The informational role of trade duration: The case of an index options market

Doojin Ryu*

* Corresponding author, Doojin Ryu, School of Economics, College of Business and Economics, Chung-Ang University, Heukseok-ro 84, Dongjak-gu, Seoul 156-756, Republic of Korea. Tel: +82-2-820-5495, Fax: +82-2-813-5487, e-mail: sharpjin@cau.ac.kr

■ Doojin Ryu is a Professor of Financial Economics at Chung-Ang University (School of Economics), Seoul, Republic of Korea.

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The informational role of trade duration: The case of an index options market

Abstract

Under a structural market microstructure model framework, this study examines whether there is a significant information role of inter-transaction time (referred to as trade duration) among options trades. To answer this research question, we extend the MRR model (Madhavan, Richardson, and Roomans, 1997) to incorporate trade duration into the structural model and analyze the high-quality transaction dataset of the KOSPI 200 options market, which is the most liquid and remarkable derivatives market in the world.

We find that the duration between two consecutive options trades conveys meaningful information, and that the implications of trade duration are significantly different across option moneyness. While fast trading indicates informed trading in an out-of-the-money (OTM) options market, also known as a speculative market, the opposite is true in the case of in-the-money (ITM) options trading. This study provides robust results because the same patterns for the information content of the trade duration are observed after we control trade sizes or intraday time periods. We also find that the informational role of trade duration becomes more significant when informed trading is more concentrated, liquidity is relatively lower, many days are left before maturity date, and the market is more volatile.

JEL Classifications: G10, G15

Keywords: Inter-transaction time (trade duration); KOSPI 200 options; Market microstructure; Price impact; Structural model

1. Introduction

In the field of market microstructure research, making inferences about the information content of trades based on their size, direction, and intensity is a steady research interest for both theoretical and empirical studies. While the first classical market microstructure studies suggest purely theoretical backgrounds (Admati and Pfleiderer, 1988; Copeland and Galai, 1983; Easley and O'Hara, 1987; Garman, 1976; Glosten and Milgrom, 1985; Parlour, 1998; Kyle, 1985), later empirical studies directly test the theories and hypotheses suggested in the previous studies. This testing is made possible by the advent of high performance data processing systems and increased accessibility of the intraday transaction-level datasets of major financial markets. However, the findings of empirical studies are inconsistent with one another, and their conclusions vary with regard to structure, maturity, and behavior of markets. Thus, these remain unresolved empirical topics.

The following are examples of such issues. Though the majority of studies claim that trade size matters and that the information content of trades differs significantly depending on size, there are two distinctly opposing views about investor-preferred size of trades and about the relationship between trade informativeness and size. Some studies claim that large trades carry greater information content than small trades (Ahn, Kang, and Ryu, 2010; Easley, Kiefer, and O'Hara, 1997a, 1997b; Easley and O'Hara, 1987; Holthausen, Leftwich, and Mayers, 1987, 1990; Kang and Ryu, 2010; Lin, Sanger, and Booth, 1995), whereas other studies report opposing evidence and claim that informed investors prefer using smaller trades and fragment their trades to camouflage their trading intentions (Alexander and Peterson, 2007; Barclay and Warner, 1993; Chakravarty, 2001; Chou and Wang, 2009; Chung, Chuwonganant, and Jiang, 2008, Huang and Masulis, 2003; Kim and Ryu, 2012; Kyle, 1985; Ryu, 2012*a*). Studies that examine the information content of trade direction (buy or sell) also exhibit two opposing opinions. Many previous studies find that purchase trades generally have greater permanent price impacts than sell trades and conclude that purchase trades are more informative (Ahn, Kang, and Ryu, 2010; Easley, Kiefer, O'Hara, and Paperman, 1996; Neal, 1992; Vijh, 1988, 1990). They attribute this result to market friction such as short-sale constraints, dealers' strategic behaviors, or asymmetric payoff structures of financial assets. In contrast, Ryu (2013) recently finds that sell trades can be more informative than purchase trades in the absence of friction and asymmetry.

