trading and the asset volatility. In the light of the analysis in previous univariate tests, we incorporate the two proxy variables, as time intervals and firm size represented respectively the estimated probability of informed trading and asset volatility, into the multiple regression analysis. The inclusions of dummy variables capture the variation of the two feature of individual stock during the sample period. Firstly, we conduct the following regressions to determine the effects of the probability of informed trading on the percentage spread:

$$\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 Time_i (L^{AS}_{s,time_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 Time_i (L^{AS}_{b,time_i} - \overline{V}_{b-s}) + \varepsilon$$

where $Time_i$ =0/1 dummy variable, $Time_1$ = for the trading period from 9:00 A.M. to 9:54 A.M. and 0 otherwise, with $Time_2 \sim Time_5$ defined in a similar manner for 54 minutes per time interval from 9:55 A.M. to 1:30 P.M. Taipei time. ε = the error term, which is assumed to be normally distributed.

Our results are displayed in Table 15. The coefficients of regression for each month almost turn out to be significant. Thereby, we offer the following interpretation of the spread regressions. Both adverse selection costs of seller and buyer for the different time intervals directly are calculated from the coefficients of independent variables plus intercept term in Table 15. Table 16 reveals the expected loss of adverse selection. The results indicate that the average adverse selection cost varies significantly across time quintiles. We find the largest adverse selection cost at the open and the smallest one at the noon. This pattern is in the shape of a reverse-J intraday pattern, which is consistent with Nyholm (2003) and Hong and Wang (2000).They show that the probability of informed trading is larger in the morning than in the afternoon. Table 16 show the adverse selection cost of seller and buyer respectively also appear a reverse-J intraday pattern. Figure 6 is a graph that plots the summation of the expected loss of adverse selection of seller and buyer between the different time intervals according Table 16. Besides, we also examine the quoted spreads of the simulation data by panel regression using the dummy quintiles of the probability of informed trading; quintile 1 as the smallest probability group and quintile 5 as the largest probability group. The equation is:

$$\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 p_i (L^{AS}_{s,p_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 p_i (L^{AS}_{b,p_i} - \overline{V}_{b-s}) + \varepsilon$$

where p_i =1/0 dummy variables, $p_1 =$ for the smallest probability of informed trading quintile and 0 otherwise, $p_2 \sim p_5$ defined in a similar manner. The result of simulation data show that the probability of informed trading is positively related to the expected loss of adverse selection in the last columns of Table 15 and Table 16.

Likewise, to test the monotonically increasing relation between assets volatility and adverse selection cost, we examine the hypothesis by running the following panel regression on the percentage spread:

$$\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 Size_i (L^{AS}_{s,size_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 Size_i (L^{AS}_{b,size_i} - \overline{V}_{b-s}) + \varepsilon$$

where $Size_i$ are dummies for daily firm size quintiles, $Size_1$ represents the smallest firm size quintile, and $Size_5$ represents the largest firm size quintile; others in the same manner.

The results are shown in Table 17. Most coefficients of firm size quintile dummies are significantly not equal than zero and F-statistics of regression provide that our model have the strong explanatory power on percentage spread. In the same measure, both sellers' and buyers' expected loss of adverse selection for the different firm size quintiles directly are calculated from the coefficients of independent variables plus intercept term shown in Table 18. Figure 7 is a graph that plots the summation of the expected loss of adverse selection of seller and buyer between the different firm size quintiles according Table 18. Similarly, we also examine the quoted spreads of the simulation data by panel regression using the dummy quintiles of the asset volatility recognized by sellers and buyers, respectively; quintile 1 as the smallest asset volatility group and quintile 5 as the largest asset volatility group. The equation is:

$$\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 vs_i (L^{AS}_{s,vs_i} - \overline{V}_{b-s}) + \sum_{i=1}^{5} \omega_3 vb_i (L^{AS}_{b,vb_i} - \overline{V}_{b-s}) + \varepsilon \ .$$

where vs_i and vb_i are dummies for the asset volatility recognized by sellers and buyers, respectively. $i = 1 \sim 5$ separately denote from the smallest volatility quintile to the largest volatility quintile. The result of simulation data, in the last column of Table 17 and 18, shows that the asset volatility recognized by both side traders is positively related to the expected loss of adverse selection. These results provide clear and strong support for the hypothesis about more severe adverse selection risk in markets with high stock-specific volatility. Those are consistent with Foucault (1999) and Sandas(2001). Figure 7 illustrates that the summation of buyers' and sellers' adverse selection costs is positive related to size quintile dummy variable, implying that the volatility of the asset is a main determinant of the adverse selection costs.

Finally, we try to integrate the asset volatility and the probability of informed trading into the analysis of adverse selection costs. We investigated the joint relation from the regression of the percentage spread with firm size quintile dummies and time interval dummies. The model to be estimated as:

$$\pi = \overline{V}_{b-s} + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_2 Size_i Time_j (L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}) + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_3 Size_i Time_j (L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}) + \varepsilon$$

Previous section has shown respectively the effects of asset volatility and the probability of informed trading. Hence, the comprehensive analysis is necessary for understanding the independent effects for both variables in our model. Table 19 exhibits all joint regressions. all dummy variables are mostly significant. According the regressions, we estimate the adverse selection costs for each quintile. Table 20 presents that the time intervals quintiles under different firm size quintiles for each month are also still shown the reverse-J intraday patterns. In order to observe the independent effect of the probability of informed trading, we reallocate the adverse selection costs, and Table 21 presents that the firm size quintiles under different time interval quintiles are still negatively related the adverse selection costs. Similarly, we use the simulation data to integrate the asset volatility and the probability of informed trading into the analysis of adverse selection costs. The regression model is:

$$\pi = \overline{V}_{b-s} + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_2 vs_i\, p_j (L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}) + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_3 vb_i\, p_j (L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}) + \varepsilon$$

The results of simulation data, in the last column of Table 19, Table 20 and Table 21, show that the asset volatility and the probability of informed trading are monotonically increasing relations with the expected loss of adverse selection. In comprehensive analysis, our results are still significantly consistent with previous studies (Nyholm (2003), Hong and Wang (2000), Foucault (1999) and Sandas(2001)).

In summary, our regression tests not only show that our model is fitted to analyze the equilibrium of price quotation but also provide that the asset volatility and the probability of informed trading are the key determinants for the expected loss of adverse selection and the bid-ask spread.

6. Conclusion

This paper presents a dynamic model of price quotation process which ultimately evolves into a decomposable equilibrium of bid-ask spread under integration of three basic rationales, including the heterogeneous beliefs, the adverse selection and the reward-to-variability ratio. Our major finding is that the optimal bid-ask spread consists of three factors: (i) the different valuations among two group of traders; (ii) the expected loss of adverse selection of sellers; and (iii) the expected loss of adverse selection of buyers, and their weights. Particularly, the equilibrium spread is a weighted average of the three factors. Besides, the parameters that comprise the characteristics of market participants and market competition synchronously determine the three factors and their weights. The numerical tests validate the relations between those parameters and the bid-ask spread. Finally, the empirical tests using quote data for all listed stocks from TAIEX and simulation data verify that our model is a fitting model for analyzing the process of quote setting and, furthermore, the asset volatility and the probability of informed trading are two key determinants for the adverse selection cost and the bid-ask spread.

The main contributions of this article are the follows. First, we define precisely the magnitude of the expected loss of adverse selection which is endogenously formed, not being given in the model of order strategies. In practice, market participants can’t learn the certain loss of adverse selection, and, in other word, they just estimate the loss by themselves. Second, the components and determinants of the bid-ask spread in our model are benignant for understanding the causes of the fluctuation of bid-ask spread, because all parts source from the characteristics of traders and market condition. Third, we achieve to clearly disentangle the adverse selection costs into buyers’ and sellers’. Basically, both of buyers and sellers are simultaneously liquidity provider and consumer. They compete to demand and supply the liquidity to the market. Therefore, the bid-ask spread in an order driven market is more complicate than in a quote driven market. If we can’t thoroughly discriminate buyers from sellers, the analysis of bid-ask spread still touch on the surface not in the core.

Appendix:

1. Proof of Proposition 1

We assume that x_1 and x_2, as random variables, have joint normal distribution, $x_1 \sim N(\mu_1, \sigma_1^2)$, $x_2 \sim N(\mu_2, \sigma_2^2)$, $\rho \neq 0$. The conditional probability density functions as:

$$f(x_1/x_2) = \frac{f(x_1, x_2)}{f(x_2)} = \frac{1}{\sqrt{2\pi\sigma_1^2(1-\rho^2)}} e^{\frac{-\left[x_1 - \mu_1 - \frac{\rho\sigma_1\sigma_2}{\sigma_2^2}(x_2 - \mu_2)\right]^2}{2\sigma_1^2(1-\rho^2)}}$$

Taking the integration, we get the approximate value of the conditional expectation of $x_1 - a$ between a and $-\infty$ as:

$$\int_{-\infty}^{a} (x_1 - a) f(x_1/x_2) dx_1 = \int_{-\infty}^{a} (x_1 - a) \frac{1}{\sqrt{2\pi\sigma_1^2(1-\rho^2)}} e^{\frac{-\left[x_1 - \mu_1 - \frac{\rho\sigma_1\sigma_2}{\sigma_2^2}(x_2 - \mu_2)\right]^2}{2\sigma_1^2(1-\rho^2)}} dx_1$$

$$\approx -\left[a - \mu_1 - \frac{\rho\sigma_1}{\sigma_2}(x_2 - \mu_2)\right] - \frac{1}{\sqrt{2\pi}} \frac{(\sigma_1\sqrt{1-\rho^2})^3}{\left[a - \mu_1 - \frac{\rho\sigma_1}{\sigma_2}(x_2 - \mu_2)\right]^2} e^{\frac{-\left[a - \mu_1 - \frac{\rho\sigma_1}{\sigma_2}(x_2 - \mu_2)\right]^2}{2\sigma_1^2(1-\rho^2)}} \quad \ldots\text{(A1)}$$

By the assumption in the modeling framework, we presume that buyers use the noisy private signal $\tilde{S}_b$ to infer the true value of asset $\tilde{X}$, and consider both of the variables having joint normal distribution. In order to solve the expected profits of limit order for buyers, we let $x_1 = \tilde{X}$, $x_2 = \tilde{S}_b$ and $a = P_B$. Using the approximate equation of (A1), we rewrite the first term of (1).

$$\int_{-\infty}^{a}(x_1 - a)f(x_1/x_2)dx_1 = \int_{-\infty}^{P_B}(X - P_B)f(X/S_b)dX$$

$$= \int_{-\infty}^{P_B}(X - P_B)\frac{1}{\sqrt{2\pi\sigma_{b,x}^2(1-\rho_b^2)}}e^{\frac{-\left[X-\mu_x^H-\frac{\rho_b\sigma_{b,x}\sqrt{\sigma_{b,x}^2+\sigma_{b,u}^2}}{\sigma_{b,x}^2+\sigma_{b,u}^2}(S_b-\mu_x^H)\right]^2}{2\sigma_{b,x}^2(1-\rho_b^2)}}dX$$

$$\approx -\left[P_B - \mu_x^H - \rho_b^2(S_b - \mu_x^H)\right]$$

$$-\frac{1}{\sqrt{2\pi}}\frac{(\sigma_{b,x}\sqrt{1-\rho_b^2})^3}{\left[P_B - \mu_x^H - \rho_b^2(S_b - \mu_x^H)\right]^2}e^{\frac{-\left[P_B-\mu_x^H-\rho_b^2(S_b-\mu_x^H)\right]^2}{2\sigma_{b,x}^2(1-\rho_b^2)}} \quad \text{.................(A2)}$$

On the other hand, in order to solve the second term of (1), we apply Projection Theorem.

$$E(\tilde{X}/S_b) = \mu_x^H + \frac{\sigma_{b,x}^2}{\sigma_{b,x}^2 + \sigma_{b,u}^2}(S_b - \mu_x^H) = \mu_x^H + \rho_b^2(S_b - \mu_x^H)$$

$$V(\tilde{X}/S_b) = \frac{\sigma_{b,x}^2\sigma_{b,u}^2}{\sigma_{b,x}^2 + \sigma_{b,u}^2} = \sigma_{b,u}^2\rho_b^2$$

So, the solution of the second term of (1) is:

$$\int_{-\infty}^{\infty}(X - P_B)f(X/S_b)dX = \left[\mu_x^H + \rho_b^2(S_b - \mu_x^H)\right] - P_B \quad \text{..........................(A3)}$$

Finally, we integrate the first term of (1) with the second term. We get the expected profits of buyers by submitting limit orders with the private noisy signals:

$$E(profit_{\lim}^b/S_b) = k\left[p \times \int_{-\infty}^{P_B}(X - P_B)f(X/S_b)dX + q \times \int_{-\infty}^{\infty}(X - P_B)f(X/S_b)dX\right]$$

$$\approx k\left\{p\left[-\left[P_B - \mu_x^H - \rho_b^2(S_b - \mu_x^H)\right] - \frac{1}{\sqrt{2\pi}}\frac{(\sigma_{b,x}\sqrt{1-\rho_b^2})^3}{\left[P_B - \mu_x^H - \rho_b^2(S_b - \mu_x^H)\right]^2}e^{\frac{-\left[P_B-\mu_x^H-\rho_b^2(S_b-\mu_x^H)\right]^2}{2\sigma_{b,x}^2(1-\rho_b^2)}}\right]\right.$$

$$+(1-p)\left[\mu_x^H+\rho_b^2(S_b-\mu_x^H)-P_B\right]\Bigg\}\ldots\ldots\ldots\text{(A4)}$$

Given the private noisy signal of buyers as S_b, the conditional probability of $X=P_B$ as:

$$\mathrm{P}(X=P_B/S_b)=\frac{1}{\sqrt{2\pi\sigma_{b,x}^2(1-\rho_b^2)}}e^{\frac{-\left[P_B-\mu_x^H-\rho_b^2(S_b-\mu_x^H)\right]^2}{2\sigma_{b,x}^2(1-\rho_b^2)}}$$

Besides, by Projection Theorem, if buyer's cost of the investment is P_B, we can obtain the condition expectation and variance of the investment.

$$E(\tilde{X}-P_B/S_b)=\mu_x^H+\rho_b^2(S_b-\mu_x^H)-P_B,\quad V(\tilde{X}-P_B/S_b)=\sigma_{b,u}^2\rho_b^2$$

Suppose that $R_b=\mu_x^H+\rho_b^2(S_b-\mu_x^H)-P_B$ and $\sigma_{R_b}^2=\sigma_{b,u}^2\rho_b^2$, then $\mathrm{P}(X=P_B/S_b)$, $\sigma_{R_b}^2$ and R_b are substituted into (A4).

$$E(profit_{\lim}^b/S_b)\approx k\left[p\left(R_b-\frac{\sigma_{b,x}^4(1-\rho_b^2)^2}{R_b^2}\mathrm{P}(X=P_B/S_b)\right)+(1-p)R_b\right]$$

$$=k\left[R_b-p\mathrm{P}(X=P_B/S_b)\left(\frac{\sigma_{R_b}^2}{R_b}\right)^2\right]$$

$$=k\left[R_b-p\mathrm{P}(X=P_B/S_b)(\frac{1}{R/V_{R_b}})^2\right]$$

$$=k\left[R_b-L_b^{AS}\right]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(A5)}$$

where $L_b^{AS}=p\mathrm{P}(X=P_B/S_b)(\frac{1}{R/V_{R_b}})^2$ as the expected loss of adverse selection of buyers, $R/V_{R_b}=\frac{R_b}{\sigma_{R_b}^2}$ as the reward-to-variability ratio of buyers' investment.

Moreover, in order to the solution of (2), we apply Projection Theorem. The expected profits of buyers by submitting market order as:

$$E(profit_{mkt}^b/S_b)=\int_{-\infty}^{\infty}(X-P_A)f(X/S_b)dX=\mu_x^H+\rho_b^2(S_b-\mu_x^H)-P_A\ldots\ldots\ldots\text{(A6)}$$

2. Proof of Proposition 2

Likewise, we have the same assumption in proposition 1. Taking the integration, we get the approximate value of the conditional expectation of $a - x_1$ between ∞ and a as:

$$\int_a^\infty (a-x_1) f(x_1/x_2)dx_1 = \int_a^\infty (a-x_1)\frac{1}{\sqrt{2\pi\sigma_1^2(1-\rho^2)}} e^{\frac{-(x_1-\mu_1-\frac{\rho\sigma_1\sigma_2}{\sigma_2^2}(x_2-\mu_2))^2}{2\sigma_1^2(1-\rho^2)}} dx_1$$

$$\approx \left[a-\mu_1-\frac{\rho\sigma_1}{\sigma_2}(x_2-\mu_2)\right] - \frac{1}{\sqrt{2\pi}}\frac{(\sigma_1\sqrt{1-\rho^2})^3}{\left[a-\mu_1-\frac{\rho\sigma_1}{\sigma_2}(x_2-\mu_2)\right]^2} e^{\frac{-\left[a-\mu_1-\frac{\rho\sigma_1}{\sigma_2}(x_2-\mu_2)\right]^2}{2\sigma_1^2(1-\rho^2)}} \quad \text{……..….(A7)}$$

Similarly, by the assumption in the modeling framework, we presume that sellers use the noisy private signal $\tilde{S}_s$ to infer the true value of asset $\tilde{X}$, and consider both of the variables having joint normal distribution. In order to solve the expected profits of limit order for sellers, we let $x_1 = \tilde{X}$, $x_2 = \tilde{S}_s$ and $a = P_A$. Using the approximate equation of (A7), we rewrite the first term of (3).

$$\int_a^\infty (a-x_1) f(x_1/x_2)dx_1 = \int_{P_A}^\infty (P_A - X) f(X/S_s)dx_1$$

$$= \int_{P_A}^\infty (P_A - X)\frac{1}{\sqrt{2\pi\sigma_{s,x}^2(1-\rho_s^2)}} e^{\frac{-\left[X-\mu_x^L-\frac{\rho_s\sigma_{s,x}\sqrt{\sigma_{s,x}^2+\sigma_{s,u}^2}}{\sigma_{s,x}^2+\sigma_{s,u}^2}(S_s-\mu_x^L)\right]^2}{2\sigma_{s,x}^2(1-\rho_s^2)}} dX$$

$$\approx \left[P_A-\mu_x^L-\rho_s^2(S_s-\mu_x^L)\right] - \frac{1}{\sqrt{2\pi}}\frac{(\sigma_{s,x}\sqrt{1-\rho_s^2})^3}{\left[P_A-\mu_x^L-\rho_s^2(S_s-\mu_x^L)\right]^2} e^{\frac{-\left[P_A-\mu_x^L-\rho_s^2(S_s-\mu_x^L)\right]^2}{2\sigma_{s,x}^2(1-\rho_s^2)}} \quad \text{…(A8)}$$

On the other hand, in order to solve the second term of (3), we apply Projection Theorem.

$$E(\tilde{X}/S_s) = \mu_x^L + \frac{\sigma_{s,x}^2}{\sigma_{s,x}^2+\sigma_{s,u}^2}(S_s-\mu_x^L) = \mu_x^L + \rho_s^2(S_s-\mu_x^L)$$

$$V(\tilde{X}/S_s) = \frac{\sigma_{s,x}^2\sigma_{s,u}^2}{\sigma_{s,x}^2+\sigma_{s,u}^2} = \sigma_{s,u}^2\rho_s^2$$

So, the solution of the second term of (3) is:

$$\int_{-\infty}^{\infty}(P_A - X) f(X/S_s)dX = P_A - \left[\mu_x^L + \rho_s^2(S_s - \mu_x^L)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots(A9)$$

Finally, we integrate the first term of (3) with the second term. We get the expected profits of sellers by submitting limit orders with the private noisy signals:

$$E(profit_{\lim}^s / S_s) = (1-k)\left[p \times \int_{P_A}^{\infty}(P_A - X) f(X/S_s)dX + q \times \int_{-\infty}^{\infty}(P_A - X) f(X/S_s)dX \right]$$

$$\approx (1-k)\left\{ p\left[\left[P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L)\right] - \frac{1}{\sqrt{2\pi}} \frac{(\sigma_{s,x}\sqrt{1-\rho_s^2})^3}{\left[P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L)\right]^2} e^{\frac{-\left[P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L)\right]^2}{2\sigma_{s,x}^2(1-\rho_s^2)}}\right]\right.$$

$$\left. + (1-p)\left[P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L)\right]\right\} \ldots\ldots\ldots\ldots(A10)$$

Given the private noisy signal of sellers as S_s, the conditional probability of $X = P_A$ as:

$$\mathrm{P}(X = P_A / S_s) = \frac{1}{\sqrt{2\pi\sigma_{s,x}^2(1-\rho_s^2)}} e^{\frac{-\left[P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L)\right]^2}{2\sigma_{s,x}\sqrt{1-\rho_s^2}}}$$

Besides, by Projection Theorem, if seller's revenue of the investment is P_A, we can obtain the condition expectation and variance of the investment.

$$E(P_A - \tilde{X} / S_s) = P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L),\ \ V(P_A - \tilde{X} / S_s) = \sigma_{s,u}^2\rho_s^2$$

Suppose that $R_s = P_A - \mu_x^L - \rho_s^2(S_s - \mu_x^L)$ and $\sigma_{R_s}^2 = \sigma_{s,u}^2\rho_s^2$, then $\mathrm{P}(X = P_A / S_s)$, $\sigma_{R_s}^2$ and R_s are substituted into (A10).

$$E(profit_{\lim}^s / S_s) \approx (1-k)\left[p(R_s - \frac{\sigma_{s,x}^4(1-\rho_s^2)^2}{R_s^2}\mathrm{P}(X = P_A / S_s) + (1-p)R_s \right]$$

$$= (1-k)\left[R_s - p\mathrm{P}(X = P_A / S_s)\left(\frac{\sigma_{R_s}^2}{R_b}\right)^2 \right]$$

$$= (1-k)\left[R_s - p\mathrm{P}(X = P_A / S_s)(\frac{1}{R / V_{R_s}})^2 \right]$$

$$= (1-k)\left[R_s - L_s^{AS}\right] \ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(A11)$$

where $L_s^{AS} = p\mathrm{P}(X = P_A / S_s)(\frac{1}{R/V_{R_s}})^2$ as the expected loss of adverse selection of sellers, $R/V_{R_s} = \frac{R_s}{\sigma_{R_s}^2}$ as the reward-to-variability ratio of sellers' investment.

Moreover, in order to the solution of (4), we apply Projection Theorem. The expected profits of sellers by submitting market order as:

$$E(profit_{mkt}^{s} / S_s) = \int_{-\infty}^{\infty} (P_A - X) f(X / S_s) dX = P_A - \mu_x^L - \rho_s^2 (S_s - \mu_x^L) \ldots\ldots\ldots \text{(A12)}$$

3. Proof of Proposition 3

Based on the proposition 1 and 2, we already have the expected profits for both side about submitting limit and market orders. For buyers, if their expected profits of placing limit orders are higher than those of placing market orders, they will submit limit orders. That will lead to escalate the bid price and shrink the expect profits of submitting limit orders. The transaction of limit order will proceed persistently until the expected profits of submitting limit orders close to those of submitting market orders. Eventually, buyers are indifferent between trading via limit order and trading via market order namely that the expected profits via a limit order equal those via a market order, i.e., (2) equal (1) or (A6) equal (A5).

$$\mu_x^H + \rho_x^2 (S_b - \mu_x^H) - P_A$$

$$= k\left[(1-\rho_b^2)\mu_x^H + \rho_b^2 S_b - pP(X = P_B / S_b)\left(\frac{\sigma_{b,u}^2 \rho_b^2}{(1-\rho_b^2)\mu_x^H + \rho_b^2 S_b - P_B} \right)^2 - P_B \right] \ldots\text{(A13)}$$

Given the expected stock value of buyers $\overline{V_b} = (1-\rho_b^2)\mu_x^H + \rho_b^2 S_b$ and $\overline{V_b}^{AS} = \overline{V_b} - L_b^{AS}$ aforementioned in main body of this article, we transpose the above equation to the ask price P_A function.

$$\overline{V}_b - P_A = k\left[\overline{V}_b - pP(X = P_B / S_b)\left(\frac{1}{R/V_{R_b}}\right)^2 - P_B\right]$$

$$\Rightarrow \overline{V}_b - P_A = k\left[\overline{V}_b - L_b^{AS} - P_B\right]$$

$$\Rightarrow P_A = \overline{V}_b - k\left[\overline{V}_b - L_b^{AS} - P_B\right] \text{ or } P_A = \overline{V}_b - k\left[\overline{V}_b^{AS} - P_B\right] \text{…………………..(A14)}$$

Likewise for sellers, sellers are indifferent between trading via limit order and trading via market order, i.e., (4) equal (3) or (A12) equal (A11).

$$P_B - \mu_x^L - \rho_s^2(S_s - \mu_x^L)$$

$$= (1-k)\left[P_A - (1-\rho_s^2)\mu_x^L - \rho_s^2 S_s - pP(X = P_A / S_s)\left(\frac{\sigma_{s,u}^2 \rho_s^2}{P_A - (1-\rho_s^2)\mu_x^L - \rho_s^2 S_s}\right)^2\right] \text{..(A15)}$$

Given the expected stock value of sellers $\overline{V}_s = (1-\rho_s^2)\mu_x^L + \rho_s^2 S_s$ and $\overline{V}_s^{AS} = \overline{V}_s + L_s^{AS}$, we transpose the above equation to the bid price P_B function.

$$P_B - \overline{V}_s = (1-k)\left[P_A - \overline{V}_s - pP(X = P_A / S_s)\left(\frac{1}{R/V_{R_b}}\right)^2\right]$$

$$\Rightarrow P_B - \overline{V}_s = (1-k)\left[P_A - \overline{V}_s - L_s^{AS}\right]$$

$$\Rightarrow P_B = \overline{V}_s + (1-k)\left[P_A - \overline{V}_s - L_s^{AS}\right] \text{ or } P_B = \overline{V}_s + (1-k)\left[P_A - \overline{V}_s^{AS}\right] \text{……..….(A16)}$$

Solving equations (A15) and (A16) contemporaneously, we can get the optimal bid and ask prices:

$$\begin{cases} P_A = \overline{V}_b - k\left[\overline{V}_b - L_b^{AS} - P_B\right] \\ P_B = \overline{V}_s + (1-k)\left[P_A - \overline{V}_s - L_s^{AS}\right] \end{cases}$$

$$\Rightarrow \begin{cases} P_A^* = \phi\overline{V}_b + (1-\phi)(\overline{V}_s + L_s^{AS}) + \lambda(L_b^{AS} - L_s^{AS}) \\ P_B^* = \lambda\overline{V}_s + (1-\lambda)(\overline{V}_b - L_b^{AS}) + \phi(L_b^{AS} - L_s^{AS}) \end{cases}$$

$$\text{or } \begin{cases} P_A^* = \phi\overline{V}_b + (1-\phi)\overline{V}_S^{AS} + \lambda(L_b^{AS} - L_s^{AS}) \\ P_B^* = \lambda\overline{V}_s + (1-\lambda)\overline{V}_b^{AS} + \phi(L_b^{AS} - L_s^{AS}) \end{cases} \text{………………………(A17.1,A17.2)}$$

where $\lambda = \dfrac{k}{1-k(1-k)}$ and $\phi = \dfrac{1-k}{1-k(1-k)}$

4. Proof of Proposition 4

According to the results of the proof of proposition 3, we have already obtained the optimal bid and ask prices. As we know, the optimal ask minus the optimal bid equals the equilibrium spread π. Therefore, (A17.1) minus (A17.2) as:

$$\pi = P_A^* - P_B^*$$

$$= \left[\phi \overline{V}_b + (1-\phi)\overline{V}_s^{AS} + \lambda(L_b^{AS} - L_s^{AS})\right] - \left[\lambda \overline{V}_s + (1-\lambda)\overline{V}_b^{AS} + \phi(L_b^{AS} - L_s^{AS})\right]$$

Simplified the expression of the bid-ask spread:

$$\pi = \gamma(\overline{V}_b - \overline{V}_s) + (1-\lambda)L_s^{AS} + (1-\phi)L_b^{AS}$$

where $\omega_1 = \gamma = \dfrac{k(1-k)}{1-k(1-k)}, \omega_2 = 1-\lambda = \dfrac{(1-k)^2}{1-k(1-k)}, \omega_3 = 1-\phi = \dfrac{k^2}{1-k(1-k)}$

We find out the weights of the three factor of the spread added to unity. So, rewrite the equation of the spread:

$$\pi = \omega_1(\overline{V}_b - \overline{V}_s) + \omega_2 L_s^{AS} + \omega_3 L_b^{AS} \quad \text{...(A18)}$$

where $\omega_1 + \omega_2 + \omega_3 = 1$

For simplification, we assume that both sides trader have the same expected loss of adverse selection ($L_b^{AS} = L_s^{AS} = L^{AS}$), and then rewrite the equation of the spread:

$$\pi = \frac{k(1-k)}{1-k(1-k)}\overline{V}_{b-s} + \frac{1-2k+2k^2}{1-k(1-k)}L^{AS}$$

where $\overline{V}_b - \overline{V}_s = \overline{V}_{b-s}$

Taking the first derivative for π, we can get:

$$\frac{d\pi}{dk} = \frac{1-2k}{\left[1-k(1-k)\right]^2}\overline{V}_{b-s} - \frac{1-2k}{\left[1-k(1-k)\right]^2}L^{AS}$$

We find out that $\dfrac{d\pi}{dk} = 0$ and $\dfrac{d^2\pi}{dk^2} < 0$ as $k = \dfrac{1}{2}$. $k = \dfrac{1}{2}$ leads the spread to the maximum. At this time the weights of the three facts of spread equivalently equal one-third, so the spread is an equal-weighted combination of the three factors. On the other hand, the minimum of the spread will be at the upper and lower bounds of k (as $k = 0$ or 1); in the meanwhile, the spread only reflects the expected loss of adverse selection due to $\omega_2 = 1$ or $\omega_3 = 1$.