While the issues related to the information content of trade size and direction have been continuously addressed since the onset of market microstructure studies, academics have only recently started to focus on the informational role of inter-transaction times between trades. In their seminal empirical paper, Dufour and Engle (2000) incorporate inter-transaction times (i.e., "trade duration") into their vector autoregressive (VAR) framework and find that the price impact of trades becomes greater as the duration between trades becomes shorter. Considering that the size of permanent price impact generally increases with the degree of informed trading, they interpret this result as follows: "Fast trading means informed trading." Many of the following empirical studies adopt the VAR framework of Dufour and Engle (2000) and examine the global stock markets (Chen, Li, and Cai, 2008; Furfine, 2007; Liu and Maheu, 2012; Spierdijk, 2004; Xu, Chen, and Wu, 2006). Their results also support the hypothesis that fast trading indicates informed trading. On the other hand, some recent empirical studies by Peng (2001), Grammig, Theissen, and Wünsche (2011), and Bentran-Lopez, Grammig, and Menkveld (2012) find that the price impact of trades increases with the trade duration. They argue that fast trading is mostly related to noisy trading, not to informed trading.

The inconsistent results of previous studies imply that, as in the case of studying trade size and direction, the trade duration is decided by strategic decisions of informed and liquidity traders and their interactions. In other words, the information content of trade duration can show greater variation depending on variables in the trading environments of financial markets, such as market structure, degree of informed trading, market maturation, and investor behavior. Since investors often make strategic decisions regarding their trades (Lee, Eom, and Park, 2013; Obizhaeva and Wang, 2013), the information content of inter-transaction time and the relationship between trade duration and informed trading are not easily predicted without serious and intensive data analysis. Much room for interpretation on the information content of trade duration is evident even in classical market microstructure studies. For example, the famous "sunshine trading hypothesis" of Admati and Pfleiderer (1988) can be interpreted either way regarding the information content of trade duration. The sunshine trading hypothesis assumes that informed traders prefer trading when markets become relatively liquid. Since a shorter duration between trades indicates greater liquidity, we can expect active participation of informed traders who want to enjoy the ample liquidity as follows: shorter duration (i.e., fast trading) means a higher concentration of informed trading. Meanwhile, the active participation of informed traders can also discourage the participation of liquidity traders and/or uninformed traders. As a result, the liquidity will decrease, and slow trading will prevail in the market. In this situation, we observe a positive relationship between trade duration and informed trading.

In addition to the inconsistency, previous studies that examine the information content of trade duration are not fully satisfactory, and we think that more in-depth research is needed to obtain the clear economic implications of trade duration. In particular, the following reasons motivate us to start this study.

First, the majority of studies that find a negative association between trade duration and informed trading depend on the VAR framework of Dufour and Engle (2000) or extended VAR models (e.g., Chen, Li, and Cai, 2008; Furfine, 2007; Xu, Chen, and Wu, 2006). Their results might be contaminated due to the arbitrary trade-event filtering process incurred in the VAR models. Furthermore, though some recent studies adopt the structural model approach to mitigate the problem of the VAR approach, their results are also inconsistent. For example, Grammig, Theissen, and Wünsche (2011) insist that the previous conclusion (i.e., fast trading means informed trading) is just an artifact of the VAR model and report the opposite result based on their structural model framework. In contrast, employing a structural market microstructure model, Ryu (forthcoming-d) finds that the price impact incurred by informed trading increases as the inter-transaction times become shorter. Considering these results, our suggestion sheds new light on duration-related issues by examining how the informational role of trade duration changes with the characteristics of assets that are traded under a same trading condition. An index options market is a strong candidate for our research topic because the options contracts exhibit different characteristics across option moneyness and maturity, whereas they are traded under the same trading condition and environment (e.g., options orders are transacted by a same trading mechanism in a same exchange and the options contracts of a same type have the same payoff structure). We also use an extended structural market microstructure model that can mitigate the possible shortcomings of the old VAR framework.

Second, while previous studies have focused on equity markets, little is known about emerging derivatives markets. Though the KOSPI 200 options market plays a quite important role and captures the interest of global investors, there remains much to be analyzed about the informational role of options trades, and there is no research about the duration between options trades. Further, there is little market friction in the KOSPI 200 options market. The options market is highly liquid and characterized by extremely small bid-ask spreads and deep market depth. These traits of the KOSPI 200 options market make our results more interesting and reliable.[1]

By employing the extended MRR model (Madhavan, Richardson, and Roomans, 1997) to incorporate the trade duration effect, we obtain the following implications about the informational role of trade duration in the KOSPI 200 options market, the most liquid and famous derivatives market in the world. First, the inter-transaction time between trades has significant information content in the KOSPI 200 options market. Second, the informational role of trade duration is clearly different according to option moneyness and leverage. We find a negative association between trade duration and informed trading for out-of-the-money (OTM) options, whereas a positive association is observed for in-the-money (ITM) options. Third, this pattern remains the same after we control for the effects of trade size and intraday time periods. Fourth, the informational role of trade duration is more important when informed trading is more concentrated, liquidity is relatively lower, maturity dates are many days away, and the market is more volatile.

The rest of this paper is organized as follows. Section 2 discusses the characteristics of the KOSPI 200 options market and explains why it provides the optimal experimental environment to examine the issues raised in this study. We also explain the sample data in this section. Section 3 introduces the extended MRR models and explains their structures. Section 4 presents our empirical findings and discusses their economic implications. The conclusion of this study is provided in Section 5.

2. KOSPI 200 Options Market and Sample Data

2.1 Characteristics of the KOSPI 200 options market

The KOSPI 200 options product is the representative derivatives asset traded in the Korea Exchange (KRX). Currently, the KOSPI 200 options market is the most liquid and well-known index options market in the world. Despite its short history, it has maintained a position as a top-tier derivatives market. Until recently, its trading volume has been ranked first in the world.[2] The outstanding position of the KOSPI 200 options market has also been solidified due to the synergistic effect of combined trading with the KOSPI 200 futures product, one of the most liquid index futures in the

[1] More details about the KOSPI 200 options market are described in Section 2. Additional reasons why we focus on the KOSPI 200 options market are provided in that section.

[2] Refer to the website of the Futures Industry Association (www.futuresindustry.org). The top-tier position and importance of the KOSPI 200 options market are also well-documented in previous studies (Han, Guo, and Ryu, and Webb, 2012; Guo, Han, and Ryu, 2013; Lee and Ryu, 2013; Ryu, 2012*c*; Ryu, Kang, and Suh, forthcoming).

world.[3]

Unlike derivatives markets of developed countries, the KOSPI 200 options market is dominated by individual investors. While domestic and foreign institutional investors are the major market players in established derivatives markets, individual investors' trades comprise a substantial portion of the total trading volume in the KOSPI 200 options market. Table 1 presents the trading activity from January 2003 to June 2005, classified according to investor types which are domestic individuals, domestic institutions, and foreigners. As shown in the table, the transactions of domestic individuals account for more than half of the total trading volume (51%) during the sample period (2003-2005). Though the active participation of the individual investors results in a speculative futures market, it also makes the market more liquid. These effects point to the pros and cons of the options market. On the one hand, most of the individual investors are extremely-short-term investors and day traders, and the trades made by these individuals can largely be characterized as noisy trading. Against the intentions of the government and the KRX, which have promoted index futures and options trading, individuals do not use index derivatives as hedging tools or trading vehicles for long-term portfolio management (Kim and Ryu, 2012; Ryu 2011, 2012*a*, 2012*b*, forthcoming-a, forthcoming-b, forthcoming-c). Their trading tends to make the market more volatile, unstable, and excessively speculative. On the other hand, market participants can enjoy the ample liquidity provided by numerous individual investors, which has enabled the KOSPI 200 options market to occupy the top position as a world-class index options market.

[Table 1 about here]

The KOSPI 200 options market is classified as a purely order-driven market in which there is no designated market maker. All trades are made by the central electronic limit order book (CLOB). The orders submitted by investors are fairly and transparently transacted according to the price and time priority rules. Meanwhile, this trading mechanism guarantees the anonymity of all market participants and market transparency. On a normal trading day, the KOSPI 200 options market opens at 09:00 and closes at 15:15.[4] During the last 10 minutes (from 15:05 to 15:15) and during the hour long pre-opening session (from 08:00 to 09:00), standing orders are transacted under the uniform pricing rule.