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Figure 1: The probability of arrival state

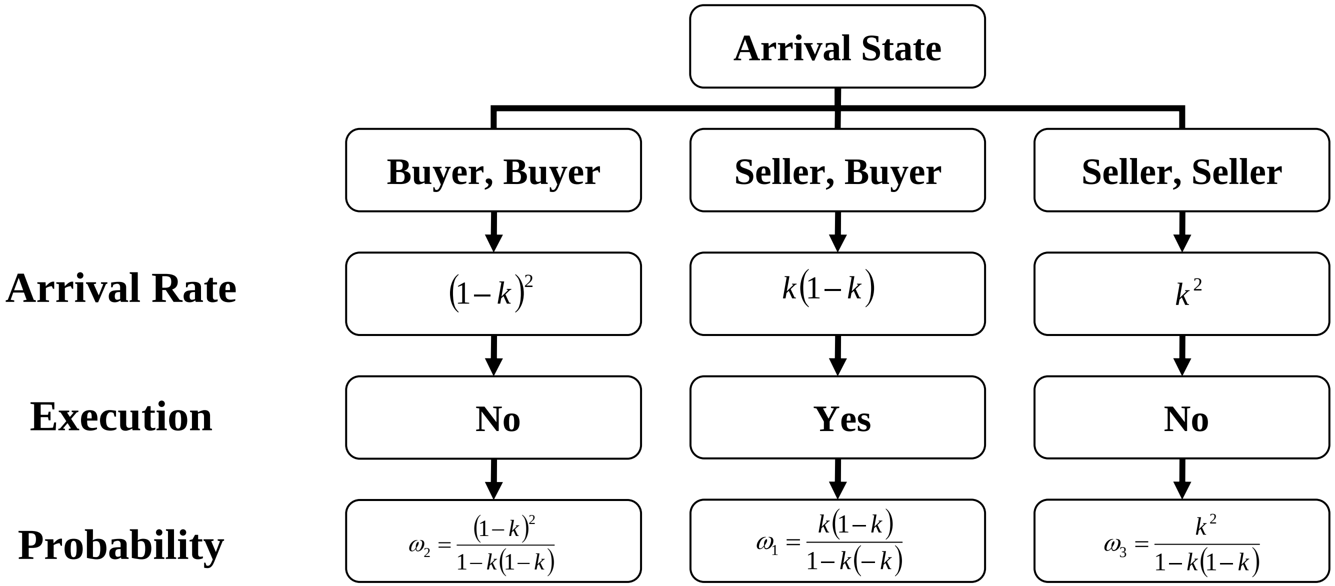

Figure 2

Quintiles of Market competition measure versus mean percentage spreads

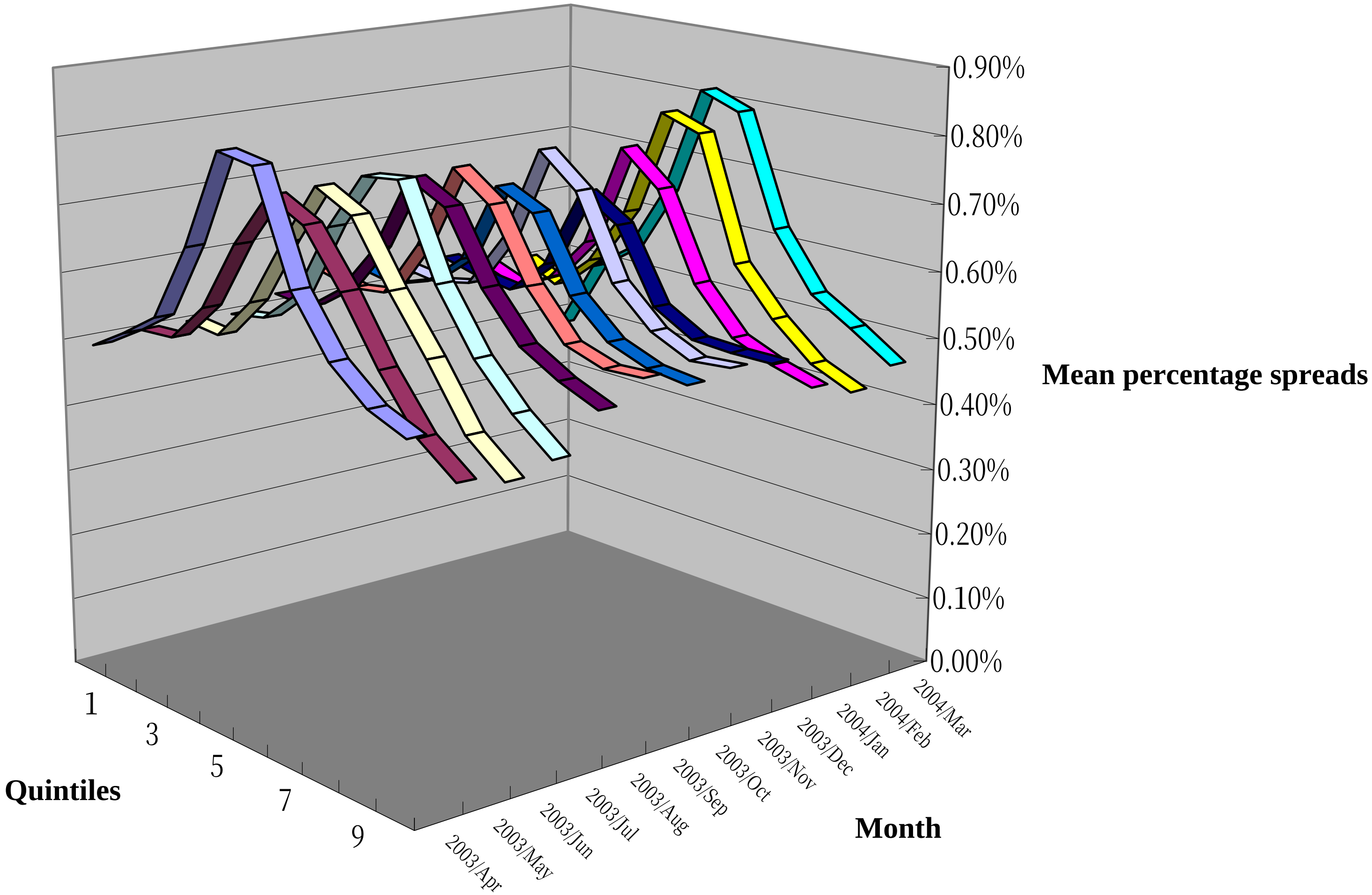

Figure 3

Quintiles of the weight of the different valuations versus mean percentage spreads

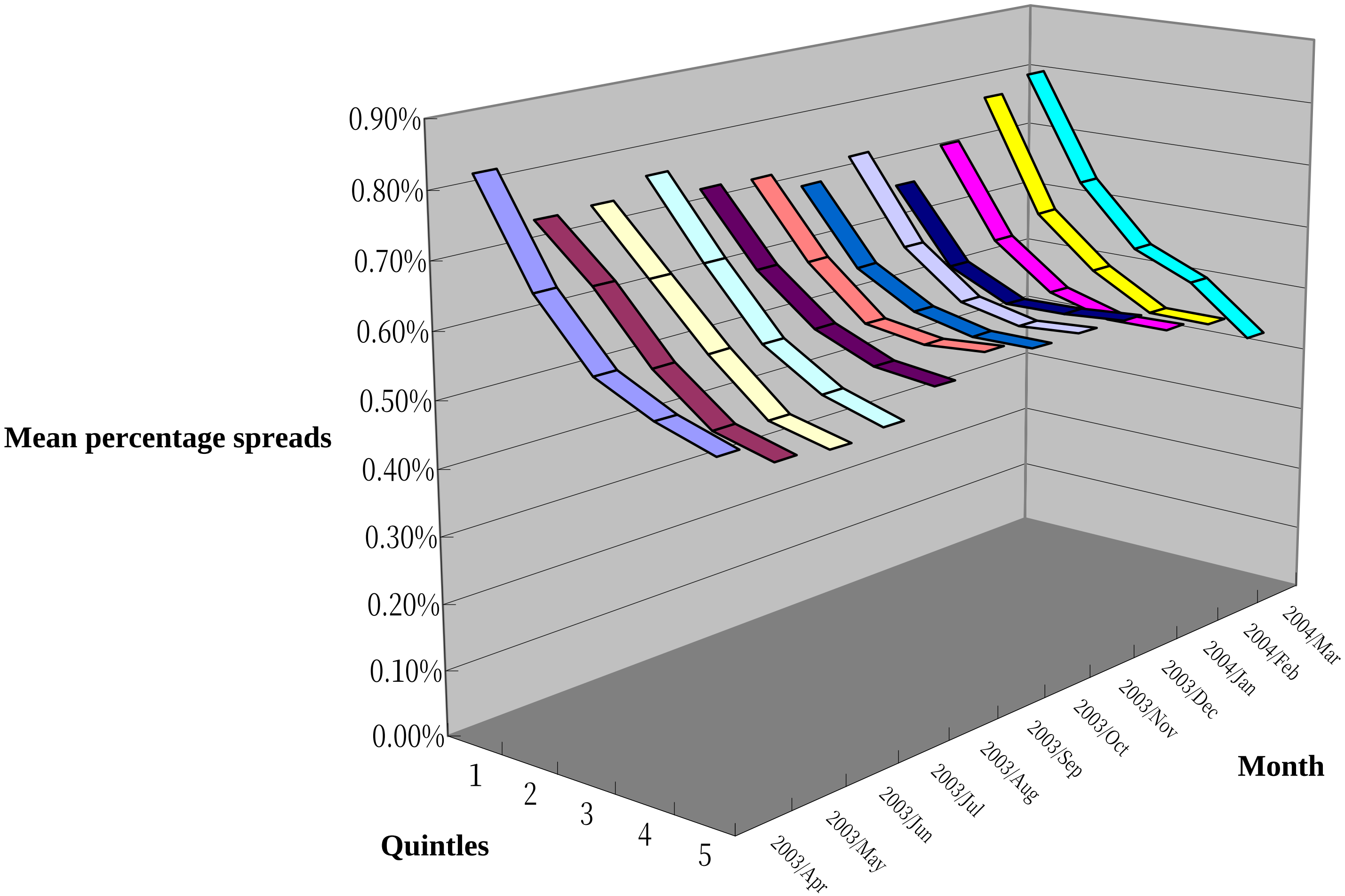

Figure 4

Quintiles of time intervals versus mean percentage spreads

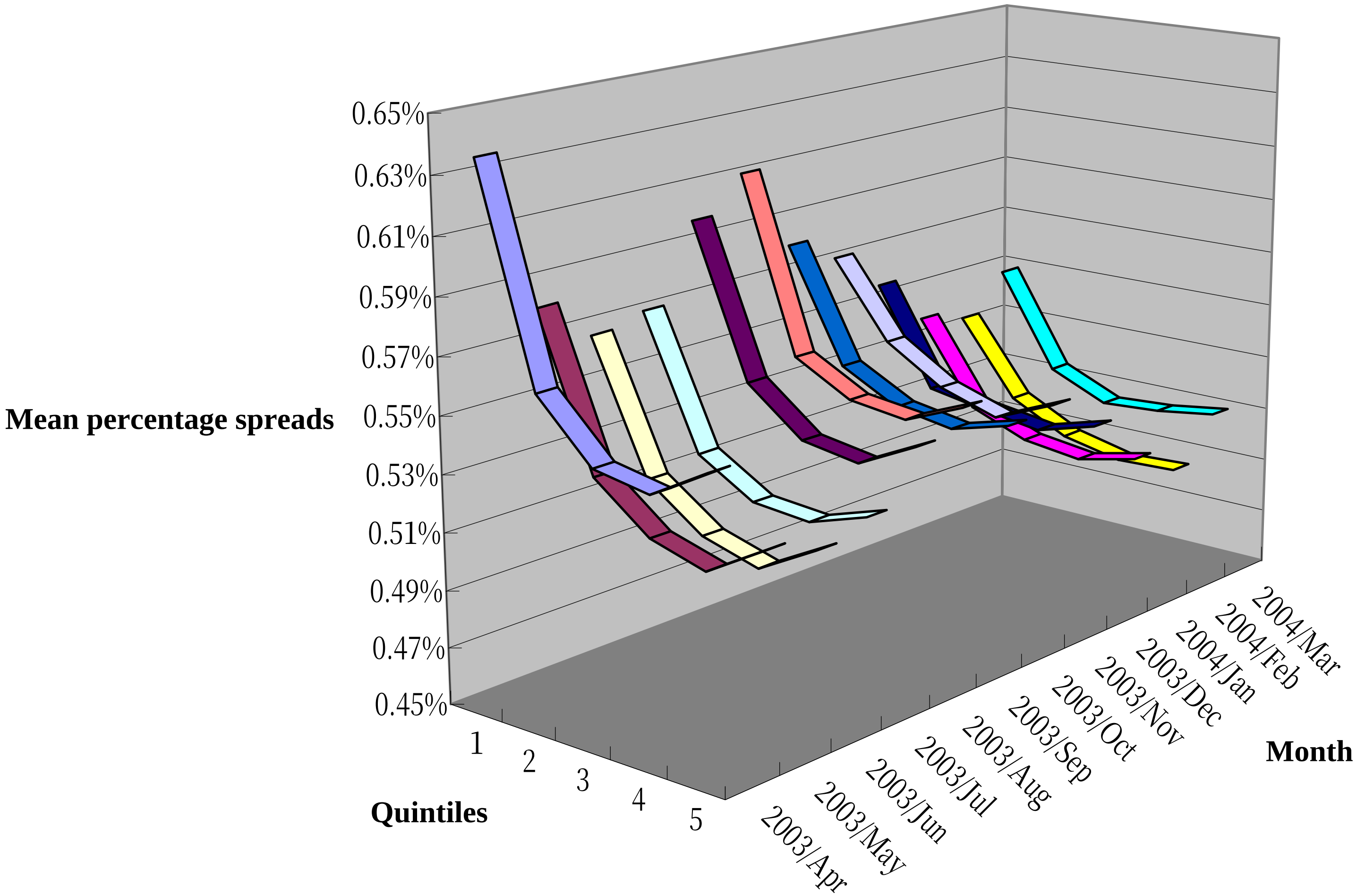

Figure 5

Quintiles of firm size versus mean percentage spreads

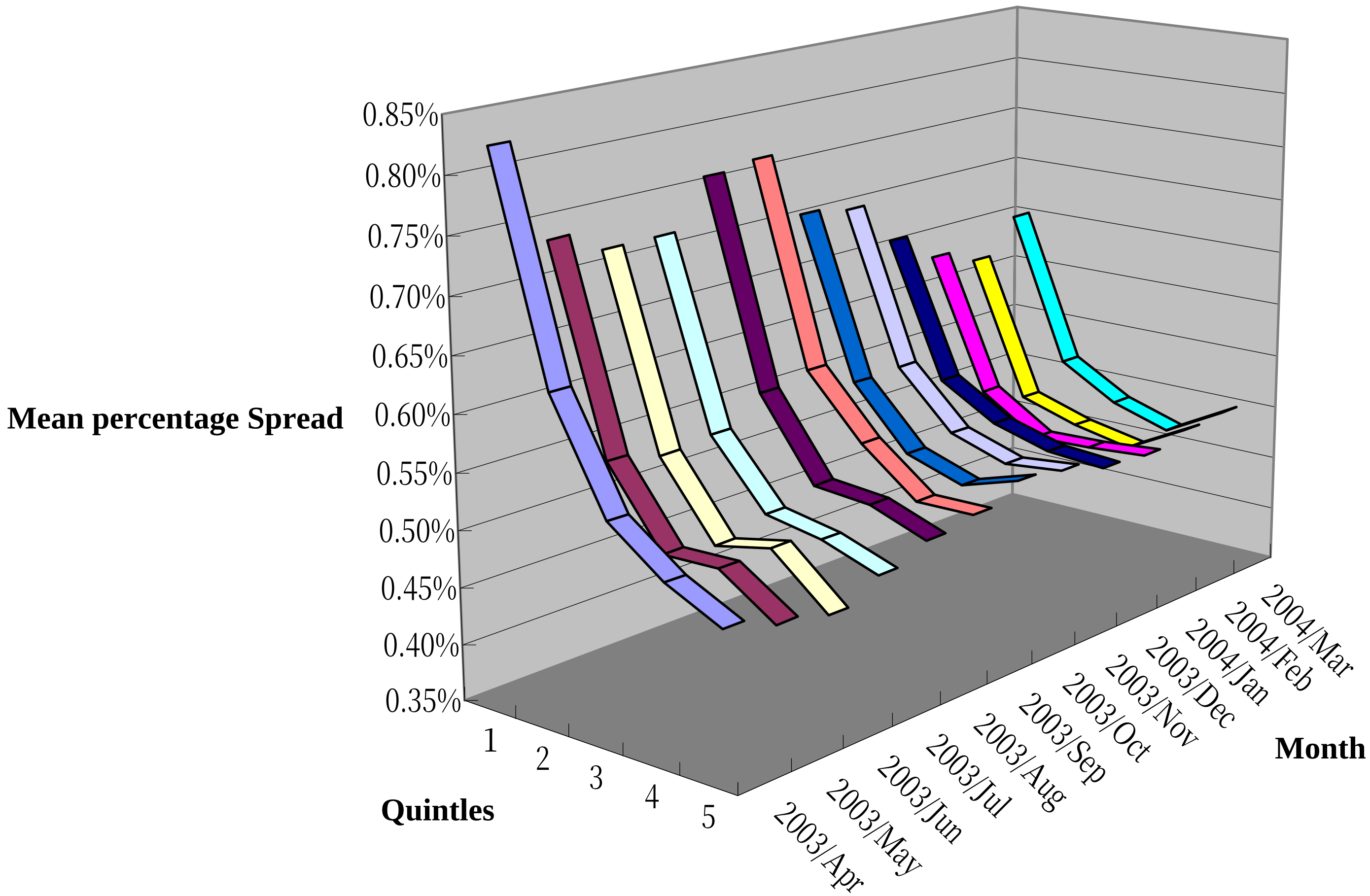

Figure 6

The summation of sellers' and buyers' expected loss of adverse selection versus time interval quintiles

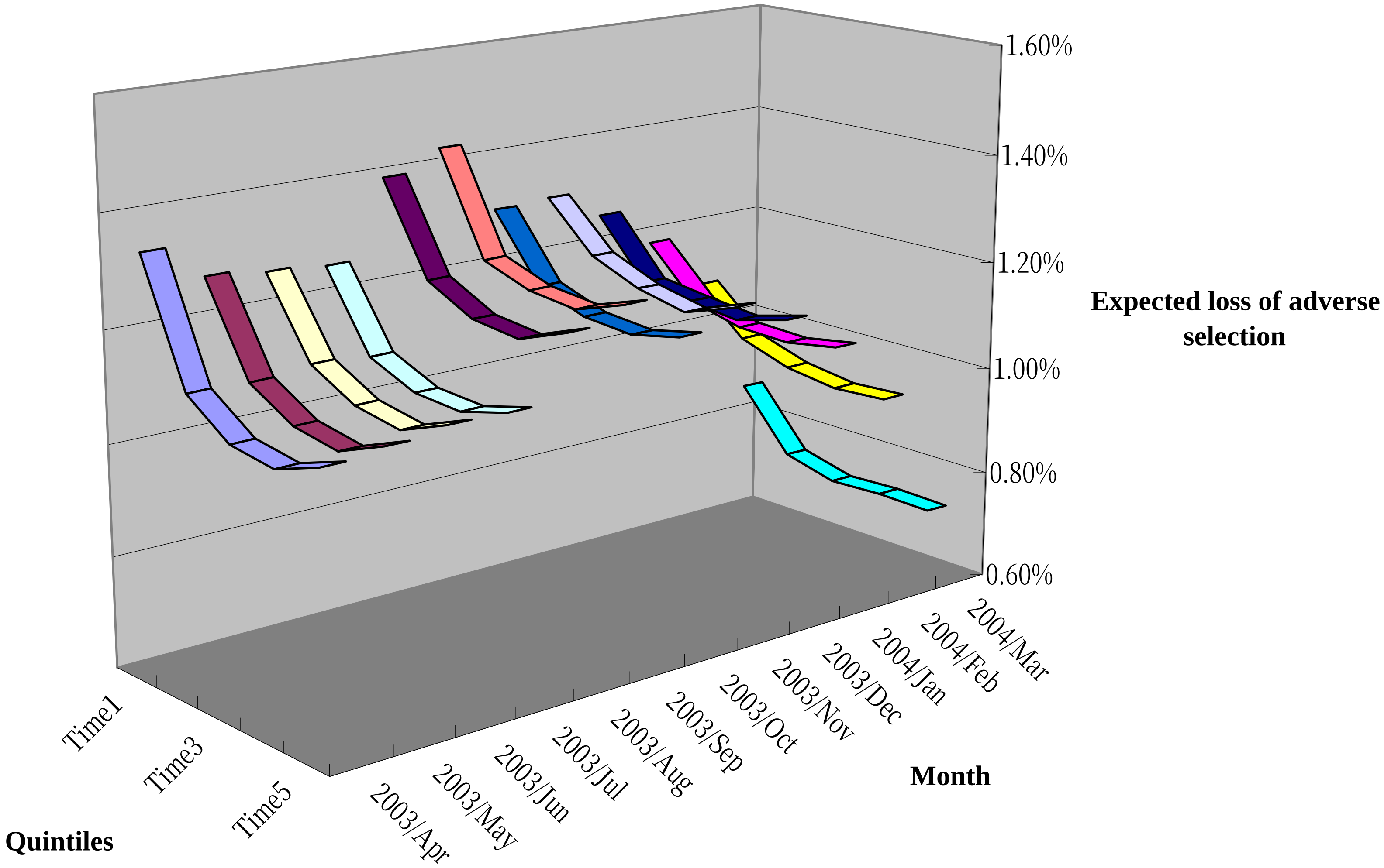

Figure 7
The summation of sellers' and buyers' expected loss of adverse selection versus firm size quintiles

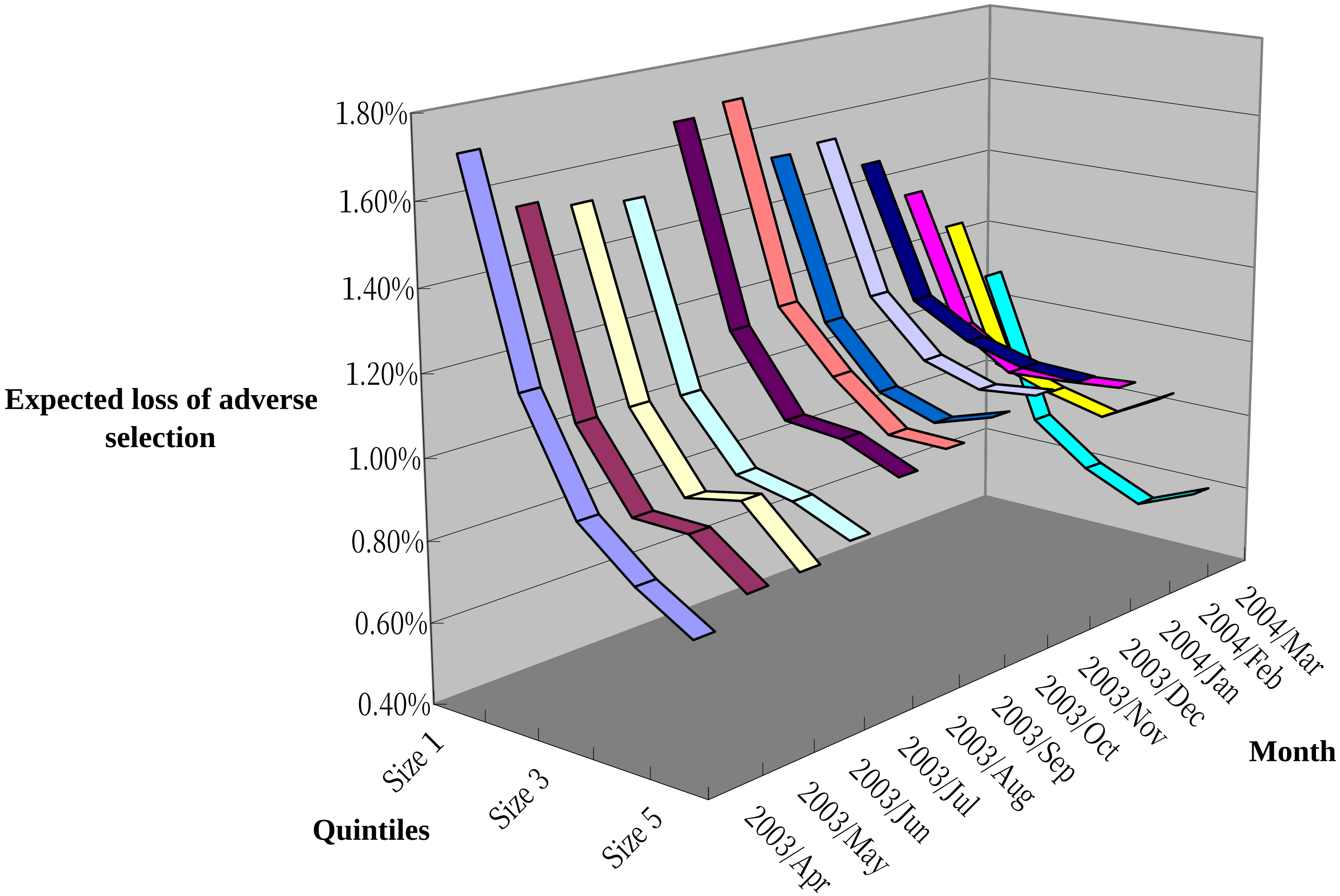

Table 1

The numerical test results when change the valuations of buyers and sellers

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the valuation and, for robustness, the remainder panels are about the same effects while another parameter alters a unit. The empty cells are the divergent results of the numerical tests.