[3] Practically, KOSPI 200 futures serve as underlying assets of KOSPI 200 options. Since it is quite costly to construct a stock portfolio consisting of 200 underlying stocks, most professional investors use the futures as hedging and/or speculative tools related to options trading. In addition, academics and market experts believe that many derivatives traders in the Korean market participate simultaneously in both KOSPI 200 futures and options markets. This concurrent participation in both markets strengthens the association between the two markets (Ryu, 2011, 2013, forthcoming-a, forthcoming-b, forthcoming-c).

[4] There are some exceptions. On the maturity dates, the trading session closes 25 minutes earlier than on normal trading days. The trading begins one hour later (at 10:00) on the first trading date of each calendar year and on Korea's scholastic aptitude test (SAT) date.

For other intraday periods (from 09:00 to 15:05), all submitted orders are immediately traded or consolidated into the limit order book.

Four different options contracts with varying maturities can be traded each day. The maturity dates are the second Thursdays of three consecutive near-term months and one month nearest to each quarterly cycle (March, June, September, or December). However, among the four contracts, only the nearest maturity futures contracts are actively traded. The other three longer-term contracts are rarely traded (Ahn, Kang, and Ryu, 2008, 2010; Ryu, 2011, forthcoming-b).[5] The basic quoting unit of the KOSPI 200 options market is the “point.” One point corresponds to 100,000 Korean Won (KRW). We present the sizes of estimated parameters in terms of both the points and the percentages of futures prices.

2.2 Why the KOSPI 200 options market?

The ample liquidity and the unique investor participation rate of the KOSPI 200 index options market present a valuable and interesting opportunity to study the characteristics of options markets. The KOSPI 200 options market provides an ideal setting to investigate the information value of trade duration for the following reasons.

First, as we briefly point out in our introduction, in the index options market, all options contracts classified by strike price are traded under the same market structure and similar trading environments. For example, all investors use the same information source (i.e., market-wide information and news about the Korean economy), and all submitted orders are transacted by the CLOB. In these situations, distinct patterns for the informational role of trade duration by options contracts indicate that the different characteristics are due to option moneyness (i.e., option leverage).

Second, the definition of information in the KOSPI 200 options market is somewhat different from that in equity markets. In the latter markets, informed investors make transaction decisions based on their private information, which they expect to place them in superior positions for relatively long periods. In contrast, in the index options market, investors achieve information advantages by processing public and market-wide information faster than other traders and by acquiring trading skills and knowledge. Such advantages can disappear quickly if the information is not immediately utilized. In these situations, we assume that timing is important for the informed investors, and, as a result, the trade duration carries more meaning than in the equity markets.

Third, we expect to obtain uncontaminated results by analyzing the intraday transaction data of the KOSPI 200 options market because the market has little friction and can absorb almost all demands of derivatives investors in the Korean market. Bid-ask spreads are quite narrow, market depths are great

[5] This situation is the same in the KOSPI 200 futures market, which is closely related to the KOSPI 200 options market. Refer to Ryu (2011, 2012*a*, 2012*b*, 2013, forthcoming-a, forthcoming-d) for details on the KOSPI 200 futures market.

(Ahn, Kang, and Ryu; 2008, 2010), and no short-sale constraints exist.[6] Further, unlike the other developed markets such as the NYSE or NASDAQ, there are no designated market makers and no upstairs market for heavy traders in the KOSPI 200 options market, which creates anonymity for investors. These traits enable informed investors to freely submit their orders based only on their intraday trading strategies without caring about market friction, exposing trading intentions, transaction costs, or the adverse price movements of large trades and/or fast trading in a non-liquid market. Therefore, we can accurately measure the information content of trade duration in this options market.

Fourth, combined with the fluent liquidity, the guaranteed investor anonymity in the options market has two opposing implications on the trading intensity described by trade duration and trade size. In the KOSPI 200 options market, informed investors might have little incentive to fragment their trades.[7] The informed investors are not concerned about the adverse price movements incurred by their large trades, and they can take part in the assured liquidity while maintaining anonymity. If they actually trade in this way, the size of each trade is greatly informative, while the trade duration gives little information. On the other hand, informed traders often prefer to hide their trading intentions by spreading their trades over multiple small transactions (Anand and Chakravarty, 2007). In this case, the trade duration becomes a much better indicator of informed trading. In sum, the question of the significance of trade duration remains to be empirically investigated.

Finally, a long-standing argument exists among market practitioners and academics about the role of KOSPI 200 options trading because many continue to believe that the market is dominated by noisy and uninformed trading. If this kind of noisy trading is prevalent, then fast trading might be merely the result of noisy and/or liquidity trading, leading to the conclusion that higher trading intensity is not informative. To investigate this debated issue, more in-depth study on the options market is required.

2.3 Sample data

This study's sample data is real-time trade and quote (TAQ) data of KOSPI 200 options from January

[6] If short-sale constraints exist, we may not obtain the correct implications of the information roles of trade duration. Under short-sale constraints, negative information is only partially reflected in asset prices and trades because informed investors cannot freely submit sell orders even if they are sure of the decreases in asset prices (Diamond and Verrecchia, 1987). In this situation, long trade durations can be a result of either no information or negative information, and we cannot differentiate between them. Another liquid derivatives market of Korea is the ELWs (Equity-Linked Warrants) market. Liquidity providers comprised of established financial institutions operate this market. Only these institutions can write the ELWs, whereas individual investors cannot. That is, individuals cannot submit sell orders if they do not own the ELWs. This structure (i.e., short-sale constraints only binding to individual investors) adds to the asymmetry among market participants, and, as a result, the ELW market is not as appropriate for our analysis as is the KOSPI 200 options market.

[7] Informed traders often fragment their trades for many strategic reasons. This strategy is called "stealth-trading."

2003 to June 2005. Our dataset is filtered based on the following procedure. First, we only include the intraday transaction data of the nearest maturity contracts because the liquidity of longer-term maturity options is extremely low. Second, excluding the pre-opening and closing sessions, we include all trades and quotes recorded during the continuous session of each trading day in the final sample. Third, we define the option moneyness metric of call (put) options as S/K (K/S), where S is the current stock price and K is the strike price. We exclude options contracts for which moneyness is less than 0.88 or greater than 1.12. This strategy allows us to exclude extremely deep ITM and OTM options from the analysis because they are quite non-liquid. Fourth, if the daily number of options contract transactions is less than ten, that day is also excluded from the final sample.

Our dataset gives detailed and exact information on transaction prices, quantities, bid/ask spreads, market depth, transaction time, and trade directions. An important advantage of the dataset is that it includes an exact classification of the trade direction. The time stamp on each order and trade indicates whether the trade is initiated by a buyer or a seller, information that is essential for a reliable estimation using the structural MRR model (and its extensions), which critically depends on trade indicator variables.[8]

KOSPI 200 options have monthly maturity dates, but KOSPI 200 futures that are closely related to options trading have quarterly maturity dates. To eliminate the possible effect of maturity biases on the model estimation, we construct ten options series, each covering a three-month period. For example, the first options series covers January to March of 2003, and the second series spans from April to June of 2003. The last options series covers a longer four-month period from March to June of 2005. For each options series, we define six moneyness categories: 0.88~0.93, 0.93~0.96, 0.96~0.98, 0.98~1.0, 1.0~1.04, and 1.04~1.12. Table 2 presents summary statistics of the sample data with respect to the ten options series according to moneyness category. The table reports the number of trades, number of contracts, weighted average transaction price, average trade size, and average trade duration for call options and put options, respectively.[9]

[Table 2 around here]

Table 2 shows patterns of market liquidity measures and prices in call options and in put options. For both call and put trading, the inter-transaction time between trades is shortest and the number of transactions is highest in slightly OTM options for which moneyness lies between 0.98 and 1.0. The trading volume measured in the number of contracts is highest in OTM options for which moneyness

[8] We explain the trade indicator variables and structures of the MRR model and its extensions in Section 3.

[9] The number of trades reported in Table 2 is slightly smaller than the actual number of transactions because there is a slight loss when we construct the estimation sample. If there are defects in the raw data of a certain date, all transaction records for that day are excluded from the sample.

lies between 0.93 and 0.96. These facts indicate that OTM options are more liquid than ATM (at-the-money) and ITM options in the KOSPI 200 options market. The table also shows that option prices monotonically increase with option moneyness.