Parameter	Parameter										Quotation		R-to-V ratio		Expected Loss of AS		Expected Value		Expected Profit		Spread				Spread ratio			
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s	P_b	P_a	$R_b/\sigma_{R_b}^2$	$R_s/\sigma_{R_s}^2$	L_b^{AS}	L_s^{AS}	$\bar{V}_b^{AS}$	$\bar{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$	$\omega_1(\bar{V}_b-\bar{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\bar{V}_b-\bar{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_s^{AS}/\pi$	$\omega L^{AS}/\pi$
	110	90	0.5	0.25	20	20	0	0	130	70	95.67	104.33	0.0358	0.0358	3.0035	3.0035	107.00	93.00	5.67	5.67	6.67	1.00	1.00	8.67	0.7690	0.1155	0.1155	0.2310
	120	80	0.5	0.25	20	20	0	0	130	70	93.18	106.82	0.0670	0.0670	0.4515	0.4515	119.55	80.45	13.18	13.18	13.33	0.15	0.15	13.63	0.9779	0.0110	0.0110	0.0221
	130	70	0.5	0.25	20	20	0	0	130	70	89.98	110.02	0.1001	0.1001	0.0673	0.0673	129.93	70.07	19.98	19.98	20.00	0.02	0.02	20.04	0.9978	0.0011	0.0011	0.0022
$\mu_x^H-\mu_x^L$	120	90	0.5	0.25	20	20	0	0	130	70	99.62	110.38	0.0510	0.0510	1.1429	1.1429	118.86	91.14	9.62	9.62	10.00	0.38	0.38	10.76	0.9292	0.0354	0.0354	0.0708
	120	70	0.5	0.25	20	20	0	0	130	70	86.61	103.39	0.0835	0.0835	0.1775	0.1775	119.82	70.18	16.61	16.61	16.67	0.06	0.06	16.79	0.9929	0.0035	0.0035	0.0071
	110	80	0.5	0.25	20	20	0	0	130	70	89.62	100.38	0.0510	0.0510	1.1429	1.1429	108.86	81.14	9.62	9.62	10.00	0.38	0.38	10.76	0.9292	0.0354	0.0354	0.0708
	130	80	0.5	0.25	20	20	0	0	130	70	96.61	113.39	0.0835	0.0835	0.1775	0.1775	129.82	80.18	16.61	16.61	16.67	0.06	0.06	16.79	0.9929	0.0035	0.0035	0.0071
	110	90	0.25	0.25	30	20	0	0	130	70																		
	120	80	0.25	0.25	20	20	0	0	130	70	108.90	118.61	0.0278	0.0965	5.5464	0.0830	114.45	80.08	1.39	28.90	9.23	0.06	0.43	9.71	0.9502	0.0059	0.0439	0.0498
	130	70	0.25	0.25	20	20	0	0	130	70	111.91	125.88	0.0452	0.1397	1.6189	0.0052	128.38	70.01	4.12	41.91	13.85	0.00	0.12	13.97	0.9908	0.0003	0.0089	0.0092
k	120	90	0.25	0.25	20	20	0	0	130	70																		
	120	70	0.25	0.25	20	20	0	0	130	70	105.24	117.01	0.0369	0.1175	2.7883	0.0228	117.21	70.02	2.99	35.24	11.54	0.02	0.21	11.77	0.9804	0.0013	0.0182	0.0196
	110	80	0.25	0.25	20	20	0	0	130	70																		
	130	80	0.25	0.25	20	20	0	0	130	70	115.24	127.01	0.0369	0.1175	2.7883	0.0228	127.21	80.02	2.99	35.24	11.54	0.02	0.21	11.77	0.9804	0.0013	0.0182	0.0196
	110	90	0.5	0.2	20	20	0	0	130	70	95.84	104.16	0.0354	0.0354	2.4780	2.4780	107.52	92.48	5.84	5.84	6.67	0.83	0.83	8.32	0.8014	0.0993	0.0993	0.1986
	120	80	0.5	0.2	20	20	0	0	130	70	93.21	106.79	0.0670	0.0670	0.3628	0.3628	119.64	80.36	13.21	13.21	13.33	0.12	0.12	13.58	0.9822	0.0089	0.0089	0.0178
	130	70	0.5	0.2	20	20	0	0	130	70	89.98	110.02	0.1000	0.1000	0.0538	0.0538	129.95	70.05	19.98	19.98	20.00	0.02	0.02	20.04	0.9982	0.0009	0.0009	0.0018
p	120	90	0.5	0.2	20	20	0	0	130	70	99.69	110.31	0.0508	0.0508	0.9243	0.9243	119.08	90.92	9.69	9.69	10.00	0.31	0.31	10.62	0.9420	0.0290	0.0290	0.0580
	120	70	0.5	0.2	20	20	0	0	130	70	86.62	103.38	0.0835	0.0835	0.1423	0.1423	119.86	70.14	16.62	16.62	16.67	0.05	0.05	16.76	0.9943	0.0028	0.0028	0.0057
	110	80	0.5	0.2	20	20	0	0	130	70	89.69	100.31	0.0508	0.0508	0.9243	0.9243	109.08	80.92	9.69	9.69	10.00	0.31	0.31	10.62	0.9420	0.0290	0.0290	0.0580
	130	80	0.5	0.2	20	20	0	0	130	70	96.62	113.38	0.0835	0.0835	0.1423	0.1423	129.86	80.14	16.62	16.62	16.67	0.05	0.05	16.76	0.9943	0.0028	0.0028	0.0057
	110	90	0.5	0.25	10	10	0	0	130	70	96.59	103.41	0.1341	0.1341	0.2258	0.2258	109.77	90.23	6.59	6.59	6.67	0.08	0.08	6.82	0.9779	0.0110	0.0110	0.0221
	120	80	0.5	0.25	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0040	0.0040	120.00	80.00	13.33	13.33	13.33	0.00	0.00	13.34	0.9998	0.0001	0.0001	0.0002
	130	70	0.5	0.25	10	10	0	0	130	70	90.00	110.00	0.4000	0.4000	0.0000	0.0000	130.00	70.00	20.00	20.00	20.00	0.00	0.00	20.00	1.0000	0.0000	0.0000	0.0000
σ_x	120	90	0.5	0.25	10	10	0	0	130	70	99.99	110.01	0.2001	0.2001	0.0336	0.0336	119.97	90.03	9.99	9.99	10.00	0.01	0.01	10.02	0.9978	0.0011	0.0011	0.0022
	120	70	0.5	0.25	10	10	0	0	130	70	86.67	103.33	0.3333	0.3333	0.0003	0.0003	120.00	70.00	16.67	16.67	16.67	0.00	0.00	16.67	1.0000	0.0000	0.0000	0.0000
	110	80	0.5	0.25	10	10	0	0	130	70	89.99	100.01	0.2001	0.2001	0.0336	0.0336	109.97	80.03	9.99	9.99	10.00	0.01	0.01	10.02	0.9978	0.0011	0.0011	0.0022
	130	80	0.5	0.25	10	10	0	0	130	70	96.67	113.33	0.3333	0.3333	0.0003	0.0003	130.00	80.00	16.67	16.67	16.67	0.00	0.00	16.67	1.0000	0.0000	0.0000	0.0000
	110	90	0.5	0.25	10	20	0	0	130	70	93.48	101.79	0.1652	0.0295	0.0933	4.8282	109.91	94.83	8.21	3.48	6.67	1.61	0.03	8.31	0.8025	0.1937	0.0037	0.1975
	120	80	0.5	0.25	10	20	0	0	130	70	93.02	106.51	0.2698	0.0663	0.0036	0.4715	120.00	80.47	13.49	13.02	13.33	0.16	0.00	13.49	0.9883	0.0116	0.0001	0.0117
	130	70	0.5	0.25	10	20	0	0	130	70	89.95	109.98	0.4005	0.0999	0.0000	0.0677	130.00	70.07	20.02	19.95	20.00	0.02	0.00	20.02	0.9989	0.0011	0.0000	0.0011
$\sigma_{b,x}$	120	90	0.5	0.25	10	20	0	0	130	70	99.15	109.59	0.2085	0.0490	0.0261	1.2872	119.97	91.29	10.41	9.15	10.00	0.43	0.01	10.44	0.9581	0.0411	0.0008	0.0419
	120	70	0.5	0.25	10	20	0	0	130	70	86.55	103.27	0.3345	0.0832	0.0003	0.1806	120.00	70.18	16.73	16.55	16.67	0.06	0.00	16.73	0.9964	0.0036	0.0000	0.0036
	110	80	0.5	0.25	10	20	0	0	130	70	89.15	99.59	0.2085	0.0490	0.0261	1.2872	109.97	81.29	10.41	9.15	10.00	0.43	0.01	10.44	0.9581	0.0411	0.0008	0.0419
	130	80	0.5	0.25	10	20	0	0	130	70	96.55	113.27	0.3345	0.0832	0.0003	0.1806	130.00	80.18	16.73	16.55	16.67	0.06	0.00	16.73	0.9964	0.0036	0.0000	0.0036
	110	90	0.5	0.25	20	20	0.25	0	130	70	95.98	104.75	0.0407	0.0369	2.2763	2.7925	108.97	92.79	6.50	5.98	7.08	0.93	0.76	8.77	0.8074	0.1061	0.0865	0.1926
	120	80	0.5	0.25	20	20	0.25	0	130	70	93.38	107.18	0.0727	0.0680	0.3625	0.4288	120.26	80.43	13.44	13.38	13.54	0.14	0.12	13.81	0.9809	0.0104	0.0088	0.0191
	130	70	0.5	0.25	20	20	0.25	0	130	70	89.97	110.01	0.1067	0.1000	0.0534	0.0674	129.95	70.07	19.99	19.97	20.00	0.02	0.02	20.04	0.9980	0.0011	0.0009	0.0020
ρ_b	120	90	0.5	0.25	20	20	0.25	0	130	70	99.79	110.68	0.0556	0.0517	0.9354	1.0938	119.69	91.09	9.95	9.79	10.21	0.36	0.31	10.88	0.9379	0.0335	0.0286	0.0621
	120	70	0.5	0.25	20	20	0.25	0	130	70	86.81	103.79	0.0902	0.0845	0.1379	0.1678	120.49	70.17	16.84	16.81	16.88	0.06	0.05	16.98	0.9940	0.0033	0.0027	0.0060
	110	80	0.5	0.25	20	20	0.25	0	130	70	90.02	101.08	0.0566	0.0527	0.8815	1.0307	110.37	81.03	10.17	10.02	10.42	0.34	0.29	11.05	0.9423	0.0311	0.0266	0.0577
	130	80	0.5	0.25	20	20	0.25	0	130	70	96.60	113.37	0.0891	0.0834	0.1466	0.1781	129.85	80.18	16.63	16.60	16.67	0.06	0.05	16.77	0.9935	0.0035	0.0029	0.0065

Table 2

The numerical test results when change the proportion of sellers to all traders

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the proportion of sellers to all traders and, for robustness, the remainder panels are about the same effects while another parameter alters a unit. The empty cells are the divergent results of the numerical tests.

Parameter	**Value of Parameter**										**Quotation**		**R-to-V ratio**		**Expected Loss of AS**		**Expected Value**		**Expected Profit**		**Spread**				**Spread ratio**			
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s	P_b	P_a	$R_b/\sigma_{R_b}^2$	$R_s/\sigma_{R_s}^2$	L_b^{AS}	L_s^{AS}	$\bar{V}_b^{AS}$	$\bar{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$	$\omega_1(\bar{V}_b-\bar{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\bar{V}_b-\bar{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_b^{AS}/\pi$	$\omega L^{AS}/\pi$
	120	80	0	0.25	20	20	0	0	130	70	119.933	120.000	0.000	0.100	∞	0.067	$-\infty$	80.067	0.000	39.933	0.0000	0.0675	0.0000	0.0675	0.0000	1.0000	0.0000	1.0000
	120	80	0.25	0.25	20	20	0	0	130	70	108.896	118.610	0.028	0.097	5.546	0.083	114.454	80.083	1.390	28.896	9.2308	0.0575	0.4266	9.7149	0.9502	0.0059	0.0439	0.0498
k	120	80	0.5	0.25	20	20	0	0	130	70	93.183	106.817	0.067	0.067	0.452	0.452	119.548	80.452	13.183	13.183	13.3333	0.1505	0.1505	13.6344	0.9779	0.0110	0.0110	0.0221
	120	80	0.75	0.25	20	20	0	0	130	70	81.390	91.104	0.097	0.028	0.083	5.546	119.917	85.546	28.896	1.390	9.2308	0.4266	0.0575	9.7149	0.9502	0.0439	0.0059	0.0498
	120	80	1	0.25	20	20	0	0	130	70	80.000	80.067	0.100	0.000	0.067	$-\infty$	119.933	∞	39.933	0.000	0.0000	0.0000	0.0675	0.0675	0.0000	0.0000	1.0000	1.0000
	130	70	0	0.25	20	20	0	0	130	70	129.998	130.000	0.000	0.150	∞	0.002	$-\infty$	70.002	0.000	59.998	0.0000	0.0025	0.0000	0.0025	0.0000	1.0000	0.0000	1.0000
	130	70	0.25	0.25	20	20	0	0	130	70	111.907	125.882	0.045	0.140	1.619	0.005	128.381	70.005	4.118	41.907	13.8462	0.0036	0.1245	13.9743	0.9908	0.0003	0.0089	0.0092
$\mu_x^H-\mu_x^L$	130	70	0.5	0.25	20	20	0	0	130	70	89.978	110.022	0.100	0.100	0.067	0.067	129.933	70.067	19.978	19.978	20.0000	0.0224	0.0224	20.0448	0.9978	0.0011	0.0011	0.0022
	130	70	0.75	0.25	20	20	0	0	130	70	74.118	88.093	0.140	0.045	0.005	1.619	129.995	71.619	41.907	4.118	13.8462	0.1245	0.0036	13.9743	0.9908	0.0089	0.0003	0.0092
	130	70	1	0.25	20	20	0	0	130	70	70.000	70.002	0.150	0.000	0.002	$-\infty$	129.998	∞	59.998	0.000	0.0000	0.0000	0.0025	0.0025	0.0000	0.0000	1.0000	1.0000
	130	80	0	0.25	20	20	0	0	130	70	129.986	130.000	0.000	0.125	∞	0.014	$-\infty$	80.014	0.000	49.986	0.0000	0.0140	0.0000	0.0140	0.0000	1.0000	0.0000	1.0000
	130	80	0.25	0.25	20	20	0	0	130	70	115.238	127.007	0.037	0.118	2.788	0.023	127.212	80.023	2.993	35.238	11.5385	0.0158	0.2145	11.7687	0.9804	0.0013	0.0182	0.0196
μ_x^H	130	80	0.5	0.25	20	20	0	0	130	70	96.607	113.393	0.083	0.083	0.178	0.178	129.822	80.178	16.607	16.607	16.6667	0.0592	0.0592	16.7850	0.9929	0.0035	0.0035	0.0071
	120	80	0.75	0.2	20	20	0	0	140	70	81.812	91.412	0.095	0.029	0.071	4.165	119.929	84.165	28.588	1.812	9.2308	0.3204	0.0490	9.6001	0.9615	0.0334	0.0051	0.0385
	130	80	1	0.25	20	20	0	0	130	70	80.000	80.014	0.125	0.000	0.014	$-\infty$	129.986	∞	49.986	0.000	0.0000	0.0000	0.0140	0.0140	0.0000	0.0000	1.0000	1.0000
	120	80	0	0.2	20	20	0	0	140	70	119.946	120.000	0.000	0.100	∞	0.054	$-\infty$	80.054	0.000	39.946	0.0000	0.0540	0.0000	0.0540	0.0000	1.0000	0.0000	1.0000
	120	80	0.25	0.2	20	20	0	0	140	70	108.588	118.188	0.029	0.095	4.165	0.071	115.835	80.071	1.812	28.588	9.2308	0.0490	0.3204	9.6001	0.9615	0.0051	0.0334	0.0385
p	120	80	0.5	0.2	20	20	0	0	140	70	93.212	106.788	0.067	0.067	0.363	0.363	119.637	80.363	13.212	13.212	13.3333	0.1209	0.1209	13.5752	0.9822	0.0089	0.0089	0.0178
	120	80	0.75	0.2	20	20	0	0	140	70	81.812	91.412	0.095	0.029	0.071	4.165	119.929	84.165	28.588	1.812	9.2308	0.3204	0.0490	9.6001	0.9615	0.0334	0.0051	0.0385
	120	80	1	0.2	20	20	0	0	140	70	80.000	80.054	0.100	0.000	0.054	$-\infty$	119.946	∞	39.946	0.000	0.0000	0.0000	0.0540	0.0540	0.0000	0.0000	1.0000	1.0000
	120	80	0	0.25	10	10	0	0	130	70	120.000	120.000	0.000	0.400	∞	0.000	$-\infty$	80.000	0.000	40.000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	1.0000
	120	80	0.25	0.25	10	10	0	0	130	70	107.765	117.020	0.122	0.370	0.315	0.000	119.685	80.000	2.980	27.765	9.2308	0.0001	0.0242	9.2551	0.9974	0.0000	0.0026	0.0026
σ_x	120	80	0.5	0.25	10	10	0	0	130	70	93.332	106.668	0.267	0.267	0.004	0.004	119.996	80.004	13.332	13.332	13.3333	0.0013	0.0013	13.3360	0.9998	0.0001	0.0001	0.0002
	120	80	0.75	0.25	10	10	0	0	130	70	82.980	92.235	0.370	0.122	0.000	0.315	120.000	80.315	27.765	2.980	9.2308	0.0242	0.0001	9.2551	0.9974	0.0026	0.0000	0.0026
	120	80	1	0.25	10	10	0	0	130	70	80.000	80.000	0.400	0.000	0.000	$-\infty$	120.000	∞	40.000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
	120	80	0	0.25	10	20	0	0	130	70	119.933	120.000	0.001	0.100	∞	0.067	$-\infty$	80.067	0.000	39.933	0.0000	0.0675	0.0000	0.0675	0.0000	1.0000	0.0000	1.0000
	120	80	0.25	0.25	10	20	0	0	130	70	107.666	116.993	0.123	0.092	0.306	0.105	119.694	80.105	3.007	27.666	9.2308	0.0730	0.0236	9.3273	0.9897	0.0078	0.0025	0.0103
$\sigma_{b,x}$	120	80	0.5	0.25	10	20	0	0	130	70	93.020	106.512	0.270	0.066	0.004	0.472	119.996	80.472	13.488	13.020	13.3333	0.1572	0.0012	13.4917	0.9883	0.0116	0.0001	0.0117
	120	80	0.75	0.25	10	20	0	0	130	70	81.333	90.999	0.387	0.027	0.000	5.669	120.000	85.669	29.001	1.333	9.2308	0.4361	0.0000	9.6669	0.9549	0.0451	0.0000	0.0451
	120	80	1	0.25	10	20	0	0	130	70	80.000	80.000	0.400	0.000	0.000	$-\infty$	120.000	∞	40.000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
	120	80	0	0.25	20	20	0.25	0	130	70	120.564	120.625	0.000	0.102	∞	0.061	$-\infty$	80.061	0.000	40.564	0.0000	0.0614	0.0000	0.0614	0.0000	1.0000	0.0000	1.0000
	120	80	0.25	0.25	20	20	0.25	0	130	70	109.107	118.889	0.031	0.097	4.574	0.080	116.051	80.080	1.736	29.107	9.3750	0.0552	0.3519	9.7820	0.9584	0.0056	0.0360	0.0416
ρ_b	120	80	0.5	0.25	20	20	0.25	0	130	70	93.377	107.182	0.073	0.068	0.362	0.429	120.263	80.429	13.443	13.377	13.5417	0.1429	0.1208	13.8054	0.9809	0.0104	0.0088	0.0191
	120	80	0.75	0.25	20	20	0.25	0	130	70	81.513	91.337	0.104	0.028	0.062	5.287	120.563	85.287	29.288	1.513	9.3750	0.4067	0.0426	9.8243	0.9543	0.0414	0.0043	0.0457
	120	80	1	0.25	20	20	0.25	0	130	70	80.000	80.049	0.108	0.000	0.049	$-\infty$	120.576	∞	40.576	0.000	0.0000	0.0000	0.0486	0.0486	0.0000	0.0000	1.0000	1.0000
	120	80	0	0.25	20	20	0.25	0	140	70	121.194	121.250	0.000	0.103	∞	0.056	$-\infty$	80.056	0.000	41.194	0.0000	0.0559	0.0000	0.0559	0.0000	1.0000	0.0000	1.0000
	120	80	0.25	0.25	20	20	0.25	0	140	70	109.496	119.401	0.031	0.099	4.360	0.074	116.890	80.074	1.849	29.496	9.5192	0.0511	0.3354	9.9057	0.9610	0.0052	0.0339	0.0390
S_b	120	80	0.5	0.25	20	20	0.25	0	140	70	93.594	107.593	0.074	0.069	0.342	0.405	120.908	80.405	13.657	13.594	13.7500	0.1349	0.1138	13.9987	0.9822	0.0096	0.0081	0.0178
	120	80	0.75	0.25	20	20	0.25	0	140	70	81.639	91.585	0.106	0.029	0.057	5.027	121.193	85.027	29.665	1.639	9.5192	0.3867	0.0394	9.9454	0.9572	0.0389	0.0040	0.0428
	120	80	1	0.25	20	20	0.25	0	140	70	80.000	80.044	0.110	0.000	0.044	$-\infty$	121.206	∞	41.206	0.000	0.0000	0.0000	0.0440	0.0440	0.0000	0.0000	1.0000	1.0000

Table 3

The numerical test results when change the probability of infomred trading

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the probability of informed trading and, for robustness, the remainder panels are about the same effects while another parameter alters a unit.

Parameter	**Value of Parameter**										**Quotation**		**R-to-V ratio**		**Expected Loss of AS**		**Expected Value**		**Expected Profit**		**Spread**				**Spread ratio**			
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s	P_b	P_a	$R_b/\sigma_{R_b}^2$	$R_s/\sigma_{R_s}^2$	L_b^{AS}	L_s^{AS}	$\bar{V}_b^{AS}$	$\bar{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$	$\omega_1(\bar{V}_b-\bar{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\bar{V}_b-\bar{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_s^{AS}/\pi$	$\omega L^{AS}/\pi$
	120	80	0.5	0	20	20	0	0	130	70	93.33	106.67	0.0667	0.0667	0.0000	0.0000	120.00	80.00	13.33	13.33	13.3333	0.0000	0.0000	13.3333	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.05	20	20	0	0	130	70	93.30	106.70	0.0667	0.0667	0.0919	0.0919	119.91	80.09	13.30	13.30	13.3333	0.0306	0.0306	13.3946	0.9954	0.0023	0.0023	0.0046
p	120	80	0.5	0.1	20	20	0	0	130	70	93.27	106.73	0.0668	0.0668	0.1829	0.1829	119.82	80.18	13.27	13.27	13.3333	0.0610	0.0610	13.4553	0.9909	0.0045	0.0045	0.0091
	120	80	0.5	0.15	20	20	0	0	130	70	93.24	106.76	0.0669	0.0669	0.2732	0.2732	119.73	80.27	13.24	13.24	13.3333	0.0911	0.0911	13.5155	0.9865	0.0067	0.0067	0.0135
	120	80	0.5	0.2	20	20	0	0	130	70	93.21	106.79	0.0670	0.0670	0.3628	0.3628	119.64	80.36	13.21	13.21	13.3333	0.1209	0.1209	13.5752	0.9822	0.0089	0.0089	0.0178
	130	70	0.5	0	20	20	0	0	130	70	90.00	110.00	0.1000	0.1000	0.0000	0.0000	130.00	70.00	20.00	20.00	20.0000	0.0000	0.0000	20.0000	1.0000	0.0000	0.0000	0.0000
	130	70	0.5	0.05	20	20	0	0	130	70	90.00	110.00	0.1000	0.1000	0.0135	0.0135	129.99	70.01	20.00	20.00	20.0000	0.0045	0.0045	20.0090	0.9996	0.0002	0.0002	0.0004
$\mu_x^H-\mu_x^L$	130	70	0.5	0.1	20	20	0	0	130	70	89.99	110.01	0.1000	0.1000	0.0270	0.0270	129.97	70.03	19.99	19.99	20.0000	0.0090	0.0090	20.0180	0.9991	0.0004	0.0004	0.0009
	130	70	0.5	0.15	20	20	0	0	130	70	89.99	110.01	0.1000	0.1000	0.0404	0.0404	129.96	70.04	19.99	19.99	20.0000	0.0135	0.0135	20.0269	0.9987	0.0007	0.0007	0.0013
	130	70	0.5	0.2	20	20	0	0	130	70	89.98	110.02	0.1000	0.1000	0.0538	0.0538	129.95	70.05	19.98	19.98	20.0000	0.0179	0.0179	20.0359	0.9982	0.0009	0.0009	0.0018
	130	80	0.5	0	20	20	0	0	130	70	96.67	113.33	0.0833	0.0833	0.0000	0.0000	130.00	80.00	16.67	16.67	16.6667	0.0000	0.0000	16.6667	1.0000	0.0000	0.0000	0.0000
	130	80	0.5	0.05	20	20	0	0	130	70	96.65	113.35	0.0834	0.0834	0.0358	0.0358	129.96	80.04	16.65	16.65	16.6667	0.0119	0.0119	16.6905	0.9986	0.0007	0.0007	0.0014
μ_x^H	130	80	0.5	0.1	20	20	0	0	130	70	96.64	113.36	0.0834	0.0834	0.0714	0.0714	129.93	80.07	16.64	16.64	16.6667	0.0238	0.0238	16.7143	0.9972	0.0014	0.0014	0.0028
	130	80	0.5	0.15	20	20	0	0	130	70	96.63	113.37	0.0834	0.0834	0.1069	0.1069	129.89	80.11	16.63	16.63	16.6667	0.0356	0.0356	16.7379	0.9957	0.0021	0.0021	0.0043
	130	80	0.5	0.2	20	20	0	0	130	70	96.62	113.38	0.0835	0.0835	0.1423	0.1423	129.86	80.14	16.62	16.62	16.6667	0.0474	0.0474	16.7615	0.9943	0.0028	0.0028	0.0057
	120	80	0.25	0	20	20	0	0	130	70	107.69	116.92	0.0308	0.0923	0.0000	0.0000	120.00	80.00	3.08	27.69	9.2308	0.0000	0.0000	9.2308	1.0000	0.0000	0.0000	0.0000
	120	80	0.25	0.05	20	20	0	0	130	70	107.88	117.20	0.0303	0.0930	0.9045	0.0205	119.10	80.02	2.80	27.88	9.2308	0.0142	0.0696	9.3145	0.9910	0.0015	0.0075	0.0090
k	120	80	0.25	0.1	20	20	0	0	130	70	108.09	117.49	0.0298	0.0937	1.8848	0.0392	118.12	80.04	2.51	28.09	9.2308	0.0271	0.1450	9.4029	0.9817	0.0029	0.0154	0.0183
	120	80	0.25	0.15	20	20	0	0	130	70	108.32	117.82	0.0292	0.0946	2.9614	0.0560	117.04	80.06	2.18	28.32	9.2308	0.0388	0.2278	9.4973	0.9719	0.0041	0.0240	0.0281
	120	80	0.25	0.2	20	20	0	0	130	70	108.59	118.19	0.0285	0.0955	4.1651	0.0707	115.83	80.07	1.81	28.59	9.2308	0.0490	0.3204	9.6001	0.9615	0.0051	0.0334	0.0385
	120	80	0.5	0	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0000	0.0000	120.00	80.00	13.33	13.33	13.3333	0.0000	0.0000	13.3333	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.05	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0008	0.0008	120.00	80.00	13.33	13.33	13.3333	0.0003	0.0003	13.3339	1.0000	0.0000	0.0000	0.0000
σ_x	120	80	0.5	0.1	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0016	0.0016	120.00	80.00	13.33	13.33	13.3333	0.0005	0.0005	13.3344	0.9999	0.0000	0.0000	0.0001
	120	80	0.5	0.15	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0024	0.0024	120.00	80.00	13.33	13.33	13.3333	0.0008	0.0008	13.3349	0.9999	0.0001	0.0001	0.0001
	120	80	0.5	0.2	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0032	0.0032	120.00	80.00	13.33	13.33	13.3333	0.0011	0.0011	13.3355	0.9998	0.0001	0.0001	0.0002
	120	80	0.5	0	10	20	0	0	130	70	93.33	106.67	0.2667	0.0667	0.0000	0.0000	120.00	80.00	13.33	13.33	13.3333	0.0000	0.0000	13.3333	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.05	10	20	0	0	130	70	93.27	106.64	0.2673	0.0666	0.0008	0.0927	120.00	80.09	13.36	13.27	13.3333	0.0309	0.0003	13.3645	0.9977	0.0023	0.0000	0.0023
$\sigma_{b,x}$	120	80	0.5	0.1	10	20	0	0	130	70	93.21	106.61	0.2679	0.0665	0.0015	0.1861	120.00	80.19	13.39	13.21	13.3333	0.0620	0.0005	13.3959	0.9953	0.0046	0.0000	0.0047
	120	80	0.5	0.15	10	20	0	0	130	70	93.15	106.57	0.2685	0.0664	0.0023	0.2804	120.00	80.28	13.43	13.15	13.3333	0.0935	0.0008	13.4276	0.9930	0.0070	0.0001	0.0070
	120	80	0.5	0.2	10	20	0	0	130	70	93.08	106.54	0.2692	0.0664	0.0029	0.3755	120.00	80.38	13.46	13.08	13.3333	0.1252	0.0010	13.4595	0.9906	0.0093	0.0001	0.0094
	120	80	0.5	0	20	20	0.25	0	130	70	93.54	107.08	0.0722	0.0677	0.0000	0.0000	120.63	80.00	13.54	13.54	13.5417	0.0000	0.0000	13.5417	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.05	20	20	0.25	0	130	70	93.51	107.10	0.0723	0.0678	0.0739	0.0867	120.55	80.09	13.52	13.51	13.5417	0.0289	0.0246	13.5952	0.9961	0.0021	0.0018	0.0039
ρ_b	120	80	0.5	0.1	20	20	0.25	0	130	70	93.48	107.12	0.0724	0.0678	0.1471	0.1729	120.48	80.17	13.50	13.48	13.5417	0.0576	0.0490	13.6483	0.9922	0.0042	0.0036	0.0078
	120	80	0.5	0.15	20	20	0.25	0	130	70	93.44	107.14	0.0725	0.0679	0.2196	0.2587	120.41	80.26	13.48	13.44	13.5417	0.0862	0.0732	13.7011	0.9884	0.0063	0.0053	0.0116
	120	80	0.5	0.2	20	20	0.25	0	130	70	93.41	107.16	0.0726	0.0679	0.2914	0.3440	120.33	80.34	13.46	13.41	13.5417	0.1147	0.0971	13.7535	0.9846	0.0083	0.0071	0.0154
	120	80	0.5	0	20	20	0.25	0	140	70	93.75	107.50	0.0733	0.0688	0.0000	0.0000	121.25	80.00	13.75	13.75	13.7500	0.0000	0.0000	13.7500	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.05	20	20	0.25	0	140	70	93.72	107.52	0.0734	0.0688	0.0696	0.0818	121.18	80.08	13.73	13.72	13.7500	0.0273	0.0232	13.8004	0.9963	0.0020	0.0017	0.0037
S_b	120	80	0.5	0.1	20	20	0.25	0	140	70	93.69	107.54	0.0735	0.0688	0.1385	0.1631	121.11	80.16	13.71	13.69	13.7500	0.0544	0.0462	13.8505	0.9927	0.0039	0.0033	0.0073
	120	80	0.5	0.15	20	20	0.25	0	140	70	93.66	107.56	0.0736	0.0689	0.2068	0.2440	121.04	80.24	13.69	13.66	13.7500	0.0813	0.0689	13.9003	0.9892	0.0059	0.0050	0.0108
	120	80	0.5	0.2	20	20	0.25	0	140	70	93.63	107.57	0.0737	0.0689	0.2745	0.3245	120.98	80.32	13.68	13.63	13.7500	0.1082	0.0915	13.9497	0.9857	0.0078	0.0066	0.0143

Table 4

The numerical test results when change the variance of true value recognized by all traders

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the variance of true value recognized by all traders and, for robustness, the remainder panels are about the same effects while another parameter alters a unit. The empty cells are the divergent results of the numerical tests.

Parameter	**Value of Parameter**										**Quotation**		**R-to-V ratio**		**Expected Loss of AS**		**Expected Value**		**Expected Profit**		**Spread**				**Spread ratio**			
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s	P_b	P_a	$R_b/\sigma_{R_b}^2$	$R_s/\sigma_{R_s}^2$	L_b^{AS}	L_s^{AS}	$\overline{V}_b^{AS}$	$\overline{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$	$\omega_1(\overline{V}_b-\overline{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\overline{V}_b-\overline{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_s^{AS}/\pi$	$\omega L^{AS}/\pi$
	120	80	0.5	0.25	0	0	0	0	130	70	93.33	106.67	∞	∞	0.0000	0.0000	120.00	80.00	13.33	13.33	13.3333	0.0000	0.0000	13.3333	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.25	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0040	0.0040	120.00	80.00	13.33	13.33	13.3333	0.0013	0.0013	13.3360	0.9998	0.0001	0.0001	0.0002
σ_x	120	80	0.5	0.25	20	20	0	0	130	70	93.18	106.82	0.0670	0.0670	0.4515	0.4515	119.55	80.45	13.18	13.18	13.3333	0.1505	0.1505	13.6344	0.9779	0.0110	0.0110	0.0221
	120	80	0.5	0.25	30	30	0	0	130	70	92.55	107.45	0.0305	0.0305	2.3513	2.3513	117.65	82.35	12.55	12.55	13.3333	0.7838	0.7838	14.9009	0.8948	0.0526	0.0526	0.1052
	120	80	0.5	0.25	40	40	0	0	130	70	91.33	108.67	0.0179	0.0179	6.0070	6.0070	113.99	86.01	11.33	11.33	13.3333	2.0023	2.0023	17.3380	0.7690	0.1155	0.1155	0.2310
	130	70	0.5	0.25	0	0	0	0	130	70	90.00	110.00	∞	∞	0.0000	0.0000	130.00	70.00	20.00	20.00	20.0000	0.0000	0.0000	20.0000	1.0000	0.0000	0.0000	0.0000
	130	70	0.5	0.25	10	10	0	0	130	70	90.00	110.00	0.4000	0.4000	0.0000	0.0000	130.00	70.00	20.00	20.00	20.0000	0.0000	0.0000	20.0000	1.0000	0.0000	0.0000	0.0000
$\mu_x^H-\mu_x^L$	130	70	0.5	0.25	20	20	0	0	130	70	89.98	110.02	0.1001	0.1001	0.0673	0.0673	129.93	70.07	19.98	19.98	20.0000	0.0224	0.0224	20.0448	0.9978	0.0011	0.0011	0.0022
	130	70	0.5	0.25	30	30	0	0	130	70	89.77	110.23	0.0447	0.0447	0.6773	0.6773	129.32	70.68	19.77	19.77	20.0000	0.2258	0.2258	20.4515	0.9779	0.0110	0.0110	0.0221
	130	70	0.5	0.25	40	40	0	0	130	70	89.24	110.76	0.0255	0.0255	2.2857	2.2857	127.71	72.29	19.24	19.24	20.0000	0.7619	0.7619	21.5238	0.9292	0.0354	0.0354	0.0708
	130	80	0.5	0.25	0	0	0	0	130	70	96.67	113.33	∞	∞	0.0000	0.0000	130.00	80.00	16.67	16.67	16.6667	0.0000	0.0000	16.6667	1.0000	0.0000	0.0000	0.0000
	130	80	0.5	0.25	10	10	0	0	130	70	96.67	113.33	0.3333	0.3333	0.0003	0.0003	130.00	80.00	16.67	16.67	16.6667	0.0001	0.0001	16.6669	1.0000	0.0000	0.0000	0.0000
μ_x^H	130	80	0.5	0.25	20	20	0	0	130	70	96.61	113.39	0.0835	0.0835	0.1775	0.1775	129.82	80.18	16.61	16.61	16.6667	0.0592	0.0592	16.7850	0.9929	0.0035	0.0035	0.0071
	130	80	0.5	0.25	30	30	0	0	130	70	96.25	113.75	0.0375	0.0375	1.2553	1.2553	128.74	81.26	16.25	16.25	16.6667	0.4184	0.4184	17.5036	0.9522	0.0239	0.0239	0.0478
	130	80	0.5	0.25	40	40	0	0	130	70	95.44	114.56	0.0216	0.0216	3.6795	3.6795	126.32	83.68	15.44	15.44	16.6667	1.2265	1.2265	19.1197	0.8717	0.0641	0.0641	0.1283
	120	80	0.25	0.25	0	0	0	0	130	70	107.69	116.92	∞	∞	0.0000	0.0000	120.00	80.00	3.08	27.69	9.2308	0.0000	0.0000	9.2308	1.0000	0.0000	0.0000	0.0000
	120	80	0.25	0.25	10	10	0	0	130	70	107.76	117.02	0.1224	0.3702	0.3152	0.0001	119.68	80.00	2.98	27.76	9.2308	0.0001	0.0242	9.2551	0.9974	0.0000	0.0026	0.0026
k	120	80	0.25	0.25	20	20	0	0	130	70	108.90	118.61	0.0278	0.0965	5.5464	0.0830	114.45	80.08	1.39	28.90	9.2308	0.0575	0.4266	9.7149	0.9502	0.0059	0.0439	0.0498
	120	80	0.25	0.25	30	30	0	0	130	70																		
	120	80	0.25	0.25	40	40	0	0	130	70																		
	120	80	0.5	0.2	0	0	0	0	130	70	93.33	106.67	∞	∞	0.0000	0.0000	120.00	80.00	13.33	13.33	13.3333	0.0000	0.0000	13.3333	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.2	10	10	0	0	130	70	93.33	106.67	0.2667	0.2667	0.0032	0.0032	120.00	80.00	13.33	13.33	13.3333	0.0011	0.0011	13.3355	0.9998	0.0001	0.0001	0.0002
p	120	80	0.5	0.2	20	20	0	0	130	70	93.21	106.79	0.0670	0.0670	0.3628	0.3628	119.64	80.36	13.21	13.21	13.3333	0.1209	0.1209	13.5752	0.9822	0.0089	0.0089	0.0178
	120	80	0.5	0.2	30	30	0	0	130	70	92.70	107.30	0.0303	0.0303	1.9099	1.9099	118.09	81.91	12.70	12.70	13.3333	0.6366	0.6366	14.6066	0.9128	0.0436	0.0436	0.0872
	120	80	0.5	0.2	40	40	0	0	130	70	91.68	108.32	0.0177	0.0177	4.9561	4.9561	115.04	84.96	11.68	11.68	13.3333	1.6520	1.6520	16.6374	0.8014	0.0993	0.0993	0.1986
	120	80	0.5	0.25	0	0	0.25	0	130	70	93.54	107.08	∞	∞	0.0000	0.0000	120.63	80.00	13.54	13.54	13.5417	0.0000	0.0000	13.5417	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.25	10	10	0.25	0	130	70	93.54	107.08	0.2889	0.2708	0.0025	0.0035	120.62	80.00	13.54	13.54	13.5417	0.0012	0.0008	13.5436	0.9999	0.0001	0.0001	0.0001
ρ_b	120	80	0.5	0.25	20	20	0.25	0	130	70	93.38	107.18	0.0727	0.0680	0.3625	0.4288	120.26	80.43	13.44	13.38	13.5417	0.1429	0.1208	13.8054	0.9809	0.0104	0.0088	0.0191
	120	80	0.5	0.25	30	30	0.25	0	130	70	92.66	107.62	0.0331	0.0307	1.9659	2.3095	118.66	82.31	13.00	12.66	13.5417	0.7698	0.6553	14.9668	0.9048	0.0514	0.0438	0.0952
	120	80	0.5	0.25	40	40	0.25	0	130	70	91.06	108.32	0.0197	0.0177	4.9554	6.1929	115.67	86.19	12.30	11.06	13.5417	2.0643	1.6518	17.2578	0.7847	0.1196	0.0957	0.2153
	120	80	0.5	0.25	0	0	0.25	0	140	70	93.75	107.50	∞	∞	0.0000	0.0000	121.25	80.00	13.75	13.75	13.7500	0.0000	0.0000	13.7500	1.0000	0.0000	0.0000	0.0000
	120	80	0.5	0.25	10	10	0.25	0	140	70	93.75	107.50	0.2933	0.2750	0.0021	0.0030	121.25	80.00	13.75	13.75	13.7500	0.0010	0.0007	13.7517	0.9999	0.0001	0.0001	0.0001
S_b	120	80	0.5	0.25	20	20	0.25	0	140	70	93.59	107.59	0.0737	0.0690	0.3415	0.4046	120.91	80.40	13.66	13.59	13.7500	0.1349	0.1138	13.9987	0.9822	0.0096	0.0081	0.0178
	120	80	0.5	0.25	30	30	0.25	0	140	70	92.90	108.02	0.0336	0.0311	1.8892	2.2173	119.36	82.22	13.23	12.90	13.7500	0.7391	0.6297	15.1189	0.9095	0.0489	0.0417	0.0905
	120	80	0.5	0.25	40	40	0.25	0	140	70	91.37	108.72	0.0199	0.0179	4.8189	5.9807	116.43	85.98	12.53	11.37	13.7500	1.9936	1.6063	17.3499	0.7925	0.1149	0.0926	0.2075

Table 5

The numerical test results when change the variance of true value recognized by buyers

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the variance of true value recognized by buyers and, for robustness, the remainder panels are about the same effects while another parameter alters a unit. The empty cells are the divergent results of the numerical tests.

Parameter	**Value of Parameter**										**Quotation**		**R-to-V ratio**		**Expected Loss of AS**		**Expected Value**		**Expected Profit**		**Spread**				**Spread ratio**			
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s	P_b	P_a	$R_b/\sigma_{R_b}^2$	$R_s/\sigma_{R_s}^2$	L_b^{AS}	L_s^{AS}	$\bar{V}_b^{AS}$	$\bar{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$	$\omega_1(\bar{V}_b-\bar{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\bar{V}_b-\bar{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_b^{AS}/\pi$	$\omega L^{AS}/\pi$
$\sigma_{b,x}$	120	80	0.5	0.25	0	20	0	0	130	70	93.02	106.51	∞	0.07	0.00	0.47	120.00	80.47	13.49	13.02	13.3333	0.1572	0.0000	13.4906	0.9883	0.0117	0.0000	0.0117
	120	80	0.5	0.25	10	20	0	0	130	70	93.02	106.51	0.27	0.07	0.00	0.47	120.00	80.47	13.49	13.02	13.3333	0.1572	0.0012	13.4917	0.9883	0.0116	0.0001	0.0117
	120	80	0.5	0.25	20	20	0	0	130	70	93.18	106.82	0.07	0.07	0.45	0.45	119.55	80.45	13.18	13.18	13.3333	0.1505	0.1505	13.6344	0.9779	0.0110	0.0110	0.0221
	120	80	0.5	0.25	30	20	0	0	130	70	94.00	108.37	0.03	0.07	2.74	0.36	117.26	80.36	11.63	14.00	13.3333	0.1208	0.9125	14.3667	0.9281	0.0084	0.0635	0.0719
	120	80	0.5	0.25	40	20	0	0	130	70	96.43	113.04	0.01	0.08	9.66	0.19	110.34	80.19	6.96	16.43	13.3333	0.0622	3.2188	16.6143	0.8025	0.0037	0.1937	0.1975
$\mu_x^H-\mu_x^L$	130	70	0.5	0.25	0	20	0	0	130	70	89.95	109.98	∞	0.10	0.00	0.07	130.00	70.07	20.02	19.95	20.0000	0.0226	0.0000	20.0226	0.9989	0.0011	0.0000	0.0011
	130	70	0.5	0.25	10	20	0	0	130	70	89.95	109.98	0.40	0.10	0.00	0.07	130.00	70.07	20.02	19.95	20.0000	0.0226	0.0000	20.0226	0.9989	0.0011	0.0000	0.0011
	130	70	0.5	0.25	20	20	0	0	130	70	89.98	110.02	0.10	0.10	0.07	0.07	129.93	70.07	19.98	19.98	20.0000	0.0224	0.0224	20.0448	0.9978	0.0011	0.0011	0.0022
	130	70	0.5	0.25	30	20	0	0	130	70	90.19	110.45	0.04	0.10	0.70	0.06	129.30	70.06	19.55	20.19	20.0000	0.0210	0.2349	20.2559	0.9874	0.0010	0.0116	0.0126
	130	70	0.5	0.25	40	20	0	0	130	70	90.82	111.70	0.02	0.10	2.57	0.05	127.43	70.05	18.30	20.82	20.0000	0.0174	0.8581	20.8755	0.9581	0.0008	0.0411	0.0419
μ_x^H	130	80	0.5	0.25	0	20	0	0	130	70	96.55	113.27	∞	0.08	0.00	0.18	130.00	80.18	16.73	16.55	16.6667	0.0602	0.0000	16.7269	0.9964	0.0036	0.0000	0.0036
	130	80	0.5	0.25	10	20	0	0	130	70	96.55	113.27	0.33	0.08	0.00	0.18	130.00	80.18	16.73	16.55	16.6667	0.0602	0.0001	16.7270	0.9964	0.0036	0.0000	0.0036
	130	80	0.5	0.25	20	20	0	0	130	70	96.61	113.39	0.08	0.08	0.18	0.18	129.82	80.18	16.61	16.61	16.6667	0.0592	0.0592	16.7850	0.9929	0.0035	0.0035	0.0071
	130	80	0.5	0.25	30	20	0	0	130	70	97.01	114.18	0.04	0.09	1.35	0.16	128.65	80.16	15.82	17.01	16.6667	0.0528	0.4506	17.1701	0.9707	0.0031	0.0262	0.0293
	130	80	0.5	0.25	40	20	0	0	130	70	98.11	116.34	0.02	0.09	4.57	0.12	125.43	80.12	13.66	18.11	16.6667	0.0386	1.5229	18.2282	0.9143	0.0021	0.0835	0.0857
k	120	80	0.25	0.25	0	20	0	0	130	70	107.59	116.90	∞	0.09	0.00	0.11	120.00	80.11	3.10	27.59	9.2308	0.0740	0.0000	9.3047	0.9920	0.0080	0.0000	0.0080
	120	80	0.25	0.25	10	20	0	0	130	70	107.67	116.99	0.12	0.09	0.31	0.11	119.69	80.11	3.01	27.67	9.2308	0.0730	0.0236	9.3273	0.9897	0.0078	0.0025	0.0103
	120	80	0.25	0.25	20	20	0	0	130	70	108.90	118.61	0.03	0.10	5.55	0.08	114.45	80.08	1.39	28.90	9.2308	0.0575	0.4266	9.7149	0.9502	0.0059	0.0439	0.0498
	120	80	0.25	0.25	30	20	0	0	130	70																		
	120	80	0.25	0.25	40	20	0	0	130	70																		
p	120	80	0.5	0.2	0	20	0	0	140	70	93.08	106.54	∞	0.07	0.00	0.38	120.00	80.38	13.46	13.08	13.3333	0.1252	0.0000	13.4585	0.9907	0.0093	0.0000	0.0093
	120	80	0.5	0.2	10	20	0	0	140	70	93.08	106.54	0.27	0.07	0.00	0.38	120.00	80.38	13.46	13.08	13.3333	0.1252	0.0010	13.4595	0.9906	0.0093	0.0001	0.0094
	120	80	0.5	0.2	20	20	0	0	140	70	93.21	106.79	0.07	0.07	0.36	0.36	119.64	80.36	13.21	13.21	13.3333	0.1209	0.1209	13.5752	0.9822	0.0089	0.0089	0.0178
	120	80	0.5	0.2	30	20	0	0	140	70	93.85	108.00	0.03	0.07	2.15	0.31	117.85	80.31	12.00	13.85	13.3333	0.1018	0.7180	14.1532	0.9421	0.0072	0.0507	0.0579
	120	80	0.5	0.2	40	20	0	0	140	70	95.57	111.34	0.02	0.08	7.10	0.19	112.90	80.19	8.66	15.57	13.3333	0.0635	2.3677	15.7645	0.8458	0.0040	0.1502	0.1542
ρ_b	120	80	0.5	0.25	0	20	0.25	0	130	70	93.25	106.94	∞	0.07	0.00	0.44	120.63	80.44	13.69	13.25	13.5417	0.1480	0.0000	13.6897	0.9892	0.0108	0.0000	0.0108
	120	80	0.5	0.25	10	20	0.25	0	130	70	93.25	106.94	0.29	0.07	0.00	0.44	120.62	80.44	13.69	13.25	13.5417	0.1480	0.0007	13.6904	0.9891	0.0108	0.0001	0.0109
	120	80	0.5	0.25	20	20	0.25	0	130	70	93.38	107.18	0.07	0.07	0.36	0.43	120.26	80.43	13.44	13.38	13.5417	0.1429	0.1208	13.8054	0.9809	0.0104	0.0088	0.0191
	120	80	0.5	0.25	30	20	0.25	0	130	70	94.06	108.49	0.03	0.07	2.28	0.36	118.34	80.36	12.14	14.06	13.5417	0.1189	0.7603	14.4209	0.9390	0.0082	0.0527	0.0610
	120	80	0.5	0.25	40	20	0.25	0	130	70	96.01	112.22	0.02	0.08	7.81	0.21	112.81	80.21	8.40	16.01	13.5417	0.0700	2.6034	16.2151	0.8351	0.0043	0.1606	0.1649
S_b	120	80	0.5	0.25	0	20	0.25	0	140	70	93.47	107.36	∞	0.07	0.00	0.42	121.25	80.42	13.89	13.47	13.7500	0.1394	0.0000	13.8894	0.9900	0.0100	0.0000	0.0100
	120	80	0.5	0.25	10	20	0.25	0	140	70	93.47	107.36	0.30	0.07	0.00	0.42	121.25	80.42	13.89	13.47	13.7500	0.1393	0.0006	13.8900	0.9899	0.0100	0.0000	0.0101
	120	80	0.5	0.25	20	20	0.25	0	140	70	93.59	107.59	0.07	0.07	0.34	0.40	120.91	80.40	13.66	13.59	13.7500	0.1349	0.1138	13.9987	0.9822	0.0096	0.0081	0.0178
	120	80	0.5	0.25	30	20	0.25	0	140	70	94.25	108.84	0.03	0.07	2.18	0.34	119.07	80.34	12.41	14.25	13.7500	0.1131	0.7256	14.5887	0.9425	0.0078	0.0497	0.0575
	120	80	0.5	0.25	40	20	0.25	0	140	70	96.08	112.37	0.02	0.08	7.41	0.21	113.84	80.21	8.88	16.08	13.7500	0.0685	2.4686	16.2871	0.8442	0.0042	0.1516	0.1558

Table 6

The numerical test results when change the precision of traders' private noisy signals

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the precision of traders 'private noisy signals and, for robustness, the remainder panels are about the same effects while another parameter alters a unit.

Parameter	**Value of Parameter**									
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s
	120	80	0.5	0.25	20	20	0	0	130	70
	120	80	0.5	0.25	20	20	0.05	0	130	70
ρ_b	120	80	0.5	0.25	20	20	0.1	0	130	70
	120	80	0.5	0.25	20	20	0.15	0	130	70
	120	80	0.5	0.25	20	20	0.2	0	130	70
	130	70	0.5	0.25	20	20	0	0	130	70
	130	70	0.5	0.25	20	20	0.05	0	130	70
$\mu_x^H - \mu_x^L$	130	70	0.5	0.25	20	20	0.1	0	130	70
	130	70	0.5	0.25	20	20	0.15	0	130	70
	130	70	0.5	0.25	20	20	0.2	0	130	70
	130	80	0.5	0.25	20	20	0	0	130	70
	130	80	0.5	0.25	20	20	0.05	0	130	70
μ_x^H	130	80	0.5	0.25	20	20	0.1	0	130	70
	130	80	0.5	0.25	20	20	0.15	0	130	70
	130	80	0.5	0.25	20	20	0.2	0	130	70
	120	80	0.25	0.25	20	20	0	0	130	70
	120	80	0.25	0.25	20	20	0.05	0	130	70
k	120	80	0.25	0.25	20	20	0.1	0	130	70
	120	80	0.25	0.25	20	20	0.15	0	130	70
	120	80	0.25	0.25	20	20	0.2	0	130	70
	120	80	0.5	0.2	20	20	0	0	130	70
	120	80	0.5	0.2	20	20	0.05	0	130	70
p	120	80	0.5	0.2	20	20	0.1	0	130	70
	120	80	0.5	0.2	20	20	0.15	0	130	70
	120	80	0.5	0.2	20	20	0.2	0	130	70
	120	80	0.5	0.25	10	10	0	0	130	70
	120	80	0.5	0.25	10	10	0.05	0	130	70
σ_x	120	80	0.5	0.25	10	10	0.1	0	130	70
	120	80	0.5	0.25	10	10	0.15	0	130	70
	120	80	0.5	0.25	10	10	0.2	0	130	70
	120	80	0.5	0.25	10	20	0	0	130	70
	120	80	0.5	0.25	10	20	0.05	0	130	70
$\sigma_{b,x}$	120	80	0.5	0.25	10	20	0.1	0	130	70
	120	80	0.5	0.25	10	20	0.15	0	130	70
	120	80	0.5	0.25	10	20	0.2	0	130	70
	120	80	0.5	0.25	20	20	0	0	140	70
	120	80	0.5	0.25	20	20	0.05	0	140	70
S_b	120	80	0.5	0.25	20	20	0.1	0	140	70
	120	80	0.5	0.25	20	20	0.15	0	140	70
	120	80	0.5	0.25	20	20	0.2	0	140	70

Parameter	**Quotation**		**R-to-V ratio**		**Expected Loss of AS**		**Expected Value**		**Expected Profit**	
Panel	P_b	P_a	$R_b/\sigma^2_{R_b}$	$R_s/\sigma^2_{R_s}$	L_b^{AS}	L_s^{AS}	$\overline{V}_b^{AS}$	$\overline{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$
	93.18	106.82	0.0670	0.0670	0.4515	0.4515	119.548	80.452	13.1828	13.1828
	93.19	106.83	0.0673	0.0671	0.4477	0.4506	119.577	80.451	13.1934	13.1905
ρ_b	93.21	106.88	0.0679	0.0672	0.4364	0.4479	119.664	80.448	13.2250	13.2136
	93.25	106.95	0.0690	0.0674	0.4180	0.4433	119.807	80.443	13.2774	13.2522
	93.31	107.05	0.0706	0.0676	0.3931	0.4369	120.007	80.437	13.3502	13.3064
	89.98	110.02	0.1001	0.1001	0.0673	0.0673	129.933	70.067	19.9776	19.9776
	89.98	110.02	0.1003	0.1001	0.0667	0.0673	129.933	70.067	19.9780	19.9774
$\mu_x^H - \mu_x^L$	89.98	110.02	0.1011	0.1001	0.0649	0.0673	129.935	70.067	19.9791	19.9768
	89.98	110.02	0.1024	0.1000	0.0621	0.0673	129.938	70.067	19.9811	19.9758
	89.97	110.02	0.1042	0.1000	0.0582	0.0673	129.942	70.067	19.9837	19.9745
	96.61	113.39	0.0835	0.0835	0.1775	0.1775	129.822	80.178	16.6075	16.6075
	96.61	113.39	0.0837	0.0835	0.1763	0.1776	129.824	80.178	16.6084	16.6070
μ_x^H	96.61	113.39	0.0843	0.0835	0.1724	0.1776	129.828	80.178	16.6109	16.6057
	96.60	113.38	0.0854	0.0835	0.1661	0.1777	129.834	80.178	16.6152	16.6035
	96.60	113.38	0.0870	0.0834	0.1574	0.1779	129.843	80.178	16.6210	16.6005
	108.90	118.61	0.0278	0.0965	5.5464	0.0830	114.454	80.083	1.3895	28.8956
	108.90	118.62	0.0279	0.0966	5.5034	0.0829	114.522	80.083	1.4046	28.9031
k	108.93	118.65	0.0282	0.0966	5.3768	0.0825	114.723	80.083	1.4493	28.9261
	108.97	118.70	0.0288	0.0968	5.1729	0.0819	115.052	80.082	1.5215	28.9662
	109.03	118.78	0.0296	0.0970	4.9015	0.0809	115.498	80.081	1.6182	29.0256
	93.21	106.79	0.0670	0.0670	0.3628	0.3628	119.637	80.363	13.2124	13.2124
	93.22	106.80	0.0672	0.0670	0.3597	0.3620	119.665	80.362	13.2225	13.2202
p	93.24	106.85	0.0678	0.0671	0.3507	0.3597	119.749	80.360	13.2528	13.2438
	93.28	106.92	0.0689	0.0673	0.3359	0.3559	119.889	80.356	13.3030	13.2830
	93.34	107.03	0.0705	0.0676	0.3159	0.3507	120.084	80.351	13.3729	13.3382
	93.33	106.67	0.2667	0.2667	0.0040	0.0040	119.996	80.004	13.3320	13.3320
	93.34	106.68	0.2675	0.2668	0.0039	0.0040	120.021	80.004	13.3404	13.3403
σ_x	93.37	106.73	0.2700	0.2673	0.0037	0.0039	120.096	80.004	13.3655	13.3653
	93.41	106.82	0.2744	0.2682	0.0034	0.0038	120.222	80.004	13.4073	13.4069
	93.47	106.93	0.2806	0.2693	0.0030	0.0037	120.397	80.004	13.4659	13.4652
	93.02	106.51	0.2698	0.0663	0.0036	0.4715	119.996	80.472	13.4881	13.0202
	93.03	106.53	0.2706	0.0663	0.0035	0.4704	120.021	80.470	13.4961	13.0293
$\sigma_{b,x}$	93.06	106.58	0.2732	0.0664	0.0033	0.4670	120.097	80.467	13.5201	13.0565
	93.10	106.66	0.2775	0.0667	0.0030	0.4614	120.222	80.461	13.5601	13.1018
	93.17	106.78	0.2837	0.0670	0.0027	0.4537	120.397	80.454	13.6161	13.1651
	93.18	106.82	0.0670	0.0670	0.4515	0.4515	119.548	80.452	13.1828	13.1828
	93.20	106.85	0.0673	0.0671	0.4467	0.4496	119.603	80.450	13.2021	13.1992
S_b	93.25	106.94	0.0681	0.0674	0.4324	0.4437	119.768	80.444	13.2596	13.2483
	93.33	107.09	0.0694	0.0677	0.4093	0.4341	120.041	80.434	13.3551	13.3304
	93.45	107.31	0.0712	0.0683	0.3786	0.4210	120.421	80.421	13.4879	13.4455

Parameter	**Spread**				**Spread ratio**			
Panel	$\omega_1(\overline{V}_b - \overline{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\overline{V}_b - \overline{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_s^{AS}/\pi$	$\omega L^{AS}/\pi$
	13.3333	0.1505	0.1505	13.6344	0.9779	0.0110	0.0110	0.0221
	13.3417	0.1502	0.1492	13.6411	0.9780	0.0110	0.0109	0.0220
ρ_b	13.3667	0.1493	0.1455	13.6614	0.9784	0.0109	0.0106	0.0216
	13.4083	0.1478	0.1393	13.6954	0.9790	0.0108	0.0102	0.0210
	13.4667	0.1456	0.1310	13.7433	0.9799	0.0106	0.0095	0.0201
	20.0000	0.0224	0.0224	20.0448	0.9978	0.0011	0.0011	0.0022
	20.0000	0.0224	0.0222	20.0446	0.9978	0.0011	0.0011	0.0022
$\mu_x^H - \mu_x^L$	20.0000	0.0224	0.0216	20.0441	0.9978	0.0011	0.0011	0.0022
	20.0000	0.0224	0.0207	20.0431	0.9978	0.0011	0.0010	0.0022
	20.0000	0.0224	0.0194	20.0418	0.9979	0.0011	0.0010	0.0021
	16.6667	0.0592	0.0592	16.7850	0.9929	0.0035	0.0035	0.0071
	16.6667	0.0592	0.0588	16.7846	0.9930	0.0035	0.0035	0.0070
μ_x^H	16.6667	0.0592	0.0575	16.7833	0.9930	0.0035	0.0034	0.0070
	16.6667	0.0592	0.0554	16.7813	0.9932	0.0035	0.0033	0.0068
	16.6667	0.0593	0.0525	16.7784	0.9933	0.0035	0.0031	0.0067
	9.2308	0.0575	0.4266	9.7149	0.9502	0.0059	0.0439	0.0498
	9.2365	0.0574	0.4233	9.7173	0.9505	0.0059	0.0436	0.0495
k	9.2538	0.0571	0.4136	9.7246	0.9516	0.0059	0.0425	0.0484
	9.2827	0.0567	0.3979	9.7373	0.9533	0.0058	0.0409	0.0467
	9.3231	0.0560	0.3770	9.7562	0.9556	0.0057	0.0386	0.0444
	13.3333	0.1209	0.1209	13.5752	0.9822	0.0089	0.0089	0.0178
	13.3417	0.1207	0.1199	13.5822	0.9823	0.0089	0.0088	0.0177
p	13.3667	0.1199	0.1169	13.6035	0.9826	0.0088	0.0086	0.0174
	13.4083	0.1186	0.1120	13.6389	0.9831	0.0087	0.0082	0.0169
	13.4667	0.1169	0.1053	13.6889	0.9838	0.0085	0.0077	0.0162
	13.3333	0.0013	0.0013	13.3360	0.9998	0.0001	0.0001	0.0002
	13.3417	0.0013	0.0013	13.3443	0.9998	0.0001	0.0001	0.0002
σ_x	13.3667	0.0013	0.0012	13.3692	0.9998	0.0001	0.0001	0.0002
	13.4083	0.0013	0.0011	13.4107	0.9998	0.0001	0.0001	0.0002
	13.4667	0.0012	0.0010	13.4689	0.9998	0.0001	0.0001	0.0002
	13.3333	0.1572	0.0012	13.4917	0.9883	0.0116	0.0001	0.0117
	13.3417	0.1568	0.0012	13.4996	0.9883	0.0116	0.0001	0.0117
$\sigma_{b,x}$	13.3667	0.1557	0.0011	13.5234	0.9884	0.0115	0.0001	0.0116
	13.4083	0.1538	0.0010	13.5631	0.9886	0.0113	0.0001	0.0114
	13.4667	0.1512	0.0009	13.6188	0.9888	0.0111	0.0001	0.0112
	13.3333	0.1505	0.1505	13.6344	0.9779	0.0110	0.0110	0.0221
	13.3500	0.1499	0.1489	13.6488	0.9781	0.0110	0.0109	0.0219
S_b	13.4000	0.1479	0.1441	13.6921	0.9787	0.0108	0.0105	0.0213
	13.4833	0.1447	0.1364	13.7645	0.9796	0.0105	0.0099	0.0204
	13.6000	0.1403	0.1262	13.8665	0.9808	0.0101	0.0091	0.0192

Table 7
The numerical test results when change the price of traders' private noisy signals

We make the numerical tests for the optimal quotation of our model. The parameter sets of our model are $\mu_x^H, \mu_x^L, k, p, \sigma_{b,x}, \sigma_{s,x}, \rho_b, \rho_s, S_b, S_s$ which can vary the main implicate terms that include the price quotation, the reward-to-variability ratio, the expected loss of adverse selection, the expected value of asset, the expected profits, the components of bid-ask spread, and the ratios of the three factors to the spread. First panel is about the effects of the tuning the precision of traders ’private noisy signals and, for robustness, the remainder panels are about the same effects while another parameter alters a unit.