3. Models

The structural MRR model assumes that any incoming trade influences asset price in two ways: the permanent price impact due to informed trading and the temporary price effect due to uninformed and/or liquidity trading. Most structural models, such as that of Huang and Stoll (1997), assume the existence of market makers and design the spread component related to inventory holding cost, which makes them difficult to use in the analysis of purely order-driven markets where there is no market maker. However, the MRR framework is quite flexible and does not consider the inventory holding cost. Therefore, the MRR model and its extensions can be applied to any market, irrespective of structure. Another advantage of the MRR model is its robustness. Whenever the trade direction (i.e., buy or sell) is correctly specified, the MRR yields quite reliable estimation results. Its estimation procedure also uses the generalized method of moments (GMM) estimation technique, which is free from distributional assumptions and robust to heteroskedasticity and serial correlation of errors.

However, the original MRR version is incomplete in that the model assumes a uniform trade size and exogenously determined trade duration, whereas the majority of market microstructure research finds that the size and duration of a trade are closely related to its information content and market behavior. To overcome these shortcomings of the original version, we use an extended MRR model that implements the effects of trade duration and trade size. Because the MRR framework is highly flexible, it is easily modified. Also, because the model directly measures the change in asset prices and separately considers the effects of exogenous shocks, our extended models concentrate on the information content of trade duration without worrying about the confounding effects that might be caused by the model of Dufour and Engle (2000).

Under the advantageous MRR framework, we first propose a structural model that incorporates trade duration (the duration-dependent MRR (D-MRR) model). Equation (1) describes the changes in the fundamental value of an asset based on the unexpected portion of incoming trades and market innovation.

$$\Delta\mu_t \equiv \mu_t - \mu_{t-1} = (\alpha_0 + \alpha_1 ln(T_t))(x_t - E[x_t|x_{t-1}]) + \varepsilon_t \tag{1}$$

In Equation (1), x_t is the trade indicator variable, which takes a value of 1 (-1) if the initiating trade at time t is a buy (sell) trade. μ_t is the post-trade expected fundamental value of the asset. ε_t is a serially independent error term that describes the innovation in public beliefs. T_t is the duration between two consecutive trades at time t-1 and time t. $\alpha_0 + \alpha_1 ln(T_t)$ represents the permanent price impact of trade at time t (i.e., the t^{th} trade). For this permanent price impact of the t^{th} trade, α_0 is the portion that is independent of the duration, and $\alpha_1 ln(T_t)$ is the portion that is directly dependent on the duration. α_1 captures the information content of the duration between the trades. The value of the conditional expectation $E[x_t|x_{t-1}]$ is equal to ρx_{t-1}, where ρ is the serial correlation of the trade indicator variable.

Equation (2) explains that the transaction price, P_t, is determined by the post-trade fundamental asset value, the temporary price effect component of the incoming trade, and the residual.

$$P_t=\mu_t+(\beta_0+\beta_1 ln(T_t))x_t+\xi_t \tag{2}$$

In Equation (2), $\beta_0+\beta_1 ln(T_t)$ represents the size of the temporary price effect component of the trade at time t, which is independent from the change in the fundamental value. If a trade is not made by an informed trader or if the information quality of the trade is low, the changed level of the asset price incurred by the trade will not be permanent. The price will soon return to the fundamental asset value. For this temporary price effect of the t^{th} trade, β_0 is the portion that is independent of the duration, and $\beta_1 ln(T_t)$ is the portion that depends on the trade duration. β_1 captures the effect of the trade duration on the temporary portion. The residual ξ_t is the effect of rounding errors from price discreteness and discontinuity of the quoting unit.