Parameter	Value of Parameter										Quotation		R-to-V ratio		Expected Loss of AS		Expected Value		Expected Profit		Spread				Spread ratio			
Panel	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$	ρ_b	ρ_s	S_b	S_s	P_b	P_a	$R_b/\sigma_{R_b}^2$	$R_s/\sigma_{R_s}^2$	L_b^{AS}	L_s^{AS}	$\bar{V}_b^{AS}$	$\bar{V}_s^{AS}$	$E(profit^b/S_b)$	$E(profit^s/S_s)$	$\omega_1(\bar{V}_b-\bar{V}_s)$	$\omega_2 L_s^{AS}$	$\omega_3 L_b^{AS}$	π	$\omega_1(\bar{V}_b-\bar{V}_s)/\pi$	$\omega_2 L_s^{AS}/\pi$	$\omega_3 L_s^{AS}/\pi$	$\omega L^{AS}/\pi$
	120	80	0.5	0.25	20	20	0.25	0	100	70	92.72	105.95	0.0694	0.0649	0.4332	0.5105	118.317	80.510	12.7981	12.7207	12.9167	0.1702	0.1444	13.2312	0.9762	0.0129	0.0109	0.0238
	120	80	0.5	0.25	20	20	0.25	0	110	70	92.94	106.36	0.0705	0.0659	0.4082	0.4817	118.967	80.482	13.0134	12.9400	13.1250	0.1606	0.1361	13.4216	0.9779	0.0120	0.0101	0.0221
S_b	120	80	0.5	0.25	20	20	0.25	0	120	70	93.16	106.77	0.0716	0.0669	0.3847	0.4545	119.615	80.454	13.2284	13.1586	13.3333	0.1515	0.1282	13.6130	0.9795	0.0111	0.0094	0.0205
	120	80	0.5	0.25	20	20	0.25	0	130	70	93.38	107.18	0.0727	0.0680	0.3625	0.4288	120.263	80.429	13.4430	13.3766	13.5417	0.1429	0.1208	13.8054	0.9809	0.0104	0.0088	0.0191
	120	80	0.5	0.25	20	20	0.25	0	140	70	93.59	107.59	0.0737	0.0690	0.3415	0.4046	120.908	80.405	13.6572	13.5941	13.7500	0.1349	0.1138	13.9987	0.9822	0.0096	0.0081	0.0178
	130	70	0.5	0.25	20	20	0.25	0	100	70	89.34	108.77	0.1034	0.0969	0.0648	0.0811	128.060	70.081	19.3588	19.3425	19.3750	0.0270	0.0216	19.4236	0.9975	0.0014	0.0011	0.0025
	130	70	0.5	0.25	20	20	0.25	0	110	70	89.55	109.18	0.1045	0.0980	0.0608	0.0763	128.689	70.076	19.5682	19.5527	19.5833	0.0254	0.0203	19.6290	0.9977	0.0013	0.0010	0.0023
$\mu_x^H-\mu_x^L$	130	70	0.5	0.25	20	20	0.25	0	120	70	89.76	109.60	0.1056	0.0990	0.0570	0.0717	129.318	70.072	19.7776	19.7629	19.7917	0.0239	0.0190	19.8345	0.9978	0.0012	0.0010	0.0022
	130	70	0.5	0.25	20	20	0.25	0	130	70	89.97	110.01	0.1067	0.1000	0.0534	0.0674	129.947	70.067	19.9869	19.9729	20.0000	0.0225	0.0178	20.0402	0.9980	0.0011	0.0009	0.0020
	130	70	0.5	0.25	20	20	0.25	0	140	70	90.18	110.43	0.1078	0.1011	0.0500	0.0633	130.575	70.063	20.1961	20.1828	20.2083	0.0211	0.0167	20.2461	0.9981	0.0010	0.0008	0.0019
	130	80	0.5	0.25	20	20	0.25	0	100	70	95.96	112.13	0.0858	0.0803	0.1762	0.2127	127.949	80.213	15.9951	15.9586	16.0417	0.0709	0.0587	16.1713	0.9920	0.0044	0.0036	0.0080
	130	80	0.5	0.25	20	20	0.25	0	110	70	96.17	112.54	0.0869	0.0814	0.1657	0.2005	128.584	80.200	16.2063	16.1716	16.2500	0.0668	0.0552	16.3721	0.9925	0.0041	0.0034	0.0075
μ_x^H	130	80	0.5	0.25	20	20	0.25	0	120	70	96.38	112.96	0.0880	0.0824	0.1559	0.1890	129.219	80.189	16.4174	16.3843	16.4583	0.0630	0.0520	16.5733	0.9931	0.0038	0.0031	0.0069
	130	80	0.5	0.25	20	20	0.25	0	130	70	96.60	113.37	0.0891	0.0834	0.1466	0.1781	129.853	80.178	16.6283	16.5968	16.6667	0.0594	0.0489	16.7749	0.9935	0.0035	0.0029	0.0065
	130	80	0.5	0.25	20	20	0.25	0	140	70	96.81	113.79	0.0902	0.0845	0.1379	0.1678	130.487	80.168	16.8390	16.8091	16.8750	0.0559	0.0460	16.9769	0.9940	0.0033	0.0027	0.0060
	120	80	0.25	0.25	20	20	0.25	0	100	70	107.97	117.39	0.0288	0.0935	5.3331	0.0995	113.417	80.099	1.3628	27.9658	8.9423	0.0689	0.4102	9.4214	0.9491	0.0073	0.0435	0.0509
	120	80	0.25	0.25	20	20	0.25	0	110	70	108.34	117.88	0.0294	0.0947	5.0579	0.0925	114.317	80.092	1.4939	28.3415	9.0865	0.0640	0.3891	9.5396	0.9525	0.0067	0.0408	0.0475
k	120	80	0.25	0.25	20	20	0.25	0	120	70	108.72	118.38	0.0301	0.0960	4.8061	0.0859	115.194	80.086	1.6179	28.7221	9.2308	0.0595	0.3697	9.6599	0.9556	0.0062	0.0383	0.0444
	120	80	0.25	0.25	20	20	0.25	0	130	70	109.11	118.89	0.0307	0.0972	4.5744	0.0797	116.051	80.080	1.7359	29.1071	9.3750	0.0552	0.3519	9.7820	0.9584	0.0056	0.0360	0.0416
	120	80	0.25	0.25	20	20	0.25	0	140	70	109.50	119.40	0.0313	0.0985	4.3602	0.0738	116.890	80.074	1.8485	29.4958	9.5192	0.0511	0.3354	9.9057	0.9610	0.0052	0.0339	0.0390
	120	80	0.5	0.2	20	20	0.25	0	100	70	92.76	105.93	0.0693	0.0648	0.3485	0.4097	118.401	80.410	12.8209	12.7597	12.9167	0.1366	0.1162	13.1694	0.9808	0.0104	0.0088	0.0192
	120	80	0.5	0.2	20	20	0.25	0	110	70	92.98	106.34	0.0704	0.0659	0.3283	0.3865	119.047	80.387	13.0349	12.9768	13.1250	0.1288	0.1094	13.3633	0.9822	0.0096	0.0082	0.0178
p	120	80	0.5	0.2	20	20	0.25	0	120	70	93.19	106.75	0.0715	0.0669	0.3093	0.3646	119.691	80.365	13.2487	13.1934	13.3333	0.1215	0.1031	13.5580	0.9834	0.0090	0.0076	0.0166
	120	80	0.5	0.2	20	20	0.25	0	130	70	93.41	107.16	0.0726	0.0679	0.2914	0.3440	120.334	80.344	13.4621	13.4095	13.5417	0.1147	0.0971	13.7535	0.9846	0.0083	0.0071	0.0154
	120	80	0.5	0.2	20	20	0.25	0	140	70	93.63	107.57	0.0737	0.0689	0.2745	0.3245	120.976	80.325	13.6752	13.6252	13.7500	0.1082	0.0915	13.9497	0.9857	0.0078	0.0066	0.0143
	120	80	0.5	0.25	10	10	0.25	0	100	70	92.91	105.83	0.2756	0.2583	0.0039	0.0053	118.746	80.005	12.9159	12.9144	12.9167	0.0018	0.0013	12.9197	0.9998	0.0001	0.0001	0.0002
	120	80	0.5	0.25	10	10	0.25	0	110	70	93.12	106.25	0.2800	0.2625	0.0033	0.0046	119.372	80.005	13.1243	13.1230	13.1250	0.0015	0.0011	13.1276	0.9998	0.0001	0.0001	0.0002
σ_x	120	80	0.5	0.25	10	10	0.25	0	120	70	93.33	106.67	0.2845	0.2667	0.0029	0.0040	119.997	80.004	13.3328	13.3316	13.3333	0.0013	0.0010	13.3356	0.9998	0.0001	0.0001	0.0002
	120	80	0.5	0.25	10	10	0.25	0	130	70	93.54	107.08	0.2889	0.2708	0.0025	0.0035	120.623	80.003	13.5412	13.5402	13.5417	0.0012	0.0008	13.5436	0.9999	0.0001	0.0001	0.0001
	120	80	0.5	0.25	10	10	0.25	0	140	70	93.75	107.50	0.2933	0.2750	0.0021	0.0030	121.248	80.003	13.7496	13.7487	13.7500	0.0010	0.0007	13.7517	0.9999	0.0001	0.0001	0.0001
	120	80	0.5	0.25	10	20	0.25	0	100	70	92.56	105.66	0.2793	0.0641	0.0034	0.5322	118.747	80.532	13.0918	12.5630	12.9167	0.1774	0.0011	13.0952	0.9864	0.0135	0.0001	0.0136
	120	80	0.5	0.25	10	20	0.25	0	110	70	92.79	106.08	0.2836	0.0652	0.0030	0.5009	119.372	80.501	13.2900	12.7920	13.1250	0.1670	0.0010	13.2930	0.9874	0.0126	0.0001	0.0126
$\sigma_{b,x}$	120	80	0.5	0.25	10	20	0.25	0	120	70	93.02	106.51	0.2878	0.0663	0.0026	0.4716	119.997	80.472	13.4888	13.0198	13.3333	0.1572	0.0009	13.4914	0.9883	0.0117	0.0001	0.0117
	120	80	0.5	0.25	10	20	0.25	0	130	70	93.25	106.94	0.2920	0.0673	0.0022	0.4440	120.623	80.444	13.6882	13.2464	13.5417	0.1480	0.0007	13.6904	0.9891	0.0108	0.0001	0.0109
	120	80	0.5	0.25	10	20	0.25	0	140	70	93.47	107.36	0.2963	0.0684	0.0019	0.4180	121.248	80.418	13.8881	13.4719	13.7500	0.1393	0.0006	13.8900	0.9899	0.0100	0.0000	0.0101
	120	80	0.5	0.25	20	20	0.2	0	100	70	92.89	106.26	0.0685	0.0657	0.4401	0.4884	118.760	80.488	12.9361	12.8878	13.0667	0.1628	0.1467	13.3761	0.9769	0.0122	0.0110	0.0231
	120	80	0.5	0.25	20	20	0.2	0	110	70	93.03	106.53	0.0692	0.0663	0.4238	0.4706	119.176	80.471	13.0743	13.0276	13.2000	0.1569	0.1413	13.4981	0.9779	0.0116	0.0105	0.0221
ρ_b	120	80	0.5	0.25	20	20	0.2	0	120	70	93.17	106.79	0.0699	0.0670	0.4082	0.4534	119.592	80.453	13.2124	13.1671	13.3333	0.1511	0.1361	13.6205	0.9789	0.0111	0.0100	0.0211
	120	80	0.5	0.25	20	20	0.2	0	130	70	93.31	107.05	0.0706	0.0676	0.3931	0.4369	120.007	80.437	13.3502	13.3064	13.4667	0.1456	0.1310	13.7433	0.9799	0.0106	0.0095	0.0201
	120	80	0.5	0.25	20	20	0.2	0	140	70	93.45	107.31	0.0712	0.0683	0.3786	0.4210	120.421	80.421	13.4879	13.4455	13.6000	0.1403	0.1262	13.8665	0.9808	0.0101	0.0091	0.0192

Table 8
The values of parameters for the simulation data

We create a great number of artificial data which are calculated by the parameters from our model. Some observations are divergent, so we exploit the convergent quotations which amounted to 57,463. The purpose of the analysis of simulation data is to verify that univariate tests and regression tests are feasible analysis for our non-linear price quotation model.

parameters	μ_x^H	μ_x^L	k	p	$\sigma_{b,x}$	$\sigma_{s,x}$
	110	70	0	0.05	10	10
	120	80	0.01	0.1	20	20
category	130	90	…	0.15	30	30
			0.99	0.2	40	40
			1	0.25	50	50
	3 types	3 types	101 types	5 types	5 types	5 types
Total obs.	113625					
Divergent obs.	56489					
Final obs.	57136					

Table 9

Summary statistics for spread and market variables on Taiwan Stock Exchange, April 2003-March 2004.

The dataset contains the history of the order book for all listed stocks in the TAIEX, for the 254 trading days from April 1 2003 to March 31 2004. All variables are reported for each month. The proportions of sellers to all traders are defined as:

$$k\% = \frac{\text{Trades Volume} + \text{Limit Sell Orders at the Best Ask}}{\text{Trades Volume} + \text{Limit Sell Orders at the Best Ask} + \text{Limit Buy Orders at the Best Bid}} \times 100\%.$$

For each observation, we compute the below variables, Quoted Spread = Best Ask Price − Best Bid Price,

Relative Spread $= \frac{\text{Quoted Spread}}{1/2\,(\text{Best Ask Price} + \text{Best Bid Price})} \times 100\%$, $\omega_1\% = \frac{k(1-k)}{1-k(1-k)} \times 100\%$, $\omega_2\% = \frac{(1-k)^2}{1-k(1-k)} \times 100\%$ and $\omega_3\% = \frac{k^2}{1-k(1-k)} \times 100\%$.

The final column is the description of simulation data which we create from different values of parameters associated to the characteristics of traders and market competition.

Year/Month	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data
No. of Trading Days	22	19	20	23	20	21	22	20	22	24	19	22	
No. of Shares	454	461	457	456	457	459	458	456	452	452	455	458	
No. of Observations	1,128,579	1,144,693	1,224,595	2,858,807	2,247,310	2,113,863	2,367,778	2,249,506	2,284,934	1,864,149	2,586,179	2,779,685	57,136
Mean of Quoted Spread	0.12431	0.12973	0.12892	0.14137	0.14993	0.15380	0.14682	0.14683	0.14407	0.14277	0.14389	0.15367	12.28
Std. Dev. of Quoted Spread	0.16657	0.16664	0.16544	0.17778	0.18992	0.19466	0.18918	0.18398	0.17937	0.17846	0.17523	0.19649	4.98
Mean of Relative Spread	0.5699%	0.5326%	0.5245%	0.5296%	0.5493%	0.5588%	0.5436%	0.5433%	0.5283%	0.5113%	0.5064%	0.5177%	12.5%
Std. Dev. of Relative Spread	0.3853%	0.3342%	0.3158%	0.3020%	0.3084%	0.3173%	0.2891%	0.2821%	0.2707%	0.2514%	0.2734%	0.3361%	5.2%
Mean k	49.20%	48.98%	48.92%	48.89%	48.80%	48.71%	48.69%	48.68%	48.62%	48.91%	48.62%	49.76%	50.0%
Mean ω_1	28.81%	29.57%	29.69%	29.73%	29.28%	28.93%	29.15%	29.27%	28.73%	29.62%	29.93%	28.86%	24.6%
Mean ω_2	36.58%	36.38%	36.38%	36.41%	36.77%	37.04%	36.96%	36.93%	37.24%	36.46%	36.63%	35.99%	37.7%
Mean ω_3	34.61%	34.05%	33.92%	33.86%	33.94%	34.02%	33.89%	33.80%	34.03%	33.92%	33.44%	35.15%	37.7%

Table 10

Mean quoted spread classified by the market competition measure and the weight of the different valuations

Panel A presents the results of the first part sample that the observations are market competition measure $k\%$ larger than 50%. Quoted spreads are classified by the market competition measure $k\%$ into five groups in each stock. Mean quoted spreads of each quintile are shown for each month in our sample period. Quintile 1 is the largest $k\%$ group; in contrast, quintile 5 is the smallest $k\%$ group. Panel B presents the results of the second part sample that the observations are market competition measure $k\%$ smaller than 50%. Similarly, we divide second part sample into five groups, quintile 6 as the largest $k\%$ group, quintile 10 as the smallest group. In Panel C, quoted spreads are classified by the weight of the different valuations $W_1\%$ into five groups in each stock, quintile 1 as the largest $W_1\%$ group, quintile 5 as the smallest $W_1\%$ group. In final column, we examine the simulation data in the same method. The last low of each Panel present the value of F-test that examine the null hypothesis that the quintile means are equal.

Year/Month		**2003/Apr**	**2003/May**	**2003/Jun**	**2003/Jul**	**2003/Aug**	**2003/Sep**	**2003/Oct**	**2003/Nov**	**2003/Dec**	**2004/Jan**	**2004/Feb**	**2004/Mar**	**Simulation Data**
Penal A	k													
	1 (largest)	0.11881	0.12676	0.12732	0.13634	0.15855	0.15506	0.14830	0.14587	0.14498	0.14390	0.14356	0.11887	6.997
	2	0.12215	0.12321	0.12099	0.13768	0.13977	0.16990	0.14215	0.14017	0.14216	0.14104	0.12574	0.14768	10.998
$1 \geq k \geq 0.5$	**3**	0.12235	0.13464	0.13828	0.16178	0.16314	0.13826	0.14361	0.14181	0.13910	0.14235	0.14700	0.14577	12.944
	4	0.13824	0.16751	0.15864	0.16873	0.15867	0.16363	0.15855	0.15506	0.14887	0.15298	0.18844	0.19744	14.867
	5 (smallest)	0.24566	0.29926	0.30625	0.23010	0.18544	0.21261	0.23783	0.29285	0.22444	0.31244	0.48081	0.38378	15.857
	F-test	1056.64	2695.49	3338.96	2587.19	835.36	1569.19	1966.93	4410.11	2452.18	4517.25	19705.25	11503.46	4543.78
Penal B	k													
	6 (largest)	0.17721	0.16839	0.18296	0.18034	0.15353	0.15807	0.20397	0.21930	0.19780	0.24883	0.37770	0.32407	15.804
	7	0.13319	0.16153	0.15302	0.14971	0.17121	0.14578	0.14955	0.14539	0.13811	0.14337	0.17572	0.17920	14.729
$0 \leq k < 0.5$	**8**	0.12238	0.12282	0.12585	0.14368	0.14304	0.15374	0.13744	0.14619	0.13760	0.12983	0.12971	0.14950	12.806
	9	0.11851	0.11652	0.11031	0.13070	0.14275	0.15067	0.14072	0.13632	0.13793	0.13488	0.12498	0.14992	10.787
	10 (smallest)	0.11559	0.11656	0.12143	0.12180	0.13519	0.14737	0.14154	0.14228	0.13792	0.12986	0.13054	0.14386	6.712
	F-test	627.67	1407.34	1488.11	1696.29	1166.79	93.21	1519.57	2197.06	1932.73	3579.17	16761.47	6422.06	4657.04
Penal C	ω_1													
	1 (largest)	0.19954	0.21836	0.23430	0.19858	0.16464	0.17729	0.21677	0.24567	0.20877	0.27439	0.41859	0.34692	15.826
	2	0.13516	0.16439	0.15570	0.15858	0.16516	0.15441	0.15382	0.14980	0.14304	0.14805	0.18101	0.18809	14.786
$1 \geq k \geq 0$	**3**	0.12253	0.12871	0.13181	0.15244	0.15251	0.14611	0.14041	0.14407	0.13835	0.13582	0.13781	0.14770	12.858
	4	0.12037	0.11982	0.11576	0.13411	0.14128	0.15999	0.14142	0.13817	0.13995	0.13790	0.12534	0.14879	10.855
	5 (smallest)	0.11713	0.12169	0.12423	0.12914	0.14627	0.15103	0.14481	0.14401	0.14126	0.13663	0.13675	0.13212	6.779
	F-test	1493.75	3478.00	4151.25	3965.32	1121.57	718.97	3311.61	5860.61	4205.28	7736.56	35120.07	16722.90	9354.75

Table 11

Mean percentage spread classified by the market competition measure and the weight of the different valuations

Panel A presents the results of the first part sample that the observations are market competition measure $k\%$ larger than 50%. Percentage Spreads are classified by the market competition measure $k\%$ into five groups in each stock. Mean Percentage spreads of each quintile are shown for each month in our sample period. Quintile 1 is the largest $k\%$ group; in contrast, quintile 5 is the smallest $k\%$ group. Panel B presents the results of the second part sample that the observations are market competition measure $k\%$ smaller than 50%. Similarly, we divide second part sample into five groups, quintile 6 as the largest $k\%$ group, quintile 10 as the smallest group. In Panel C, percentage spreads are classified by the weight of the different valuations $W_1\%$ into five groups in each stock, quintile 1 as the largest $W_1\%$ group, quintile 5 as the smallest $W_1\%$ group. In final column, we examine the simulation data in the same method. The last low of each Panel present the value of F-test that examine the null hypothesis that the quintile means are equal.

Year/Month		**2003/Apr**	**2003/May**	**2003/Jun**	**2003/Jul**	**2003/Aug**	**2003/Sep**	**2003/Oct**	**2003/Nov**	**2003/Dec**	**2004/Jan**	**2004/Feb**	**2004/Mar**	**Simulation Data**
Panel A	k													
	1 (largest)	0.4953%	0.5057%	0.5052%	0.5033%	0.5219%	0.5474%	0.5364%	0.5262%	0.5313%	0.5087%	0.5066%	0.3840%	8.43%
	2	0.5296%	0.5095%	0.4999%	0.5128%	0.5167%	0.5336%	0.5270%	0.5187%	0.5164%	0.4865%	0.4768%	0.4942%	12.76%
$1 \geq k \geq 0.5$	**3**	0.5680%	0.5691%	0.5640%	0.5623%	0.5584%	0.5416%	0.5466%	0.5307%	0.5085%	0.5154%	0.5303%	0.5367%	14.42%
	4	0.6833%	0.6754%	0.6658%	0.6772%	0.6329%	0.6277%	0.5948%	0.6160%	0.5626%	0.5851%	0.6222%	0.6418%	15.80%
	5 (smallest)	0.8304%	0.7586%	0.7603%	0.7644%	0.7510%	0.7553%	0.7177%	0.7614%	0.6872%	0.7448%	0.7885%	0.8136%	16.05%
	F-test	4343.38	4802.32	5877.19	13639.35	7241.47	5856.15	4318.63	7904.96	5321.13	8497.80	12859.13	23587.76	2806.62
Panel B	k													
	6 (largest)	0.8221%	0.7302%	0.7323%	0.7720%	0.7216%	0.7144%	0.6906%	0.7126%	0.6502%	0.6940%	0.7681%	0.7911%	15.65%
	7	0.6671%	0.6517%	0.6410%	0.6378%	0.6200%	0.6097%	0.5839%	0.5897%	0.5417%	0.5639%	0.5818%	0.6235%	13.95%
$0 \leq k < 0.5$	**8**	0.5851%	0.5608%	0.5614%	0.5487%	0.5524%	0.5413%	0.5317%	0.5341%	0.5079%	0.4971%	0.5125%	0.5379%	11.68%
	9	0.5394%	0.4850%	0.4731%	0.4882%	0.5198%	0.5232%	0.5094%	0.5074%	0.5051%	0.4729%	0.4607%	0.5012%	9.55%
	10 (smallest)	0.5174%	0.4426%	0.4274%	0.4426%	0.4961%	0.5272%	0.5026%	0.5133%	0.5058%	0.4558%	0.4349%	0.4604%	5.79%
	F-test	4433.29	7541.19	10099.02	21396.72	9629.77	6760.85	7461.95	8455.03	5475.58	10628.06	18072.28	13289.05	5838.74
Panel C	ω_1													
	1 (largest)	0.8255%	0.7414%	0.7440%	0.7692%	0.7318%	0.7288%	0.7009%	0.7301%	0.6656%	0.7144%	0.7762%	0.7997%	15.85%
	2	0.6743%	0.6633%	0.6531%	0.6563%	0.6263%	0.6184%	0.5891%	0.6017%	0.5513%	0.5742%	0.5986%	0.6324%	14.89%
$1 \geq k \geq 0$	**3**	0.5766%	0.5648%	0.5627%	0.5553%	0.5552%	0.5415%	0.5389%	0.5324%	0.5082%	0.5059%	0.5208%	0.5374%	13.06%
	4	0.5345%	0.4971%	0.4866%	0.5003%	0.5183%	0.5282%	0.5180%	0.5128%	0.5105%	0.4796%	0.4688%	0.4977%	11.15%
	5 (smallest)	0.5069%	0.4742%	0.4661%	0.4732%	0.5083%	0.5367%	0.5189%	0.5195%	0.5179%	0.4813%	0.4691%	0.4245%	7.05%
	F-test	8725.08	11922.55	15107.08	33556.69	16519.59	12378.17	11307.49	15955.49	10455.63	18369.46	28827.30	35013.51	7430.86

Table 12
Distribution of mean percentage spread for time interval-sorted samples of the TAIEX securities

We attempt to treat time intervals of a trading day as the proxy variable for the probability of informed trading. During the sample period, trading on the TAIEX was conducted from 9:00 A.M. to 1:30 P.M. Taipei time. A time series of percentage bid-ask spreads over the trading day in the market is constructed. We partition each trading day into one 54-minute interval and five successive 54-minute intervals. Besides, we also classified the quoted spreads of the simulation data by the quintiles of the probability of informed trading; quintile 1 as the smallest group and quintile 5 as the largest group. The last low presents the value of F-test that examines the null hypothesis that the quintile means are equal.

Year/Month Time Interval	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data *p*	Simulation Data qouted spread
1 (9:00 A.M. to 9:54 A.M.)	0.6363%	0.5820%	0.5678%	0.5715%	0.5987%	0.6113%	0.5811%	0.5719%	0.5572%	0.5395%	0.5347%	0.5485%	**1** (smallest)	11.18
2 (9:55 A.M. to 10:48 A.M.)	0.5628%	0.5289%	0.5222%	0.5254%	0.5452%	0.5493%	0.5408%	0.5448%	0.5218%	0.5091%	0.5074%	0.5137%	**2**	11.97
3 (10:49 A.M. to 11:42 A.M.)	0.5427%	0.5133%	0.5078%	0.5133%	0.5292%	0.5383%	0.5302%	0.5320%	0.5182%	0.5012%	0.4969%	0.5046%	**3**	12.54
4 (11:43 A.M. to 12:36 P.M.)	0.5392%	0.5074%	0.5019%	0.5117%	0.5261%	0.5358%	0.5268%	0.5254%	0.5151%	0.4984%	0.4923%	0.5059%	**4**	12.97
5 (12:37 P.M. to 1:30 P.M.)	0.5512%	0.5198%	0.5135%	0.5184%	0.5365%	0.5446%	0.5326%	0.5345%	0.5212%	0.5033%	0.4932%	0.5092%	**5** (largest)	13.37
All	0.5699%	0.5326%	0.5245%	0.5296%	0.5493%	0.5588%	0.5436%	0.5433%	0.5283%	0.5113%	0.5064%	0.5177%	**All**	12.28
F-test	2752.77	2031.93	1864.19	4238.37	4632.66	4730.32	3021.00	2056.72	2106.77	1799.31	2425.35	1812.06	**F-test**	332.97

Table 13

Distribution of the percentage spread for firm size quintile-sorted samples of the TAIEX securities, April 2003-March 2004

As a matter of factor, small (big) firms should have higher (lower) asset volatility. We tend to treat firm size as the proxy variable of asset volatility. For comparison, the percentage spread is proper spread variable to compare between stocks. Mean percentage spreads, which are classified all stocks of TAIEX by quintiles of firm size on a daily basis, are shown for each month. In addition, we also classified the quoted spreads of the simulation data by quintiles of the asset volatility recognized by buyers and sellers, respectively; quintile 1 as the smallest volatility group and quintile 5 as the largest volatility group. The last low presents the value of F-test that examines the null hypothesis that the quintile means are equal.

Year/Month Firm Size	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	simulation data volatility	quoted spread $\sigma_{b,x}$	 $\sigma_{s,x}$
1 (smallest)	0.8253%	0.7372%	0.7180%	0.7178%	0.7605%	0.7663%	0.7061%	0.7001%	0.6596%	0.6331%	0.6185%	0.6511%	**1** (smallest)	10.75	10.75
2	0.6317%	0.5595%	0.5497%	0.5540%	0.5774%	0.5849%	0.5605%	0.5621%	0.5363%	0.5117%	0.4930%	0.5153%	**2**	11.76	11.76
3	0.5364%	0.4924%	0.4839%	0.4960%	0.5062%	0.5297%	0.5063%	0.5110%	0.5059%	0.4784%	0.4767%	0.4853%	**3**	12.64	12.64
4	0.4988%	0.4940%	0.4951%	0.4865%	0.5017%	0.4894%	0.4891%	0.4944%	0.4913%	0.4805%	0.4664%	0.4689%	**4**	13.34	13.34
5 (largest)	0.4745%	0.4605%	0.4514%	0.4691%	0.4832%	0.4903%	0.5055%	0.5000%	0.4877%	0.4851%	0.4948%	0.4982%	**5** (largest)	14.32	14.32
All	0.5699%	0.5326%	0.5245%	0.5296%	0.5493%	0.5588%	0.5436%	0.5433%	0.5283%	0.5113%	0.5064%	0.5177%	**All**	12.28	12.28
F-test	22924	19378	21085	48489	47742	49367	39799	36177	26712	23678	25976	24562	**F-test**	918	919

Table 14

Panel regressions, estimated values of the three factors, and percentages of the three components to spread

We performed panel data regressions of all listed stocks in TAIEX market for each month in Panel A as: $\pi = \overline{V}_{b-s} + \omega_2(L_s^{AS} - \overline{V}_{b-s}) + \omega_3(L_b^{AS} - \overline{V}_{b-s}) + \varepsilon$

The regression coefficients are reported t-statistics to test whether the mean coefficient is different from zero. The last low of Panel A presents the value of F-test of the regressions.The coefficient of ω_2 (ω_3) represents $L_s^{AS} - \overline{V}_{b-s}$ ($L_b^{AS} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then L_s^{AS} (L_b^{AS}) is obtained by the coefficient of ω_2 (ω_3) plus the intercept term. Based on this method, we further investigate monthly the size of the three factors for market and the results present in Panel B. Next, for each month, we estimate separately the values and percentages of the percentage spread coming from the three different factors according to the mean of ω_1, ω_2, and ω_3. The Panel C provides the structure of anatomy of the percentage spread for each month in our samples period. In addition, we also examine the quoted spreads of the simulation data by panel regression. The last columns present the related results.

Panel A

Year/Month	2003/Apr		2003/May		2003/Jun		2003/Jul		2003/Aug		2003/Sep		2003/Oct		2003/Nov		2003/Dec		2004/Jan		2004/Feb		2004/Mar		Overall	Simulation Data quoted spread	
Inde. Variables	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic		Coefficients	t-statistic
$\overline{V}_{b-s}$	0.0057383	195.08	0.0046906	173.657	0.0043607	173.823	0.0045657	289.948	0.003711	207.914	0.0036089	194.567	0.0041687	257.203	0.003851	233.98	0.0038818	256.119	0.0042115	255.565	0.0052918	343.345	0.0086979	562.37		40.9	343.2
ω_2	0.0002739	6.54893	0.0003701	9.68543	0.0006131	17.2999	0.0004995	22.4257	0.0024237	96.1632	0.0026631	102.354	0.0015453	67.8783	0.0021174	91.277	0.001833	86.5654	0.0008788	37.6876	-0.0008419	-38.774	-0.0043691	-194.13		-37.9	-238.4
ω_3	-0.0004033	-9.5366	0.0014698	36.7058	0.0019501	52.1596	0.0016203	69.027	0.0026231	100.118	0.0029173	107.711	0.0020535	86.2339	0.0023666	97.8768	0.0021129	95.7638	0.0017142	70.2316	0.0002404	10.3544	-0.005542	-253.78		-37.9	-238.4
F-test	658.20		2083.96		3654.17		6457.52		5094.61		5857.42		4023.69		4806.26		4587.03		4312.63		6097.61		34644.52			29247	

Panel B

Factors	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Overall	Simulation Data quoted spread
	value	value	value	value	value	value	value	value	value	value	value	value	value	value
$\overline{V}_{b-s}$	0.5738%	0.4691%	0.4361%	0.4566%	0.3711%	0.3609%	0.4169%	0.3851%	0.3882%	0.4212%	0.5292%	0.8698%	**0.473%**	40.85
L_s^{AS}	0.6012%	0.5061%	0.4974%	0.5065%	0.6135%	0.6272%	0.5714%	0.5968%	0.5715%	0.5090%	0.4450%	0.4329%	**0.540%**	2.96
L_b^{AS}	0.5335%	0.6160%	0.6311%	0.6186%	0.6334%	0.6526%	0.6222%	0.6218%	0.5995%	0.5926%	0.5532%	0.3156%	**0.583%**	2.96

Panel C

Components	2003/Apr		2003/May		2003/Jun		2003/Jul		2003/Aug		2003/Sep		2003/Oct		2003/Nov		2003/Dec		2004/Jan		2004/Feb		2004/Mar		Overall	Simulation Data quoted spread	
	value	%	value	%	value	%	value	%	value	%	value	%	value	%	value	%	value	%	value	%	value	%	value	%	%	value	%
$\omega_1\overline{V}_{b-s}$	0.1653%	29%	0.1387%	26%	0.1295%	25%	0.1358%	26%	0.1087%	20%	0.1044%	19%	0.1215%	22%	0.1127%	21%	0.1115%	21%	0.1248%	24%	0.1584%	31%	0.2510%	48%	**26.02%**	10.06	82%
$\omega_2 L_s^{AS}$	0.2199%	39%	0.1841%	35%	0.1810%	35%	0.1844%	35%	0.2256%	41%	0.2323%	42%	0.2112%	39%	0.2204%	41%	0.2128%	40%	0.1856%	36%	0.1630%	32%	0.1558%	30%	**36.95%**	1.11	9%
$\omega_3 L_b^{AS}$	0.1847%	32%	0.2098%	39%	0.2141%	41%	0.2095%	40%	0.2150%	39%	0.2220%	40%	0.2109%	39%	0.2101%	39%	0.2040%	39%	0.2010%	39%	0.1850%	37%	0.1109%	21%	**37.03%**	1.11	9%
% spread	0.5699%		0.5326%		0.5245%		0.5296%		0.5493%		0.5588%		0.5436%		0.5433%		0.5283%		0.5113%		0.5064%		0.5177%			12.28	

Table 15

Results for the regressions of percentage spreads against ω_2 and ω_3 multiplied by the time interval quintiles

We conduct the following regressions to determine the effects of the probability of informed trading on the percentage spread using the proxy variable of quintile time intervals as the probability of informed trading: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 Time_i (L^{AS}_{s,time_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 Time_i (L^{AS}_{b,time_i} - \overline{V}_{b-s}) + \varepsilon$ where $Time_i$ = 0/1 dummy variable, $Time_1$ = for the trading period from 9:00 A.M. to 9:54 A.M. and 0 otherwise, with $Time_2 \sim Time_5$ defined in a similar manner for 54 minutes per time interval from 9:55 A.M. to 1:30 P.M. Taipei time. ε = the error term, which is assumed to be normally distributed. Besides, we also examine the quoted spreads of the simulation data by panel regression using the dummy quintiles of the probability of informed traders; quintile 1 as the smallest probability group and quintile 5 as the largest probability group. The equation is: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 p_i (L^{AS}_{s,p_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 p_i (L^{AS}_{b,p_i} - \overline{V}_{b-s}) + \varepsilon$ where p_i =1/0 dummy variables, p_1 = for the smallest probability of informed trading quintile and 0 otherwise, $p_2 \sim p_5$ defined in a similar manner. The regression coefficients are reported t-statistics to test whether the mean coefficient is different from zero. The last low presents the value of F-test of the regressions.

Year/Month	2003/Apr		2003/May		2003/Jun		2003/Jul		2003/Aug		2003/Sep		2003/Oct		2003/Nov		2003/Dec		2004/Jan		2004/Feb		2004/Mar		Simulation Data		
Inde.Variables	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Coefficients	t-statistic	Inde.Variables	Coefficients	t-statistic
$\overline{V}_{b-s}$	0.00564	192.42	0.00458	169.82	0.00426	169.79	0.00447	283.79	0.00366	205.59	0.00358	193.77	0.00414	255.60	0.00382	231.77	0.00385	253.88	0.00417	252.58	0.00524	339.44	0.00854	549.53	$\overline{V}_{b-s}$	41.17	358
$\omega_2 Time_1$	0.00150	32.25	0.00135	31.33	0.00147	36.67	0.00140	55.72	0.00326	116.73	0.00354	123.99	0.00226	89.34	0.00262	102.26	0.00242	103.20	0.00152	58.23	-0.00035	-14.36	-0.00286	-109.85	$\omega_2 p_1$	-39.94	-244
$\omega_2 Time_2$	0.00030	6.40	0.00058	13.61	0.00083	20.80	0.00064	25.53	0.00255	91.61	0.00260	90.30	0.00160	63.32	0.00224	87.70	0.00179	75.74	0.00097	36.79	-0.00067	-27.33	-0.00409	-162.43	$\omega_2 p_2$	-38.93	-235
$\omega_2 Time_3$	-0.00002	-0.48	0.00027	6.34	0.00050	12.55	0.00045	18.25	0.00217	77.31	0.00236	82.67	0.00134	52.96	0.00199	76.95	0.00167	71.26	0.00067	25.83	-0.00085	-35.17	-0.00450	-176.88	$\omega_2 p_3$	-38.05	-228
$\omega_2 Time_4$	0.00002	0.39	0.00011	2.73	0.00041	10.45	0.00034	13.98	0.00218	79.06	0.00241	84.11	0.00131	52.68	0.00189	74.26	0.00166	71.33	0.00073	29.04	-0.00096	-40.22	-0.00471	-187.40	$\omega_2 p_4$	-37.27	-223
$\omega_2 Time_5$	0.00013	2.74	0.00023	5.35	0.00054	13.61	0.00029	11.42	0.00224	79.90	0.00247	85.02	0.00135	53.21	0.00202	78.07	0.00176	75.37	0.00075	28.90	-0.00104	-43.19	-0.00477	-188.20	$\omega_2 p_5$	-36.51	-218
$\omega_3 Time_1$	0.00061	13.24	0.00227	51.78	0.00268	65.41	0.00225	87.39	0.00339	119.77	0.00364	125.36	0.00251	97.26	0.00284	108.54	0.00246	104.36	0.00202	76.44	0.00074	29.34	-0.00561	-241.83	$\omega_3 p_1$	-39.94	-244
$\omega_3 Time_2$	-0.00033	-7.06	0.00145	32.75	0.00196	47.20	0.00164	62.83	0.00250	86.22	0.00276	93.14	0.00197	75.60	0.00235	88.17	0.00204	83.91	0.00165	62.10	0.00024	9.41	-0.00549	-224.67	$\omega_3 p_2$	-38.93	-235
$\omega_3 Time_3$	-0.00060	-12.59	0.00129	29.12	0.00183	44.45	0.00145	56.02	0.00243	83.81	0.00269	88.77	0.00192	73.09	0.00224	83.76	0.00205	83.04	0.00171	63.52	0.00012	4.59	-0.00533	-211.33	$\omega_3 p_3$	-38.06	-228
$\omega_3 Time_4$	-0.00076	-16.08	0.00130	28.77	0.00178	42.29	0.00151	57.90	0.00231	78.97	0.00255	83.57	0.00188	69.33	0.00214	79.11	0.00195	78.63	0.00161	57.94	0.00009	3.66	-0.00508	-195.86	$\omega_3 p_4$	-37.27	-223
$\omega_3 Time_5$	-0.00055	-11.29	0.00156	33.29	0.00201	45.93	0.00183	65.54	0.00261	85.12	0.00281	89.39	0.00204	72.98	0.00235	82.65	0.00209	80.07	0.00176	60.77	0.00023	8.25	-0.00503	-187.35	$\omega_3 p_5$	-36.51	-218
F-statistic	**1355.83**		**1331.69**		**1580.14**		**3257.62**		**3112.03**		**3258.65**		**2160.96**		**1947.76**		**1910.84**		**1703.70**		**2289.55**		**8652.13**		**F-statistic**	**6721.09**	

Table 16

Estimation of the three factors of percentage spread by regression with the time intervals

According the results of Table 15, we calculate the values of three factors as: (i) the different valuations, (ii) the sellers' expected loss of adverse selection, and (iii) the buyers' expected loss of adverse selection. The different valuations is original from the intercept term of the regression. The expected loss of adverse selection is obtained from the below method. The coefficient of $\omega_2 Time_i$ ($\omega_3 Time_i$) represents $L^{AS}_{s,Time_i} - \overline{V}_{b-s}$ ($L^{AS}_{b,Time_i} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, and then $L^{AS}_{s,Time_i}$ ($L^{AS}_{b,Time_i}$) is obtained by the coefficient of $\omega_2 Time_i$ ($\omega_3 Time_i$) plus the intercept term. Likewise, The coefficient of $\omega_2 p_i$ ($\omega_3 p_i$) represents $L^{AS}_{s,p_i} - \overline{V}_{b-s}$ ($L^{AS}_{b,p_i} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, and then L^{AS}_{s,p_i} (L^{AS}_{b,p_i}) is obtained by the coefficient of $\omega_2 p_i$ ($\omega_3 p_i$) plus the intercept term. The last panel shows the summation of sellers' and buyers' expected loss of adverse selection.

Year/Month / **The Factors of Bid-Ask Spread**		**2003/Apr**	**2003/May**	**2003/Jun**	**2003/Jul**	**2003/Aug**	**2003/Sep**	**2003/Oct**	**2003/Nov**	**2003/Dec**	**2004/Jan**	**2004/Feb**	**2004/Mar**	**Simulation Data**	
	$\overline{V}_{b-s}$	0.5636%	0.4582%	0.4259%	0.4467%	0.3661%	0.3583%	0.4143%	0.3815%	0.3854%	0.4172%	0.5238%	0.8543%	$\overline{V}_{b-s}$	41.17
Seller	$L^{AS}_{s,Time_1}$	0.7133%	0.5936%	0.5731%	0.5871%	0.6924%	0.7123%	0.6399%	0.6433%	0.6269%	0.5689%	0.4888%	0.5681%	L^{AS}_{s,p_1}	1.23
	$L^{AS}_{s,Time_2}$	0.5933%	0.5164%	0.5085%	0.5103%	0.6207%	0.6182%	0.5746%	0.6059%	0.5647%	0.5141%	0.4567%	0.4450%	L^{AS}_{s,p_2}	2.25
	$L^{AS}_{s,Time_3}$	0.5614%	0.4853%	0.4756%	0.4916%	0.5827%	0.5945%	0.5486%	0.5805%	0.5521%	0.4844%	0.4387%	0.4045%	L^{AS}_{s,p_3}	3.12
	$L^{AS}_{s,Time_4}$	0.5654%	0.4697%	0.4665%	0.4810%	0.5842%	0.5995%	0.5450%	0.5708%	0.5512%	0.4906%	0.4275%	0.3838%	L^{AS}_{s,p_4}	3.90
	$L^{AS}_{s,Time_5}$	0.5765%	0.4810%	0.4794%	0.4753%	0.5900%	0.6051%	0.5493%	0.5831%	0.5613%	0.4919%	0.4199%	0.3773%	L^{AS}_{s,p_5}	4.66
Buyer	$L^{AS}_{b,Time_1}$	0.6249%	0.6848%	0.6937%	0.6716%	0.7052%	0.7221%	0.6650%	0.6660%	0.6315%	0.6192%	0.5980%	0.2930%	L^{AS}_{b,p_1}	1.23
	$L^{AS}_{b,Time_2}$	0.5301%	0.6036%	0.6214%	0.6108%	0.6158%	0.6346%	0.6116%	0.6169%	0.5890%	0.5826%	0.5481%	0.3055%	L^{AS}_{b,p_2}	2.25
	$L^{AS}_{b,Time_3}$	0.5038%	0.5873%	0.6091%	0.5921%	0.6088%	0.6275%	0.6062%	0.6056%	0.5902%	0.5882%	0.5356%	0.3217%	L^{AS}_{b,p_3}	3.12
	$L^{AS}_{b,Time_4}$	0.4877%	0.5882%	0.6039%	0.5976%	0.5973%	0.6132%	0.6019%	0.5956%	0.5804%	0.5782%	0.5332%	0.3468%	L^{AS}_{b,p_4}	3.90
	$L^{AS}_{b,Time_5}$	0.5090%	0.6142%	0.6270%	0.6292%	0.6272%	0.6395%	0.6185%	0.6162%	0.5948%	0.5931%	0.5464%	0.3509%	L^{AS}_{b,p_5}	4.66
Both	$L^{AS}_{s,Time_1} + L^{AS}_{b,Time_1}$	1.3382%	1.2784%	1.2667%	1.2587%	1.3976%	1.4344%	1.3049%	1.3093%	1.2584%	1.1881%	1.0868%	0.8611%	$L^{AS}_{s,p_1} + L^{AS}_{b,p_1}$	2.46
	$L^{AS}_{s,Time_2} + L^{AS}_{b,Time_2}$	1.1234%	1.1200%	1.1300%	1.1210%	1.2365%	1.2529%	1.1862%	1.2228%	1.1537%	1.0966%	1.0048%	0.7505%	$L^{AS}_{s,p_2} + L^{AS}_{b,p_2}$	4.49
	$L^{AS}_{s,Time_3} + L^{AS}_{b,Time_3}$	1.0652%	1.0726%	1.0847%	1.0837%	1.1915%	1.2220%	1.1549%	1.1860%	1.1423%	1.0726%	0.9743%	0.7263%	$L^{AS}_{s,p_3} + L^{AS}_{b,p_3}$	6.24
	$L^{AS}_{s,Time_4} + L^{AS}_{b,Time_4}$	1.0531%	1.0578%	1.0704%	1.0786%	1.1815%	1.2128%	1.1470%	1.1664%	1.1316%	1.0688%	0.9607%	0.7305%	$L^{AS}_{s,p_4} + L^{As}_{b,p_4}$	7.80
	$L^{AS}_{s,Time_5} + L^{AS}_{b,Time_5}$	1.0855%	1.0952%	1.1064%	1.1045%	1.2172%	1.2446%	1.1678%	1.1993%	1.1560%	1.0850%	0.9664%	0.7283%	$L^{AS}_{s,p_5} + L^{AS}_{b,p_5}$	9.33

Table 17

Results for the regression of percentage spreads against ω_2 and ω_3 multiplied by the firm size quintiles

We conduct the following regressions to determine the effects of the asset volatility on the percentage spread using the proxy variable of firm size quintiles as the asset volatility: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 Size_i (L^{AS}_{s,size_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 Size_i (L^{AS}_{b,size_i} - \overline{V}_{b-s}) + \varepsilon$ where $Size_i$ are dummies for daily firm size quintiles, $Size_1$ represents the smallest firm size quintile, and $Size_5$ represents the largest firm size quintile; others in the same manner. ε = the error term, which is assumed to be normally distributed. Besides, we also examine the quoted spreads of the simulation data by panel regression using the dummy quintiles of the asset volatility recognized by sellers and buyers (as vs and vb, respectively); quintile 1 as the smallest asset volatility group and quintile 5 as the largest asset volatility group. The equation is: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5} \omega_2 vs_i (L^{AS}_{s,vs_i} - \overline{V}_{b-s}) + \sum_{i=}^{5} \omega_3 vb_i (L^{AS}_{b,vb_i} - \overline{V}_{b-s}) + \varepsilon$. The regression coefficients are reported t-statistics to test whether the mean coefficient is different from zero. The last low presents the value of F-test of the regressions.

Year/Month	2003/Apr		2003/May		2003/Jun		2003/Jul		2003/Aug		2003/Sep		2003/Oct		2003/Nov		2003/Dec		2004/Jan		2004/Feb		2004/Mar		Simulation Data		
Inde. Variables	Coefficients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	**Inde.Variables**	Coefficients	t-statistic
$\overline{V}_{b-s}$	0.00721	249.49	0.00611	227.71	0.00576	231.16	0.00599	381.63	0.00522	294.00	0.00514	279.59	0.00525	324.14	0.00486	296.77	0.00450	298.85	0.00502	303.69	0.00606	391.21	0.00948	609.70	$\overline{V}_{b-s}$	43.46	402
$\omega_2 Size_1$	0.00134	29.40	0.00074	18.22	0.00089	23.65	0.00078	32.54	0.00305	113.23	0.00279	102.36	0.00186	77.45	0.00249	101.50	0.00241	105.75	0.00110	45.02	-0.00072	-31.73	-0.00382	-162.02	$\omega_2 vs_1$	-43.49	-273
$\omega_2 Size_2$	-0.00109	-25.42	-0.00123	-30.83	-0.00094	-25.35	-0.00100	-43.14	0.00074	28.65	0.00091	33.94	0.00015	6.35	0.00099	40.66	0.00107	48.36	-0.00019	-7.68	-0.00230	-96.57	-0.00532	-215.26	$\omega_2 vs_2$	-43.32	-272
$\omega_2 Size_3$	-0.00224	-49.84	-0.00207	-49.98	-0.00178	-46.41	-0.00181	-73.10	-0.00029	-10.62	0.00020	7.10	-0.00024	-9.59	0.00034	13.37	0.00077	33.30	-0.00054	-21.30	-0.00220	-92.94	-0.00610	-246.87	$\omega_2 vs_3$	-42.48	-271
$\omega_2 Size_4$	-0.00251	-53.75	-0.00194	-44.12	-0.00161	-39.79	-0.00221	-87.06	-0.00031	-10.86	-0.00031	-10.62	-0.00054	-21.38	0.00001	0.51	0.00062	26.51	-0.00059	-22.24	-0.00217	-84.84	-0.00622	-235.84	$\omega_2 vs_4$	-40.49	-266
$\omega_2 Size_5$	-0.00317	-61.35	-0.00265	-54.55	-0.00245	-54.20	-0.00267	-93.71	-0.00095	-29.33	-0.00027	-7.98	-0.00042	-14.27	0.00045	15.76	0.00040	15.82	-0.00077	-26.19	-0.00173	-63.21	-0.00541	-185.39	$\omega_2 vs_5$	-37.24	-254
$\omega_3 Size_1$	0.00136	28.46	0.00266	61.47	0.00297	73.94	0.00242	95.86	0.00334	118.70	0.00399	137.86	0.00306	120.28	0.00332	128.74	0.00327	136.16	0.00246	95.34	0.00105	42.88	-0.00435	-180.17	$\omega_3 vb_1$	-43.49	-273
$\omega_3 Size_2$	-0.00143	-32.53	-0.00017	-4.06	0.00024	6.22	-0.00026	-10.63	0.00078	28.82	0.00102	36.08	0.00083	33.15	0.00111	43.39	0.00130	55.91	0.00046	17.30	-0.00086	-32.76	-0.00661	-277.89	$\omega_3 vb_2$	-43.32	-272
$\omega_3 Size_3$	-0.00291	-63.82	-0.00123	-27.96	-0.00077	-18.78	-0.00106	-40.90	-0.00010	-3.36	0.00027	9.13	-0.00026	-9.90	0.00039	14.88	0.00081	33.06	-0.00011	-4.11	-0.00144	-57.17	-0.00688	-281.19	$\omega_3 vb_3$	-42.48	-271
$\omega_3 Size_4$	-0.00377	-81.53	-0.00137	-30.10	-0.00065	-15.09	-0.00096	-35.63	-0.00021	-6.97	-0.00035	-11.71	-0.00042	-15.56	0.00026	9.66	0.00057	23.09	0.00003	1.08	-0.00182	-67.92	-0.00741	-293.22	$\omega_3 vb_4$	-40.49	-266
$\omega_3 Size_5$	-0.00394	-76.28	-0.00167	-33.94	-0.00113	-24.57	-0.00108	-35.52	-0.00016	-4.65	-0.00041	-11.96	-0.00007	-2.49	0.00000	-0.07	0.00073	28.35	0.00034	11.20	-0.00145	-50.82	-0.00759	-282.44	$\omega_3 vb_5$	-37.24	-254
F-statistic	**9334.02**		**8043.02**		**8991.89**		**20334.45**		**18688.88**		**19384.22**		**15804.05**		**14388.03**		**10756.06**		**9811.23**		**11860.66**		**19400.40**		**F-statistic**	**8887.10**	

Table 18

Estimation of the three factors of percentage spread by regression with the firm size quintiles

According the results of Table 17, we calculate the values of three factors as: (i) the different valuation of traders, (ii) the expected loss of adverse selection of sellers, and (iii) the expected loss of adverse selection of buyers. The different valuation of traders is original from the intercept term of the regression. The expected loss of adverse selection is obtained from the below method. The coefficient of $\omega_2 Size_i$ ($\omega_3 Size_i$) represents $L^{AS}_{s,Size_i} - \overline{V}_{b-s}$ ($L^{AS}_{b,Size_i} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then $L^{AS}_{s,Size_i}$ ($L^{AS}_{b,Size_i}$) is obtained by the coefficient of $\omega_2 Size_i$ ($\omega_3 Size_i$) plus the intercept term. Likewise, The coefficient of $\omega_2 vs_i$ ($\omega_3 vb_i$) represents $L^{AS}_{s,vs_i} - \overline{V}_{b-s}$ ($L^{AS}_{b,vb_i} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then L^{AS}_{s,vs_i} (L^{AS}_{b,vs_i}) is obtained by the coefficient of $\omega_2 vs_i$ ($\omega_3 vb_i$) plus the intercept term. The last panel shows the summation of sellers' and buyers' expected loss of adverse selection.