Combining Equations (1) and (2) yields the following equation, which is used for the GMM estimation. Equation (3) shows how the intraday asset prices are formulated.

$$\Delta P_t \equiv P_t-P_{t-1}=(\alpha_0+\beta_0)x_t-(\rho\alpha_0+\beta_0)x_{t-1}+(\alpha_1+\beta_1)x_t ln(T_t)-\beta_1 x_{t-1} ln(T_{t-1})-\rho\alpha_1 x_{t-1} ln(T_t)+\upsilon_t,\ where\ \upsilon_t=\varepsilon_t+\xi_t-\xi_{t-1} \tag{3}$$

Combining Equation (3) and the information on the serial correlation of the trade-indicator variables, we set up the following moment equations for GMM estimation. Equation (4) shows the moment equations used to simultaneously estimate five model parameters: α_0, β_0, α_1, β_1, and ρ. In Equation (4), υ_0 is a constant drift term. The first equation shows the information on the serial correlation in the trade indicator variable. The second equation demonstrates that the constant drift term is set to the average pricing error. The last five normalizing equations are constructed from the OLS (ordinary least square) residuals implied by Equation (3).

$$E\begin{bmatrix} x_t(x_t-\rho x_{t-1}) \\ \upsilon_t-\upsilon_0 \\ x_t(\upsilon_t-\upsilon_0) \\ x_{t-1}(\upsilon_t-\upsilon_0) \\ x_t lnT_t(\upsilon_t-\upsilon_0) \\ x_{t-1} lnT_{t-1}(\upsilon_t-\upsilon_0) \\ x_{t-1} lnT_t(\upsilon_t-\upsilon_0) \end{bmatrix}=0 \tag{4}$$

Though the main concern of this study is trade duration, we know that market liquidity is generally described both as the trading frequency, which is the number of trades within a fixed time or the average inter-transaction time between consecutive trades, and as the trading volume, which is the size of each trade. An investor has two options when trading a large amount: make a single or a few large trades, or make a series of numerous small trades by fragmenting the trades. So, to examine the issues related to trade duration, we have to control the trade size, another dimension of the liquidity. The following equations explain how the effect of trade size is incorporated into the MRR framework.

$$\mu_t=\mu_{t-1}+(\alpha_0+\alpha_1 ln(T_t)+\alpha_2\sqrt{V_t})\ (x_t-E[x_t|x_{t-1}])+\varepsilon_t \tag{5}$$

In Equation (5), V_t is the size of an incoming trade at time t (i.e., the t^{th} trade). $\alpha_0+\alpha_1 ln(T_t)+\alpha_2\sqrt{V_t}$ represents the size of the permanent price impact of a trade at time t. For the permanent price impact of the t^{th} trade, α_0 is the portion that is independent of the trade duration and trade size, $\alpha_1 ln(T_t)$ is the portion that depends on the duration, and $\alpha_2\sqrt{V_t}$ is the portion that depends on the size. That is, α_1 and α_2 capture the information contents of the duration between trades and trade size, respectively.

Equation (6) also indicates that the temporary price effect components are comprised of three parts: the duration- and size-independent portion (β_0), the duration-dependent portion ($\beta_1 ln(T_t)$), and the size-dependent portion ($\beta_2\sqrt{V_t}$).

$$P_t=\mu_t+(\beta_0+\beta_1 ln(T_t)+\beta_2\sqrt{V_t})x_t+\xi_t \tag{6}$$

By combining Equations (5) and (6), a more complicated estimation equation is derived in Equation (7), as follows.

$$\Delta P_t=(\alpha_0+\beta_0)x_t-(\rho\alpha_0+\beta_0)x_{t-1}+(\alpha_1+\beta_1)x_t ln(T_t)-\beta_1 x_{t-1} ln(T_{t-1})-\rho\alpha_1 x_{t-1} ln(T_t)+(\alpha_2+\beta_2)x_t\sqrt{V_t}-\beta_2 x_{t-1}\sqrt{V_{t-1}}-\rho\alpha_2 x_{t-1} ln(T_t)+\upsilon_t,\ where\ \upsilon_t=\varepsilon_t+\xi_t-\xi_{t-1} \tag{7}$$

We call this further extended MRR model a duration- and size-dependent MRR (DS-MRR) model. The GMM estimation equations of the DS-MRR model are given in Equation (8).