Year/Month The Factors of Bid-Ask Spread		2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data	
	$\overline{V}_{b-s}$	0.7208%	0.6105%	0.5757%	0.5992%	0.5217%	0.5144%	0.5245%	0.4859%	0.4502%	0.5021%	0.6063%	0.9475%	$\overline{V}_{b-s}$	43.46
Seller	$L^{AS}_{s,Size_1}$	0.8551%	0.6849%	0.6652%	0.6768%	0.8268%	0.7932%	0.7102%	0.7354%	0.6909%	0.6126%	0.5346%	0.5657%	L^{AS}_{s,vs_1}	-0.03
	$L^{AS}_{s,Size_2}$	0.6121%	0.4877%	0.4820%	0.4994%	0.5959%	0.6056%	0.5397%	0.5848%	0.5576%	0.4828%	0.3765%	0.4154%	L^{AS}_{s,vs_1}	0.14
	$L^{AS}_{s,Size_3}$	0.4969%	0.4038%	0.3977%	0.4182%	0.4925%	0.5344%	0.5007%	0.5194%	0.5273%	0.4484%	0.3864%	0.3378%	L^{AS}_{s,vs_3}	0.98
	$L^{AS}_{s,Size_4}$	0.4694%	0.4164%	0.4146%	0.3782%	0.4908%	0.4837%	0.4701%	0.4872%	0.5122%	0.4431%	0.3894%	0.3252%	L^{AS}_{s,vs_4}	2.97
	$L^{AS}_{s,Size_5}$	0.4039%	0.3455%	0.3307%	0.3317%	0.4270%	0.4874%	0.4827%	0.5309%	0.4902%	0.4253%	0.4329%	0.4069%	L^{AS}_{s,vs_5}	6.22
Buyer	$L^{AS}_{b,Size_1}$	0.8572%	0.8769%	0.8726%	0.8414%	0.8558%	0.9131%	0.8306%	0.8181%	0.7776%	0.7484%	0.7113%	0.5122%	L^{AS}_{b,vb_1}	-0.03
	$L^{AS}_{b,Size_2}$	0.5783%	0.5935%	0.6000%	0.5732%	0.5996%	0.6162%	0.6080%	0.5965%	0.5798%	0.5478%	0.5207%	0.2865%	L^{AS}_{b,vb_2}	0.14
	$L^{AS}_{b,Size_3}$	0.4294%	0.4875%	0.4987%	0.4930%	0.5120%	0.5410%	0.4989%	0.5251%	0.5308%	0.4912%	0.4621%	0.2598%	L^{AS}_{b,vb_3}	0.98
	$L^{AS}_{b,Size_4}$	0.3436%	0.4737%	0.5111%	0.5035%	0.5011%	0.4790%	0.4828%	0.5123%	0.5072%	0.5051%	0.4240%	0.2070%	L^{AS}_{b,vb_4}	2.97
	$L^{AS}_{b,Size_5}$	0.3265%	0.4435%	0.4626%	0.4909%	0.5059%	0.4733%	0.5171%	0.4857%	0.5237%	0.5360%	0.4611%	0.1889%	L^{AS}_{b,vb_5}	6.22
Both	$L^{AS}_{s,Size_1} + L^{AS}_{b,Size_1}$	1.7123%	1.5617%	1.5378%	1.5183%	1.6826%	1.7062%	1.5408%	1.5535%	1.4686%	1.3610%	1.2458%	1.0779%	$L^{AS}_{s,vs_1} + L^{AS}_{b,vb_1}$	-0.06
	$L^{AS}_{s,Size_2} + L^{AS}_{b,Size_2}$	1.1904%	1.0812%	1.0820%	1.0726%	1.1955%	1.2219%	1.1477%	1.1813%	1.1374%	1.0307%	0.8973%	0.7020%	$L^{AS}_{s,vs_2} + L^{AS}_{b,vb_2}$	0.29
	$L^{AS}_{s,Size_3} + L^{AS}_{b,Size_3}$	0.9263%	0.8913%	0.8964%	0.9112%	1.0045%	1.0754%	0.9996%	1.0445%	1.0582%	0.9396%	0.8485%	0.5977%	$L^{AS}_{s,vs_3} + L^{AS}_{b,vb_3}$	1.96
	$L^{AS}_{s,Size_4} + L^{AS}_{b,Size_4}$	0.8130%	0.8901%	0.9256%	0.8816%	0.9919%	0.9626%	0.9529%	0.9995%	1.0194%	0.9482%	0.8135%	0.5322%	$L^{AS}_{s,vs_4} + L^{AS}_{b,vb_4}$	5.94
	$L^{AS}_{s,Size_5} + L^{AS}_{b,Size_5}$	0.7304%	0.7890%	0.7933%	0.8226%	0.9329%	0.9606%	0.9998%	1.0165%	1.0139%	0.9613%	0.8940%	0.5958%	$L^{AS}_{s,vs_5} + L^{AS}_{b,vb_5}$	12.44

Table 19 (Contiuned)

Results for the regression of percentage spreads against ω_2 and ω_3 multiplied by the firm size and time interval

We conduct the following regressions to determine the combining effects of the probability of informed trading and the asset volatility on the percentage spread using the proxy variable of time interval quintiles as the probability of informed trading and firm size quintiles as the asset volatility: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_2 Size_i Time_j (L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}) + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_3 Size_i Time_j (L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}) + \varepsilon$. ε = the error term, which is assumed to be normally distributed. Besides, we also examine the quoted spreads of the simulation data by panel regression using the dummy quintiles of the asset volatility recognized by sellers and buyers (as vs and vb, respectively) and the probability of informed trading. The equation is: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_2 vs_i p_j (L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}) + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_3 vb_i p_j (L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}) + \varepsilon$. The regression coefficients are reported t-statistics to test whether the mean coefficient is different from zero. The last low presents the value of F-test of the regressions.

Year/Month	2003/Apr		2003/May		2003/Jun		2003/Jul		2003/Aug		2003/Sep		2003/Oct		2003/Nov		2003/Dec		2004/Jan		2004/Feb		2004/Mar		Simulation Data		
Inde. Variables	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Inde. Variables	Coeffifients	t-statistic
$\omega_3 Size_1 Time_1$	0.01102	98.17	0.00424	74.91	0.00439	83.60	0.00381	114.96	0.00471	130.81	0.00553	152.98	0.00391	121.12	0.00428	131.21	0.00405	132.09	0.00306	94.37	0.00215	69.64	-0.00392	-129.80	$\omega_3 vb_1 p_1$	-44.81	-249
$\omega_3 Size_1 Time_2$	0.00761	59.28	0.00248	40.06	0.00280	49.14	0.00217	60.67	0.00303	74.20	0.00339	85.29	0.00289	83.39	0.00319	89.51	0.00295	87.54	0.00225	65.21	0.00105	31.87	-0.00433	-128.62	$\omega_3 vb_1 p_2$	-44.60	-236
$\omega_3 Size_1 Time_3$	0.00698	50.39	0.00199	30.67	0.00247	41.55	0.00184	49.49	0.00282	67.50	0.00345	81.05	0.00273	75.34	0.00280	75.18	0.00286	80.89	0.00227	63.63	0.00066	19.65	-0.00462	-130.42	$\omega_3 vb_1 p_3$	-44.47	-226
$\omega_3 Size_1 Time_4$	0.00693	49.74	0.00202	30.53	0.00244	39.95	0.00197	51.84	0.00266	62.57	0.00320	73.20	0.00264	69.12	0.00282	73.19	0.00287	77.83	0.00225	60.42	0.00059	17.63	-0.00422	-113.47	$\omega_3 vb_1 p_4$	-44.41	-219
$\omega_3 Size_1 Time_5$	0.00779	60.50	0.00238	35.98	0.00262	42.88	0.00235	59.34	0.00300	70.00	0.00354	82.60	0.00286	75.77	0.00312	80.55	0.00331	90.63	0.00247	65.12	0.00076	21.79	-0.00381	-101.13	$\omega_3 vb_1 p_5$	-44.39	-214
$\omega_3 Size_2 Time_1$	0.00423	50.06	0.00070	13.19	0.00100	20.21	0.00036	11.58	0.00146	44.26	0.00166	48.67	0.00131	41.24	0.00146	45.90	0.00165	58.63	0.00079	23.21	-0.00028	-7.95	-0.00686	-231.18	$\omega_3 vb_2 p_1$	-44.76	-249
$\omega_3 Size_2 Time_2$	0.00310	34.11	-0.00026	-4.78	0.00022	4.31	-0.00026	-8.21	0.00067	19.21	0.00085	23.14	0.00075	22.91	0.00110	32.83	0.00125	41.17	0.00033	9.20	-0.00071	-18.76	-0.00650	-197.12	$\omega_3 vb_2 p_2$	-44.48	-236
$\omega_3 Size_2 Time_3$	0.00309	33.19	-0.00040	-7.31	0.00007	1.42	-0.00035	-11.11	0.00058	16.55	0.00081	21.12	0.00068	20.24	0.00102	29.67	0.00123	39.00	0.00036	9.82	-0.00094	-25.13	-0.00633	-178.20	$\omega_3 vb_2 p_3$	-44.28	-226
$\omega_3 Size_2 Time_4$	0.00300	32.27	-0.00040	-7.12	0.00000	0.04	-0.00035	-11.24	0.00051	14.33	0.00081	20.64	0.00068	19.29	0.00094	26.50	0.00111	34.69	0.00043	11.34	-0.00109	-29.30	-0.00601	-162.35	$\omega_3 vb_2 p_4$	-44.15	-219
$\omega_3 Size_2 Time_5$	0.00336	37.57	-0.00009	-1.47	0.00033	6.18	-0.00018	-5.24	0.00072	19.31	0.00084	21.20	0.00075	20.78	0.00101	27.64	0.00113	34.14	0.00054	13.63	-0.00096	-23.80	-0.00603	-157.04	$\omega_3 vb_2 p_5$	-44.05	-214
$\omega_3 Size_3 Time_1$	0.00120	12.35	-0.00072	-12.11	-0.00026	-4.74	-0.00050	-13.78	0.00062	16.09	0.00073	19.12	0.00012	3.45	0.00064	18.24	0.00105	33.25	0.00013	3.64	-0.00115	-34.89	-0.00699	-220.87	$\omega_3 vb_3 p_1$	-44.47	-250
$\omega_3 Size_3 Time_2$	0.00052	5.19	-0.00120	-19.98	-0.00073	-13.00	-0.00096	-26.65	-0.00005	-1.38	0.00025	6.42	-0.00032	-9.19	0.00036	10.18	0.00081	24.42	-0.00007	-1.95	-0.00143	-42.23	-0.00682	-206.45	$\omega_3 vb_3 p_2$	-43.85	-236
$\omega_3 Size_3 Time_3$	0.00033	3.26	-0.00121	-20.43	-0.00072	-13.16	-0.00124	-35.06	-0.00030	-7.74	0.00028	7.15	-0.00035	-9.95	0.00034	9.56	0.00080	23.59	-0.00007	-2.06	-0.00142	-42.23	-0.00654	-189.60	$\omega_3 vb_3 p_3$	-43.36	-227
$\omega_3 Size_3 Time_4$	0.00052	5.13	-0.00126	-20.80	-0.00082	-14.62	-0.00112	-31.65	-0.00039	-9.81	0.00003	0.72	-0.00036	-9.85	0.00029	7.98	0.00072	20.97	-0.00023	-6.39	-0.00144	-43.30	-0.00633	-176.39	$\omega_3 vb_3 p_4$	-42.92	-220
$\omega_3 Size_3 Time_5$	0.00063	6.15	-0.00117	-18.12	-0.00077	-12.84	-0.00091	-22.74	-0.00018	-4.29	0.00010	2.26	-0.00031	-8.00	0.00046	11.87	0.00064	16.75	-0.00015	-3.93	-0.00138	-37.48	-0.00656	-170.88	$\omega_3 vb_3 p_5$	-42.50	-215
$\omega_3 Size_4 Time_1$	-0.00059	-5.59	-0.00092	-13.81	-0.00025	-3.88	-0.00065	-16.74	0.00043	10.39	0.00012	3.04	-0.00030	-8.19	0.00055	14.74	0.00084	25.64	0.00015	3.87	-0.00156	-41.13	-0.00773	-222.97	$\omega_3 vb_4 p_1$	-43.72	-250
$\omega_3 Size_4 Time_2$	-0.00059	-5.77	-0.00133	-20.57	-0.00063	-10.19	-0.00088	-22.83	-0.00033	-7.99	-0.00026	-6.24	-0.00043	-11.67	0.00030	7.90	0.00047	13.93	-0.00007	-1.75	-0.00181	-46.36	-0.00740	-207.52	$\omega_2 vs_4 p_2$	-42.40	-236
$\omega_3 Size_4 Time_3$	-0.00071	-6.94	-0.00132	-20.82	-0.00059	-9.91	-0.00097	-26.37	-0.00020	-4.85	-0.00059	-13.96	-0.00037	-10.19	0.00030	7.94	0.00057	16.69	0.00031	8.23	-0.00179	-46.72	-0.00692	-185.63	$\omega_3 vb_4 p_3$	-41.25	-226
$\omega_3 Size_4 Time_4$	-0.00080	-8.01	-0.00135	-21.03	-0.00065	-10.76	-0.00086	-23.25	-0.00036	-9.00	-0.00056	-13.39	-0.00043	-11.56	0.00008	2.13	0.00051	14.89	-0.00002	-0.49	-0.00172	-45.68	-0.00679	-175.13	$\omega_3 vb_4 p_4$	-40.14	-217
$\omega_3 Size_4 Time_5$	-0.00062	-5.87	-0.00130	-18.15	-0.00055	-8.24	-0.00080	-18.60	-0.00036	-7.81	-0.00039	-8.52	-0.00045	-10.96	0.00024	5.55	0.00052	13.80	-0.00006	-1.31	-0.00177	-40.32	-0.00697	-166.57	$\omega_3 vb_4 p_5$	-39.03	-211
$\omega_3 Size_5 Time_1$	-0.00150	-10.80	-0.00134	-17.93	-0.00078	-11.20	-0.00098	-20.26	0.00004	0.82	-0.00018	-3.36	0.00027	5.79	0.00027	6.05	0.00075	20.92	0.00043	9.84	-0.00136	-33.29	-0.00751	-186.61	$\omega_3 vb_5 p_1$	-42.43	-250
$\omega_3 Size_5 Time_2$	-0.00135	-10.88	-0.00158	-20.92	-0.00110	-15.47	-0.00123	-24.52	-0.00034	-6.32	-0.00059	-11.08	-0.00027	-5.77	-0.00011	-2.39	0.00069	18.43	0.00061	13.52	-0.00143	-32.29	-0.00756	-184.01	$\omega_3 vb_5 p_2$	-39.94	-232
$\omega_3 Size_5 Time_3$	-0.00137	-11.14	-0.00149	-20.12	-0.00091	-13.07	-0.00105	-22.56	-0.00007	-1.28	-0.00029	-5.44	-0.00001	-0.31	0.00019	4.46	0.00088	23.22	0.00040	8.80	-0.00141	-31.71	-0.00734	-171.18	$\omega_3 vb_5 p_3$	-37.71	-217
$\omega_3 Size_5 Time_4$	-0.00143	-11.80	-0.00164	-21.44	-0.00113	-15.80	-0.00103	-22.32	-0.00024	-4.57	-0.00050	-9.26	-0.00013	-2.70	0.00002	0.53	0.00083	22.21	0.00010	2.13	-0.00115	-26.26	-0.00716	-164.41	$\omega_3 vb_5 p_4$	-35.80	-207
$\omega_3 Size_5 Time_5$	-0.00139	-10.59	-0.00165	-18.67	-0.00119	-14.33	-0.00038	-6.87	0.00018	2.90	-0.00026	-4.06	-0.00007	-1.27	-0.00032	-6.23	0.00060	13.51	0.00042	7.49	-0.00142	-28.07	-0.00720	-149.34	$\omega_3 vb_5 p_5$	-33.90	-196
F-statistic	2051.27		1834.09		2004.94		4535.25		4219.40		4447.39		3499.04		3133.24		2437.24		2178.14		2651.87		4331.22		**F-statistic**	2267.89	

Table 19

Results for the regression of percentage spreads against ω_2 and ω_3 multiplied by the firm size and time interval

We conduct the following regressions to determine the combining effects of the probability of informed trading and the asset volatility on the percentage spread using the proxy variable of time interval quintiles as the probability of informed trading and firm size quintiles as the asset volatility: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_2 Size_i Time_j (L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}) + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_3 Size_i Time_j (L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}) + \varepsilon$. ε = the error term, which is assumed to be normally distributed. Besides, we also examine the quoted spreads of the simulation data by panel regression using the dummy quintiles of the asset volatility recognized by sellers and buyers (as vs and vb, respectively) and the probability of informed trading. The equation is: $\pi = \overline{V}_{b-s} + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_2 vs_i p_j (L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}) + \sum_{i=1}^{5}\sum_{j=1}^{5} \omega_3 vb_i p_j (L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}) + \varepsilon$. The regression coefficients are reported t-statistics to test whether the mean coefficient is different from zero.

Year/Month	2003/Apr		2003/May		2003/Jun		2003/Jul		2003/Aug		2003/Sep		2003/Oct		2003/Nov		2003/Dec		2004/Jan		2004/Feb		2004/Mar		Simulation Data		
Inde. Variables	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Coeffifients	t-statistic	Inde. Variables	Coeffifients	t-statistic
V_{b-s}	0.00510	336.72	0.00600	223.91	0.00566	227.11	0.00590	375.25	0.00517	291.80	0.00511	278.69	0.00522	322.51	0.00483	294.92	0.00448	297.04	0.00498	300.62	0.00599	385.93	0.00932	596.38	$\overline{V}_{b-s}$	44.27	441
$\omega_2 Size_1 Time_1$	0.00376	56.80	0.00245	45.17	0.00243	48.37	0.00224	70.66	0.00461	132.61	0.00458	133.50	0.00324	105.51	0.00355	113.35	0.00362	123.01	0.00226	71.45	0.00005	1.69	-0.00163	-51.67	$\omega_2 vs_1 p_1$	-44.81	-249
$\omega_2 Size_1 Time_2$	0.00194	25.72	0.00058	10.09	0.00072	13.56	0.00063	18.93	0.00298	78.69	0.00256	68.61	0.00161	49.72	0.00239	71.32	0.00224	69.60	0.00113	33.62	-0.00054	-17.79	-0.00390	-121.55	$\omega_2 vs_1 p_2$	-44.60	-236
$\omega_2 Size_1 Time_3$	0.00105	12.78	0.00029	4.78	0.00033	5.97	0.00031	9.12	0.00252	63.17	0.00208	54.23	0.00131	38.68	0.00208	59.09	0.00196	59.64	0.00070	20.65	-0.00094	-30.65	-0.00412	-121.22	$\omega_2 vs_1 p_3$	-44.48	-226
$\omega_2 Size_1 Time_4$	0.00113	13.65	0.00001	0.21	0.00028	4.93	0.00036	10.15	0.00237	60.16	0.00204	51.82	0.00140	41.03	0.00200	55.77	0.00188	56.64	0.00066	19.67	-0.00093	-30.71	-0.00445	-130.27	$\omega_2 vs_1 p_4$	-44.41	-219
$\omega_2 Size_1 Time_5$	0.00086	10.86	0.00043	7.18	0.00077	13.95	0.00045	12.79	0.00242	62.24	0.00205	53.47	0.00143	42.70	0.00217	62.54	0.00197	60.84	0.00076	22.69	-0.00097	-31.90	-0.00452	-134.18	$\omega_2 vs_1 p_5$	-44.38	-214
$\omega_2 Size_2 Time_1$	0.00158	29.61	-0.00030	-5.68	-0.00021	-4.33	-0.00024	-7.96	0.00145	44.85	0.00164	49.25	0.00072	23.61	0.00142	45.90	0.00166	59.23	0.00026	7.94	-0.00187	-56.55	-0.00372	-106.52	$\omega_2 vs_2 p_1$	-44.76	-249
$\omega_2 Size_2 Time_2$	0.00048	8.52	-0.00109	-21.01	-0.00078	-16.19	-0.00095	-32.08	0.00076	23.32	0.00078	22.36	0.00025	7.85	0.00108	34.19	0.00092	31.39	-0.00015	-4.40	-0.00227	-65.83	-0.00518	-152.44	$\omega_2 vs_2 p_2$	-44.47	-236
$\omega_2 Size_2 Time_3$	0.00029	5.24	-0.00136	-26.05	-0.00105	-21.74	-0.00105	-35.59	0.00053	15.75	0.00071	20.16	-0.00005	-1.51	0.00088	26.86	0.00090	30.65	-0.00028	-7.92	-0.00226	-66.92	-0.00548	-154.61	$\omega_2 vs_2 p_3$	-44.28	-226
$\omega_2 Size_2 Time_4$	0.00037	6.55	-0.00143	-27.59	-0.00110	-22.95	-0.00106	-35.92	0.00056	17.10	0.00066	18.59	-0.00007	-2.15	0.00075	23.09	0.00092	31.30	-0.00031	-9.12	-0.00229	-68.31	-0.00561	-158.80	$\omega_2 vs_2 p_4$	-44.15	-219
$\omega_2 Size_2 Time_5$	0.00028	4.86	-0.00138	-26.18	-0.00100	-20.51	-0.00114	-37.03	0.00062	18.53	0.00082	23.20	0.00000	-0.08	0.00091	27.84	0.00101	34.86	-0.00029	-8.52	-0.00237	-69.91	-0.00576	-162.25	$\omega_2 vs_2 p_5$	-44.05	-214
$\omega_2 Size_3 Time_1$	0.00118	17.55	-0.00129	-22.46	-0.00117	-21.75	-0.00116	-32.52	0.00017	4.55	0.00064	17.01	0.00020	5.99	0.00066	19.52	0.00107	34.16	0.00002	0.56	-0.00167	-52.35	-0.00493	-142.23	$\omega_2 vs_3 p_1$	-44.47	-250
$\omega_2 Size_3 Time_2$	0.00024	3.64	-0.00187	-32.88	-0.00163	-30.86	-0.00173	-50.09	-0.00022	-5.90	0.00017	4.63	-0.00015	-4.33	0.00045	13.51	0.00066	20.26	-0.00051	-14.82	-0.00200	-62.14	-0.00582	-174.08	$\omega_2 vs_3 p_2$	-43.85	-236
$\omega_2 Size_3 Time_3$	0.00002	0.32	-0.00217	-38.20	-0.00189	-35.98	-0.00175	-52.26	-0.00040	-10.74	-0.00001	-0.31	-0.00031	-9.34	0.00024	7.09	0.00069	21.85	-0.00076	-22.67	-0.00211	-67.24	-0.00621	-181.27	$\omega_2 vs_3 p_3$	-43.36	-227
$\omega_2 Size_3 Time_4$	-0.00012	-1.77	-0.00220	-39.93	-0.00185	-36.20	-0.00187	-56.30	-0.00037	-10.06	0.00024	6.24	-0.00034	-10.39	0.00022	6.63	0.00074	23.54	-0.00059	-18.17	-0.00228	-74.55	-0.00621	-184.46	$\omega_2 vs_3 p_4$	-42.92	-220
$\omega_2 Size_3 Time_5$	-0.00016	-2.25	-0.00212	-36.99	-0.00174	-32.69	-0.00191	-52.67	-0.00034	-8.88	0.00016	4.13	-0.00043	-12.38	0.00024	7.07	0.00085	26.38	-0.00057	-16.56	-0.00243	-76.56	-0.00627	-179.65	$\omega_2 vs_3 p_5$	-42.50	-215
$\omega_2 Size_4 Time_1$	0.00110	13.62	-0.00148	-21.67	-0.00119	-18.70	-0.00168	-43.60	-0.00002	-0.38	0.00002	0.49	-0.00007	-1.81	0.00015	4.17	0.00078	24.64	-0.00020	-5.15	-0.00186	-50.09	-0.00519	-131.10	$\omega_2 vs_4 p_1$	-43.72	-250
$\omega_2 Size_4 Time_2$	0.00040	5.38	-0.00156	-24.57	-0.00124	-21.01	-0.00200	-54.84	-0.00006	-1.57	-0.00039	-9.87	-0.00051	-14.56	0.00022	6.23	0.00071	21.96	-0.00037	-9.85	-0.00193	-51.12	-0.00569	-153.60	$\omega_2 vs_4 p_2$	-42.40	-235
$\omega_2 Size_4 Time_3$	0.00013	1.83	-0.00185	-30.55	-0.00152	-27.12	-0.00211	-60.81	-0.00049	-12.68	-0.00029	-7.51	-0.00064	-18.45	-0.00003	-0.87	0.00057	17.91	-0.00086	-23.23	-0.00206	-57.13	-0.00624	-165.21	$\omega_2 vs_4 p_3$	-41.25	-226
$\omega_2 Size_4 Time_4$	0.00012	1.73	-0.00197	-33.07	-0.00162	-29.52	-0.00223	-64.70	-0.00030	-7.91	-0.00027	-7.12	-0.00065	-19.22	0.00000	-0.10	0.00057	17.92	-0.00058	-16.54	-0.00222	-62.70	-0.00642	-172.28	$\omega_2 vs_4 p_4$	-40.14	-217
$\omega_2 Size_4 Time_5$	0.00012	1.47	-0.00206	-31.68	-0.00177	-29.83	-0.00235	-61.69	-0.00033	-7.79	-0.00035	-8.41	-0.00064	-17.42	-0.00010	-2.59	0.00063	19.06	-0.00062	-16.05	-0.00225	-57.76	-0.00649	-163.93	$\omega_2 vs_4 p_5$	-39.03	-211
$\omega_2 Size_5 Time_1$	0.00078	6.64	-0.00234	-30.25	-0.00217	-29.93	-0.00215	-43.91	-0.00047	-8.99	0.00002	0.32	-0.00045	-9.82	0.00041	9.37	0.00056	15.22	-0.00051	-11.41	-0.00136	-33.89	-0.00478	-108.59	$\omega_2 vs_5 p_1$	-42.43	-250
$\omega_2 Size_5 Time_2$	0.00022	2.17	-0.00235	-31.40	-0.00209	-29.45	-0.00219	-46.26	-0.00054	-10.63	0.00002	0.32	-0.00010	-2.20	0.00078	18.45	0.00049	13.20	-0.00086	-19.02	-0.00150	-34.75	-0.00477	-111.06	$\omega_2 vs_5 p_2$	-39.94	-232
$\omega_2 Size_5 Time_3$	0.00016	1.58	-0.00258	-34.98	-0.00244	-35.15	-0.00248	-57.13	-0.00110	-22.40	-0.00042	-8.35	-0.00048	-10.70	0.00035	8.27	0.00031	8.55	-0.00081	-18.25	-0.00162	-38.61	-0.00528	-117.68	$\omega_2 vs_5 p_3$	-37.71	-217
$\omega_2 Size_5 Time_4$	0.00012	1.22	-0.00255	-35.39	-0.00237	-35.42	-0.00260	-61.48	-0.00097	-20.06	-0.00023	-4.50	-0.00040	-9.15	0.00037	9.12	0.00031	8.81	-0.00053	-12.29	-0.00193	-46.81	-0.00553	-124.35	$\omega_2 vs_5 p_4$	-35.80	-207
$\omega_2 Size_5 Time_5$	0.00016	1.43	-0.00263	-31.91	-0.00240	-31.79	-0.00332	-67.30	-0.00134	-23.39	-0.00050	-8.15	-0.00048	-9.15	0.00063	13.11	0.00053	13.21	-0.00088	-17.29	-0.00173	-37.91	-0.00559	-115.80	$\omega_2 vs_5 p_5$	-33.90	-196

Table 20 (Continued)

Estimation of the three factors of percentage spread by regression with the time interval quintiles under different firm size quintiles

According the results of Table 19, we calculate the values of three factors as: (i) the different valuation of traders, (ii) the expected loss of adverse selection of sellers, and (iii) the expected loss of adverse selection of buyers. The different valuation of traders is original from the intercept term of the regression. The expected loss of adverse selection is obtained from the below method. The coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) represents $L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then $L^{AS}_{s,Size_i,Time_j}$ ($L^{AS}_{b,Size_i,Time_j}$ is obtained by the coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) plus the intercept term. Likewise, The coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) represents $L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then L^{AS}_{s,vs_i,p_j} (L^{AS}_{b,vs_i,p_j}) is obtained by the coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) plus the intercept term.

The Factors of Bid-Ask Spread		2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data	
	$L^{AS}_{b,Size_1,Time_1}$	1.6127%	1.0238%	1.0050%	0.9711%	0.9880%	1.0643%	0.9131%	0.9116%	0.8533%	0.8044%	0.8137%	0.5394%	L^{AS}_{b,vb_1,p_1}	-0.54
	$L^{AS}_{b,Size_1,Time_5}$	1.2712%	0.8483%	0.8461%	0.8064%	0.8196%	0.8503%	0.8113%	0.8019%	0.7429%	0.7230%	0.7044%	0.4990%	L^{AS}_{b,vb_1,p_2}	-0.33
	$L^{AS}_{b,Size_2,Time_1}$	1.2087%	0.7988%	0.8134%	0.7734%	0.7991%	0.8558%	0.7950%	0.7633%	0.7341%	0.7253%	0.6651%	0.4699%	L^{AS}_{b,vb_1,p_3}	-0.20
	$L^{AS}_{b,Size_2,Time_2}$	1.2038%	0.8027%	0.8098%	0.7869%	0.7832%	0.8314%	0.7861%	0.7648%	0.7350%	0.7231%	0.6582%	0.5103%	L^{AS}_{b,vb_1,p_4}	-0.14
	$L^{AS}_{b,Size_1,Time_5}$	1.2893%	0.8385%	0.8282%	0.8244%	0.8166%	0.8646%	0.8080%	0.7951%	0.7794%	0.7457%	0.6751%	0.5510%	L^{AS}_{b,vb_1,p_5}	-0.12
	$L^{AS}_{b,Size_2,Time_1}$	0.9339%	0.6701%	0.6666%	0.6253%	0.6626%	0.6767%	0.6528%	0.6290%	0.6129%	0.5777%	0.5712%	0.2458%	L^{AS}_{b,vb_2,p_1}	-0.48
	$L^{AS}_{b,Size_2,Time_2}$	0.8201%	0.5740%	0.5882%	0.5639%	0.5835%	0.5957%	0.5970%	0.5936%	0.5734%	0.5313%	0.5284%	0.2816%	L^{AS}_{b,vb_2,p_2}	-0.21
	$L^{AS}_{b,Size_2,Time_3}$	0.8193%	0.5599%	0.5736%	0.5548%	0.5750%	0.5918%	0.5898%	0.5855%	0.5709%	0.5342%	0.5051%	0.2988%	L^{AS}_{b,vb_2,p_3}	-0.01
	$L^{AS}_{b,Size_2,Time_4}$	0.8100%	0.5599%	0.5665%	0.5542%	0.5681%	0.5918%	0.5899%	0.5770%	0.5588%	0.5415%	0.4901%	0.3311%	L^{AS}_{b,vb_2,p_4}	0.12
	$L^{AS}_{b,Size_2,Time_5}$	0.8469%	0.5917%	0.5998%	0.5717%	0.5891%	0.5949%	0.5971%	0.5837%	0.5616%	0.5525%	0.5031%	0.3292%	L^{AS}_{b,vb_2,p_5}	0.22
	$L^{AS}_{b,Size_3,Time_1}$	0.6309%	0.5280%	0.5399%	0.5401%	0.5791%	0.5841%	0.5339%	0.5474%	0.5530%	0.5111%	0.4841%	0.2331%	L^{AS}_{b,vb_3,p_1}	-0.20
	$L^{AS}_{b,Size_3,Time_2}$	0.5621%	0.4804%	0.4936%	0.4933%	0.5116%	0.5359%	0.4903%	0.5192%	0.5295%	0.4916%	0.4565%	0.2496%	L^{AS}_{b,vb_3,p_2}	0.43
Buyer	$L^{AS}_{b,Size_3,Time_3}$	0.5433%	0.4792%	0.4939%	0.4658%	0.4867%	0.5393%	0.4873%	0.5170%	0.5286%	0.4911%	0.4572%	0.2778%	L^{AS}_{b,vb_3,p_3}	0.91
	$L^{AS}_{b,Size_3,Time_4}$	0.5622%	0.4745%	0.4841%	0.4775%	0.4782%	0.5140%	0.4864%	0.5117%	0.5205%	0.4749%	0.4556%	0.2989%	L^{AS}_{b,vb_3,p_4}	1.35
	$L^{AS}_{b,Size_3,Time_5}$	0.5731%	0.4828%	0.4889%	0.4984%	0.4985%	0.5207%	0.4914%	0.5296%	0.5116%	0.4829%	0.4609%	0.2759%	L^{AS}_{b,vb_3,p_5}	1.77
	$L^{AS}_{b,Size_4,Time_1}$	0.4511%	0.5078%	0.5416%	0.5243%	0.5599%	0.5234%	0.4918%	0.5382%	0.5317%	0.5133%	0.4427%	0.1587%	L^{AS}_{b,vb_4,p_1}	0.56
	$L^{AS}_{b,Size_4,Time_2}$	0.4512%	0.4671%	0.5038%	0.5019%	0.4842%	0.4854%	0.4794%	0.5131%	0.4954%	0.4917%	0.4180%	0.1920%	L^{AS}_{b,vb_4,p_2}	1.87
	$L^{AS}_{b,Size_4,Time_3}$	0.4398%	0.4682%	0.5078%	0.4931%	0.4974%	0.4520%	0.4851%	0.5131%	0.5053%	0.5297%	0.4204%	0.2398%	L^{AS}_{b,vb_4,p_3}	3.03
	$L^{AS}_{b,Size_4,Time_4}$	0.4304%	0.4651%	0.5015%	0.5041%	0.4805%	0.4551%	0.4788%	0.4912%	0.4992%	0.4964%	0.4267%	0.2524%	L^{AS}_{b,vb_4,p_4}	4.13
	$L^{AS}_{b,Size_4,Time_5}$	0.4484%	0.4707%	0.5109%	0.5097%	0.4806%	0.4722%	0.4768%	0.5067%	0.5004%	0.4926%	0.4224%	0.2344%	L^{AS}_{b,vb_4,p_5}	5.24
	$L^{AS}_{b,Size_5,Time_1}$	0.3604%	0.4663%	0.4881%	0.4917%	0.5213%	0.4935%	0.5486%	0.5097%	0.5233%	0.5418%	0.4627%	0.1808%	L^{AS}_{b,vb_5,p_1}	1.84
	$L^{AS}_{b,Size_5,Time_2}$	0.3751%	0.4425%	0.4560%	0.4671%	0.4832%	0.4520%	0.4954%	0.4725%	0.5172%	0.5595%	0.4564%	0.1757%	L^{AS}_{b,vb_5,p_2}	4.33
	$L^{AS}_{b,Size_5,Time_3}$	0.3731%	0.4509%	0.4756%	0.4845%	0.5104%	0.4819%	0.5207%	0.5024%	0.5361%	0.5380%	0.4584%	0.1974%	L^{AS}_{b,vb_5,p_3}	6.57
	$L^{AS}_{b,Size_5,Time_4}$	0.3678%	0.4364%	0.4532%	0.4871%	0.4932%	0.4611%	0.5095%	0.4854%	0.5315%	0.5083%	0.4842%	0.2161%	L^{AS}_{b,vb_5,p_4}	8.48
	$L^{AS}_{b,Size_5,Time_5}$	0.3713%	0.4353%	0.4475%	0.5520%	0.5348%	0.4848%	0.5150%	0.4507%	0.5080%	0.5401%	0.4573%	0.2117%	L^{AS}_{b,vb_5,p_5}	10.38

Table 20

Estimation of the three factors of percentage spread by regression with the time interval quintiles under different firm size quintiles

According the results of Table 19, we calculate the values of three factors as: (i) the different valuation of traders, (ii) the expected loss of adverse selection of sellers, and (iii) the expected loss of adverse selection of buyers. The different valuation of traders is original from the intercept term of the regression. The expected loss of adverse selection is obtained from the below method. The coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) represents $L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then $L^{AS}_{s,Size_i,Time_j}$ ($L^{AS}_{b,Size_i,Time_j}$) is obtained by the coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) plus the intercept term. Likewise, The coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) represents $L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then L^{AS}_{s,vs_i,p_j} (L^{AS}_{b,vs_i,p_j}) is obtained by the coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) plus the intercept term.

The Factors of Bid-Ask Spread	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data	
$\overline{V}_{b-s}$	0.5104%	0.6002%	0.5663%	0.5896%	0.5169%	0.5110%	0.5221%	0.4831%	0.4481%	0.4984%	0.5991%	0.9318%	$\overline{V}_{b-s}$	**44.27**
$L^{AS}_{s,Size_1,Time_1}$	0.8866%	0.8453%	0.8091%	0.8133%	0.9782%	0.9694%	0.8462%	0.8378%	0.8103%	0.7239%	0.6040%	0.7690%	L^{AS}_{s,vs_1,p_1}	-0.54
$L^{AS}_{s,Size_1,Time_2}$	0.7047%	0.6584%	0.6383%	0.6528%	0.8147%	0.7674%	0.6834%	0.7219%	0.6719%	0.6110%	0.5453%	0.5416%	L^{AS}_{s,vs_1,p_2}	-0.33
$L^{AS}_{s,Size_1,Time_3}$	0.6155%	0.6291%	0.5997%	0.6210%	0.7693%	0.7192%	0.6528%	0.6911%	0.6442%	0.5683%	0.5053%	0.5203%	L^{AS}_{s,vs_1,p_3}	-0.20
$L^{AS}_{s,Size_1,Time_4}$	0.6232%	0.6016%	0.5940%	0.6259%	0.7543%	0.7154%	0.6621%	0.6835%	0.6362%	0.5640%	0.5059%	0.4864%	L^{AS}_{s,vs_1,p_4}	-0.14
$L^{AS}_{s,Size_1,Time_5}$	0.5967%	0.6430%	0.6432%	0.6351%	0.7593%	0.7159%	0.6650%	0.6997%	0.6448%	0.5742%	0.5025%	0.4800%	L^{AS}_{s,vs_1,p_5}	-0.11
$L^{AS}_{s,Size_2,Time_1}$	0.6681%	0.5707%	0.5454%	0.5659%	0.6620%	0.6747%	0.5946%	0.6253%	0.6144%	0.5249%	0.4126%	0.5603%	L^{AS}_{s,vs_2,p_1}	-0.48
$L^{AS}_{s,Size_2,Time_2}$	0.5587%	0.4915%	0.4884%	0.4942%	0.5931%	0.5892%	0.5466%	0.5915%	0.5406%	0.4830%	0.3723%	0.4134%	L^{AS}_{s,vs_2,p_2}	-0.20
$L^{AS}_{s,Size_2,Time_3}$	0.5399%	0.4639%	0.4610%	0.4847%	0.5698%	0.5821%	0.5173%	0.5707%	0.5384%	0.4706%	0.3731%	0.3842%	L^{AS}_{s,vs_2,p_3}	-0.01
$L^{AS}_{s,Size_2,Time_4}$	0.5470%	0.4574%	0.4568%	0.4838%	0.5734%	0.5774%	0.5154%	0.5580%	0.5400%	0.4671%	0.3704%	0.3713%	L^{AS}_{s,vs_2,p_4}	0.12
$L^{AS}_{s,Size_2,Time_5}$	0.5380%	0.4620%	0.4664%	0.4758%	0.5790%	0.5931%	0.5218%	0.5743%	0.5490%	0.4689%	0.3619%	0.3561%	L^{AS}_{s,vs_2,p_5}	0.22
$L^{AS}_{s,Size_3,Time_1}$	0.6288%	0.4709%	0.4495%	0.4739%	0.5340%	0.5748%	0.5422%	0.5493%	0.5555%	0.5003%	0.4319%	0.4385%	L^{AS}_{s,vs_3,p_1}	-0.20
$L^{AS}_{s,Size_3,Time_2}$	0.5344%	0.4133%	0.4034%	0.4169%	0.4951%	0.5285%	0.5074%	0.5286%	0.5137%	0.4478%	0.3989%	0.3500%	L^{AS}_{s,vs_3,p_2}	0.43
Seller $L^{AS}_{s,Size_3,Time_3}$	0.5125%	0.3835%	0.3775%	0.4149%	0.4768%	0.5099%	0.4906%	0.5073%	0.5171%	0.4222%	0.3877%	0.3107%	L^{AS}_{s,vs_3,p_3}	0.91
$L^{AS}_{s,Size_3,Time_4}$	0.4988%	0.3799%	0.3817%	0.4028%	0.4801%	0.5345%	0.4882%	0.5050%	0.5219%	0.4393%	0.3710%	0.3109%	L^{AS}_{s,vs_3,p_4}	1.35
$L^{AS}_{s,Size_3,Time_5}$	0.4945%	0.3880%	0.3928%	0.3991%	0.4828%	0.5272%	0.4795%	0.5076%	0.5332%	0.4409%	0.3565%	0.3053%	L^{AS}_{s,vs_3,p_5}	1.77
$L^{AS}_{s,Size_4,Time_1}$	0.6202%	0.4521%	0.4471%	0.4220%	0.5153%	0.5130%	0.5155%	0.4982%	0.5262%	0.4787%	0.4131%	0.4130%	L^{AS}_{s,vs_4,p_1}	0.56
$L^{AS}_{s,Size_4,Time_2}$	0.5503%	0.4441%	0.4420%	0.3898%	0.5108%	0.4720%	0.4709%	0.5052%	0.5189%	0.4610%	0.4059%	0.3628%	L^{AS}_{s,vs_4,p_2}	1.88
$L^{AS}_{s,Size_4,Time_3}$	0.5236%	0.4149%	0.4143%	0.3782%	0.4675%	0.4819%	0.4582%	0.4800%	0.5048%	0.4127%	0.3929%	0.3081%	L^{AS}_{s,vs_4,p_3}	3.03
$L^{AS}_{s,Size_4,Time_4}$	0.5225%	0.4031%	0.4042%	0.3668%	0.4872%	0.4836%	0.4573%	0.4828%	0.5047%	0.4406%	0.3774%	0.2902%	L^{AS}_{s,vs_4,p_4}	4.14
$L^{AS}_{s,Size_4,Time_5}$	0.5220%	0.3941%	0.3894%	0.3544%	0.4844%	0.4758%	0.4577%	0.4733%	0.5110%	0.4360%	0.3739%	0.2830%	L^{AS}_{s,vs_4,p_5}	5.24
$L^{AS}_{s,Size_5,Time_1}$	0.5883%	0.3662%	0.3493%	0.3751%	0.4694%	0.5127%	0.4766%	0.5237%	0.5040%	0.4477%	0.4629%	0.4535%	L^{AS}_{s,vs_5,p_1}	1.84
$L^{AS}_{s,Size_5,Time_2}$	0.5323%	0.3651%	0.3571%	0.3707%	0.4630%	0.5127%	0.5122%	0.5615%	0.4971%	0.4119%	0.4489%	0.4550%	L^{AS}_{s,vs_5,p_2}	4.33
$L^{AS}_{s,Size_5,Time_3}$	0.5261%	0.3422%	0.3223%	0.3419%	0.4074%	0.4686%	0.4744%	0.5181%	0.4792%	0.4177%	0.4373%	0.4039%	L^{AS}_{s,vs_5,p_3}	6.56
$L^{AS}_{s,Size_5,Time_4}$	0.5222%	0.3456%	0.3298%	0.3299%	0.4197%	0.4879%	0.4820%	0.5204%	0.4796%	0.4453%	0.4062%	0.3784%	L^{AS}_{s,vs_5,p_4}	8.48
$L^{AS}_{s,Size_5,Time_5}$	0.5261%	0.3376%	0.3262%	0.2575%	0.3834%	0.4607%	0.4742%	0.5458%	0.5008%	0.4104%	0.4257%	0.3732%	L^{AS}_{s,vs_5,p_5}	10.38

Table 21 (Continued)

Estimation of the three factors of percentage spread by regression with the firm size quintiles under different the time interval quintiles

According the results of Table 19, we calculate the values of three factors as: (i) the different valuation of traders, (ii) the expected loss of adverse selection of sellers, and (iii) the expected loss of adverse selection of buyers. The different valuation of traders is original from the intercept term of the regression. The expected loss of adverse selection is obtained from the below method. The coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) represents $L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then $L^{AS}_{s,Size_i,Time_j}$ ($L^{AS}_{b,Size_i,Time_j}$ is obtained by the coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) plus the intercept term. Likewise, The coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) represents $L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then L^{AS}_{s,vs_i,p_j} (L^{AS}_{b,vs_i,p_j}) is obtained by the coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) plus the intercept term.

The Factors of Bid-Ask Spread	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data	
$L^{AS}_{b,Size_1,Time_1}$	1.6127%	1.0238%	1.0050%	0.9711%	0.9880%	1.0643%	0.9131%	0.9116%	0.8533%	0.8044%	0.8137%	0.5394%	L^{AS}_{b,vb_1,p_1}	-0.54
$L^{AS}_{b,Size_2,Time_1}$	0.9339%	0.6701%	0.6666%	0.6253%	0.6626%	0.6767%	0.6528%	0.6290%	0.6129%	0.5777%	0.5712%	0.2458%	L^{AS}_{b,vb_2,p_1}	-0.48
$L^{AS}_{b,Size_3,Time_1}$	0.6309%	0.5280%	0.5399%	0.5401%	0.5791%	0.5841%	0.5339%	0.5474%	0.5530%	0.5111%	0.4841%	0.2331%	L^{AS}_{b,vb_3,p_1}	-0.20
$L^{AS}_{b,Size_4,Time_1}$	0.4511%	0.5078%	0.5416%	0.5243%	0.5599%	0.5234%	0.4918%	0.5382%	0.5317%	0.5133%	0.4427%	0.1587%	L^{AS}_{b,vb_4,p_1}	0.56
$L^{AS}_{b,Size_5,Time_1}$	0.3604%	0.4663%	0.4881%	0.4917%	0.5213%	0.4935%	0.5486%	0.5097%	0.5233%	0.5418%	0.4627%	0.1808%	L^{AS}_{b,vb_5,p_1}	1.84
$L^{AS}_{b,Size_1,Time_2}$	1.2712%	0.8483%	0.8461%	0.8064%	0.8196%	0.8503%	0.8113%	0.8019%	0.7429%	0.7230%	0.7044%	0.4990%	L^{AS}_{b,vb_1,p_2}	-0.33
$L^{AS}_{b,Size_2,Time_2}$	0.8201%	0.5740%	0.5882%	0.5639%	0.5835%	0.5957%	0.5970%	0.5936%	0.5734%	0.5313%	0.5284%	0.2816%	L^{AS}_{b,vb_2,p_2}	-0.21
$L^{AS}_{b,Size_3,Time_2}$	0.5621%	0.4804%	0.4936%	0.4933%	0.5116%	0.5359%	0.4903%	0.5192%	0.5295%	0.4916%	0.4565%	0.2496%	L^{AS}_{b,vb_3,p_2}	0.43
$L^{AS}_{b,Size_4,Time_2}$	0.4512%	0.4671%	0.5038%	0.5019%	0.4842%	0.4854%	0.4794%	0.5131%	0.4954%	0.4917%	0.4180%	0.1920%	L^{AS}_{b,vb_4,p_2}	1.87
$L^{AS}_{b,Size_5,Time_2}$	0.3751%	0.4425%	0.4560%	0.4671%	0.4832%	0.4520%	0.4954%	0.4725%	0.5172%	0.5595%	0.4564%	0.1757%	L^{AS}_{b,vb_5,p_2}	4.33
$L^{AS}_{b,Size_1,Time_3}$	1.2087%	0.7988%	0.8134%	0.7734%	0.7991%	0.8558%	0.7950%	0.7633%	0.7341%	0.7253%	0.6651%	0.4699%	L^{AS}_{b,vb_1,p_3}	-0.20
$L^{AS}_{b,Size_2,Time_3}$	0.8193%	0.5599%	0.5736%	0.5548%	0.5750%	0.5918%	0.5898%	0.5855%	0.5709%	0.5342%	0.5051%	0.2988%	L^{AS}_{b,vb_2,p_3}	-0.01
Buyer $L^{AS}_{b,Size_3,Time_3}$	0.5433%	0.4792%	0.4939%	0.4658%	0.4867%	0.5393%	0.4873%	0.5170%	0.5286%	0.4911%	0.4572%	0.2778%	L^{AS}_{b,vb_3,p_3}	0.91
$L^{AS}_{b,Size_4,Time_3}$	0.5622%	0.4745%	0.4841%	0.4775%	0.4782%	0.5140%	0.4864%	0.5117%	0.5205%	0.4749%	0.4556%	0.2989%	L^{AS}_{b,vb_4,p_3}	3.03
$L^{AS}_{b,Size_5,Time_3}$	0.5731%	0.4828%	0.4889%	0.4984%	0.4985%	0.5207%	0.4914%	0.5296%	0.5116%	0.4829%	0.4609%	0.2759%	L^{AS}_{b,vb_5,p_3}	6.57
$L^{AS}_{b,Size_1,Time_4}$	1.2038%	0.8027%	0.8098%	0.7869%	0.7832%	0.8314%	0.7861%	0.7648%	0.7350%	0.7231%	0.6582%	0.5103%	L^{AS}_{b,vb_1,p_4}	-0.14
$L^{AS}_{b,Size_2,Time_4}$	0.8100%	0.5599%	0.5665%	0.5542%	0.5681%	0.5918%	0.5899%	0.5770%	0.5588%	0.5415%	0.4901%	0.3311%	L^{AS}_{b,vb_2,p_4}	0.12
$L^{AS}_{b,Size_3,Time_4}$	0.5622%	0.4745%	0.4841%	0.4775%	0.4782%	0.5140%	0.4864%	0.5117%	0.5205%	0.4749%	0.4556%	0.2989%	L^{AS}_{b,vb_3,p_4}	1.35
$L^{AS}_{b,Size_4,Time_4}$	0.4304%	0.4651%	0.5015%	0.5041%	0.4805%	0.4551%	0.4788%	0.4912%	0.4992%	0.4964%	0.4267%	0.2524%	L^{AS}_{b,vb_4,p_4}	4.13
$L^{AS}_{b,Size_5,Time_4}$	0.3678%	0.4364%	0.4532%	0.4871%	0.4932%	0.4611%	0.5095%	0.4854%	0.5315%	0.5083%	0.4842%	0.2161%	L^{AS}_{b,vb_5,p_4}	8.48
$L^{AS}_{b,Size_1,Time_5}$	1.2893%	0.8385%	0.8282%	0.8244%	0.8166%	0.8646%	0.8080%	0.7951%	0.7794%	0.7457%	0.6751%	0.5510%	L^{AS}_{b,vb_1,p_5}	-0.12
$L^{AS}_{b,Size_2,Time_5}$	0.8469%	0.5917%	0.5998%	0.5717%	0.5891%	0.5949%	0.5971%	0.5837%	0.5616%	0.5525%	0.5031%	0.3292%	L^{AS}_{b,vb_2,p_5}	0.22
$L^{AS}_{b,Size_3,Time_5}$	0.5731%	0.4828%	0.4889%	0.4984%	0.4985%	0.5207%	0.4914%	0.5296%	0.5116%	0.4829%	0.4609%	0.2759%	L^{AS}_{b,vb_3,p_5}	1.77
$L^{AS}_{b,Size_4,Time_5}$	0.4484%	0.4707%	0.5109%	0.5097%	0.4806%	0.4722%	0.4768%	0.5067%	0.5004%	0.4926%	0.4224%	0.2344%	L^{AS}_{b,vb_4,p_5}	5.24
$L^{AS}_{b,Size_5,Time_5}$	0.3713%	0.4353%	0.4475%	0.5520%	0.5348%	0.4848%	0.5150%	0.4507%	0.5080%	0.5401%	0.4573%	0.2117%	L^{AS}_{b,vb_5,p_5}	10.38

Table 21

Estimation of the three factors of percentage spread by regression with the firm size quintiles under different the time interval quintiles

According the results of Table 19, we calculate the values of three factors as: (i) the different valuation of traders, (ii) the expected loss of adverse selection of sellers, and (iii) the expected loss of adverse selection of buyers. The different valuation of traders is original from the intercept term of the regression. The expected loss of adverse selection is obtained from the below method. The coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) represents $L^{AS}_{s,Size_i,Time_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,Size_i,Time_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then $L^{AS}_{s,Size_i,Time_j}$ ($L^{AS}_{b,Size_i,Time_j}$ is obtained by the coefficient of $\omega_2 Size_i Time_j$ ($\omega_3 Size_i Time_j$) plus the intercept term. Likewise, The coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) represents $L^{AS}_{s,vs_i,p_j} - \overline{V}_{b-s}$ ($L^{AS}_{b,vb_i,p_j} - \overline{V}_{b-s}$), besides the intercept term as $\overline{V}_{b-s}$, then L^{AS}_{s,vs_i,p_j} (L^{AS}_{b,vs_i,p_j}) is obtained by the coefficient of $\omega_2 vs_i p_j$ ($\omega_3 vb_i p_j$) plus the intercept term.

The Factors of Bid-Ask Spread	2003/Apr	2003/May	2003/Jun	2003/Jul	2003/Aug	2003/Sep	2003/Oct	2003/Nov	2003/Dec	2004/Jan	2004/Feb	2004/Mar	Simulation Data	
V_{b-s}	0.5104%	0.6002%	0.5663%	0.5896%	0.5169%	0.5110%	0.5221%	0.4831%	0.4481%	0.4984%	0.5991%	0.9318%	V_{b-s}	**44.27**
$L^{AS}_{s,Size_1,Time_1}$	0.8866%	0.8453%	0.8091%	0.8133%	0.9782%	0.9694%	0.8462%	0.8378%	0.8103%	0.7239%	0.6040%	0.7690%	L^{AS}_{s,vs_1,p_1}	-0.54
$L^{AS}_{s,Size_2,Time_1}$	0.6681%	0.5707%	0.5454%	0.5659%	0.6620%	0.6747%	0.5946%	0.6253%	0.6144%	0.5249%	0.4126%	0.5603%	L^{AS}_{s,vs_2,p_1}	-0.48
$L^{AS}_{s,Size_3,Time_1}$	0.6288%	0.4709%	0.4495%	0.4739%	0.5340%	0.5748%	0.5422%	0.5493%	0.5555%	0.5003%	0.4319%	0.4385%	L^{AS}_{s,vs_3,p_1}	-0.20
$L^{AS}_{s,Size_4,Time_1}$	0.6202%	0.4521%	0.4471%	0.4220%	0.5153%	0.5130%	0.5155%	0.4982%	0.5262%	0.4787%	0.4131%	0.4130%	L^{AS}_{s,vs_4,p_1}	0.56
$L^{AS}_{s,Size_5,Time_1}$	0.5883%	0.3662%	0.3493%	0.3751%	0.4694%	0.5127%	0.4766%	0.5237%	0.5040%	0.4477%	0.4629%	0.4535%	L^{AS}_{s,vs_5,p_1}	1.84
$L^{AS}_{s,Size_1,Time_2}$	0.7047%	0.6584%	0.6383%	0.6528%	0.8147%	0.7674%	0.6834%	0.7219%	0.6719%	0.6110%	0.5453%	0.5416%	L^{AS}_{s,vs_1,p_2}	-0.33
$L^{AS}_{s,Size_2,Time_2}$	0.5587%	0.4915%	0.4884%	0.4942%	0.5931%	0.5892%	0.5466%	0.5915%	0.5406%	0.4830%	0.3723%	0.4134%	L^{AS}_{s,vs_2,p_2}	-0.20
$L^{AS}_{s,Size_3,Time_2}$	0.5344%	0.4133%	0.4034%	0.4169%	0.4951%	0.5285%	0.5074%	0.5286%	0.5137%	0.4478%	0.3989%	0.3500%	L^{AS}_{s,vs_3,p_2}	0.43
$L^{AS}_{s,Size_4,Time_2}$	0.5503%	0.4441%	0.4420%	0.3898%	0.5108%	0.4720%	0.4709%	0.5052%	0.5189%	0.4610%	0.4059%	0.3628%	L^{AS}_{s,vs_4,p_2}	1.88
$L^{AS}_{s,Size_5,Time_2}$	0.5323%	0.3651%	0.3571%	0.3707%	0.4630%	0.5127%	0.5122%	0.5615%	0.4971%	0.4119%	0.4489%	0.4550%	L^{AS}_{s,vs_5,p_2}	4.33
$L^{AS}_{s,Size_1,Time_3}$	0.6155%	0.6291%	0.5997%	0.6210%	0.7693%	0.7192%	0.6528%	0.6911%	0.6442%	0.5683%	0.5053%	0.5203%	L^{AS}_{s,vs_1,p_3}	-0.20
$L^{AS}_{s,Size_2,Time_3}$	0.5399%	0.4639%	0.4610%	0.4847%	0.5698%	0.5821%	0.5173%	0.5707%	0.5384%	0.4706%	0.3731%	0.3842%	L^{AS}_{s,vs_2,p_3}	-0.01
Seller $L^{AS}_{s,Size_3,Time_3}$	0.5125%	0.3835%	0.3775%	0.4149%	0.4768%	0.5099%	0.4906%	0.5073%	0.5171%	0.4222%	0.3877%	0.3107%	L^{AS}_{s,vs_3,p_3}	0.91
$L^{AS}_{s,Size_4,Time_3}$	0.5236%	0.4149%	0.4143%	0.3782%	0.4675%	0.4819%	0.4582%	0.4800%	0.5048%	0.4127%	0.3929%	0.3081%	L^{AS}_{s,vs_4,p_3}	3.03
$L^{AS}_{s,Size_5,Time_3}$	0.5261%	0.3422%	0.3223%	0.3419%	0.4074%	0.4686%	0.4744%	0.5181%	0.4792%	0.4177%	0.4373%	0.4039%	L^{AS}_{s,vs_5,p_3}	6.56
$L^{AS}_{s,Size_1,Time_4}$	0.6232%	0.6016%	0.5940%	0.6259%	0.7543%	0.7154%	0.6621%	0.6835%	0.6362%	0.5640%	0.5059%	0.4864%	L^{AS}_{s,vs_1,p_4}	-0.14
$L^{AS}_{s,Size_2,Time_4}$	0.5470%	0.4574%	0.4568%	0.4838%	0.5734%	0.5774%	0.5154%	0.5580%	0.5400%	0.4671%	0.3704%	0.3713%	L^{AS}_{s,vs_2,p_4}	0.12
$L^{AS}_{s,Size_3,Time_4}$	0.4988%	0.3799%	0.3817%	0.4028%	0.4801%	0.5345%	0.4882%	0.5050%	0.5219%	0.4393%	0.3710%	0.3109%	L^{AS}_{s,vs_3,p_4}	1.35
$L^{AS}_{s,Size_4,Time_4}$	0.5225%	0.4031%	0.4042%	0.3668%	0.4872%	0.4836%	0.4573%	0.4828%	0.5047%	0.4406%	0.3774%	0.2902%	L^{AS}_{s,vs_4,p_4}	4.14
$L^{AS}_{s,Size_5,Time_4}$	0.5222%	0.3456%	0.3298%	0.3299%	0.4197%	0.4879%	0.4820%	0.5204%	0.4796%	0.4453%	0.4062%	0.3784%	L^{AS}_{s,vs_5,p_4}	8.48
$L^{AS}_{s,Size_1,Time_5}$	0.5967%	0.6430%	0.6432%	0.6351%	0.7593%	0.7159%	0.6650%	0.6997%	0.6448%	0.5742%	0.5025%	0.4800%	L^{AS}_{s,vs_1,p_5}	-0.11
$L^{AS}_{s,Size_2,Time_5}$	0.5380%	0.4620%	0.4664%	0.4758%	0.5790%	0.5931%	0.5218%	0.5743%	0.5490%	0.4689%	0.3619%	0.3561%	L^{AS}_{s,vs_2,p_5}	0.22
$L^{AS}_{s,Size_3,Time_5}$	0.4945%	0.3880%	0.3928%	0.3991%	0.4828%	0.5272%	0.4795%	0.5076%	0.5332%	0.4409%	0.3565%	0.3053%	L^{AS}_{s,vs_3,p_5}	1.77
$L^{AS}_{s,Size_4,Time_5}$	0.5220%	0.3941%	0.3894%	0.3544%	0.4844%	0.4758%	0.4577%	0.4733%	0.5110%	0.4360%	0.3739%	0.2830%	L^{AS}_{s,vs_4,p_5}	5.24
$L^{AS}_{s,Size_5,Time_5}$	0.5261%	0.3376%	0.3262%	0.2575%	0.3834%	0.4607%	0.4742%	0.5458%	0.5008%	0.4104%	0.4257%	0.3732%	L^{AS}_{s,vs_5,p_5}	10.38