$$
\mathrm{E}\begin{bmatrix} x_t(x_t-\rho x_{t-1}) \\ v_t-v_0 \\ x_t(v_t-v_0) \\ x_{t-1}(v_t-v_0) \\ x_t lnT_t(v_t-v_0) \\ x_{t-1}lnT_{t-1}(v_t-v_0) \\ x_{t-1}lnT_t(v_t-v_0) \\ x_t\sqrt{V_t}(v_t-v_0) \\ x_{t-1}\sqrt{V_{t-1}}(v_t-v_0) \\ x_{t-1}\sqrt{V_t}(v_t-v_0) \end{bmatrix}=0 \qquad (8)
$$

4. Empirical Findings

4.1 The information effects of trade duration

This section presents our empirical findings, which support the significant information content of trade duration and its distinct role according to option moneyness. Table 3 shows the estimation results for the D-MRR model by option type (call or put). The table reports the estimated model parameters (α_0, α_1, β_0, β_1) and their significance (using *t*-statistics) and presents the spread component measures ($PI=\alpha_0+\alpha_1\overline{lnT}$, $TE=\beta_0+\beta_1\overline{lnT}$, $IS=2(PI+TE)$, $\gamma=PI/(PI+TE)$) and their relative values to transaction prices.[10] Except in the case of deep ITM options, all model parameter estimates are statistically significant. For example, in the case of call options for which moneyness ranges from 0.96 to 0.98 (see column "*M3*" in Table 3), the average estimates of α_0, α_1, β_0, and β_1 are 0.00055, -0.00011, 0.00334, and 0.00014 points, respectively. On average, the permanent price impact component (*PI*) equals 0.072% of the options price, and the temporary price effect component (*TE*) is equal to 0.658% of the options price. The model implied spread (*IS*) is 1.460% of the options price on average, and γ values indicate that about 10.0% of the implied spread is explained by informed trading.

[Table 3 around here]

In Table 3, our main interest is parameter α_1, which captures the information content of trade duration. While other parameters, α_0, β_0, and β_1, are often insignificant especially in ITM options, α_1 estimates are highly significant in every option moneyness category. This information indicates that incorporating the trade duration into the model is quite important and is an effective way to estimate the permanent price impacts and capture the information content of trades. The α_1 estimates imply that the informational role of trade duration varies with option moneyness, which characterizes options trading. The size of α_1 estimates monotonically increases with option moneyness. While α_1 estimates

[10] The ρ estimates are not reported because they do not have important economic implications. $\overline{lnT}$ denotes the average value of the trade duration in each futures series.

are always negative in OTM options, which are quite liquid and speculative (see columns "*M1*," "*M2*," and "*M3*" in Table 3), they are significantly positive in ITM options, which are less liquid (see columns "*M5*" and "*M6*" in Table 3). The signs of α_1 estimates indicate that the hypothesis "fast trading means informed trading" is supported only in the case of OTM options trading, whereas the opposite is true in the case of ITM options trading. Considering the liquidity patterns across option moneyness, which are detected in Table 2 (i.e., OTMs are more liquid than ITMs), we can attribute the information content of trade duration to options market liquidity. This result is also noteworthy because the OTM options market has been known to be dominated by noisy traders though it is quite liquid and speculative. For example, Ahn, Kang, and Ryu (2008, 2010) claim that the OTM options market is dominated by individual investors who are regarded as uninformed and noisy, whereas the relative participation rate of institutional investors who are sophisticated and more informed monotonically increases with ITM options. However, our results reveal that higher trading intensity in the OTM options market is not necessarily noisy, and that the short trade duration reveals more concentrated informed trading. Since the OTM options market is highly competitive, informed investors might be required to trade fast to fully exploit their information superiority. This explanation is quite plausible considering that the information superiority is caused by fast information processing skills and fast trading ability based on market-wide and public information in the KOSPI 200 options market. In this situation, it is natural that fast trading indicates informed trading.

The positive signs of α_1 estimates in ITM options indicate that slower trading represents informed trading. One possible interpretation is that prudent trading is more informed, while hasty trading is less informed in the ITM options market where nominal prices are quite high, sophisticated and prudent investors dominate, and speculative investors are less prevalent. In addition, the ITM options market is less liquid compared to the OTM options market. Fast trading in the non-liquid market incurs higher transaction costs and is likely to be noisy, hasty, and aggressive, uninformed trading.

In contrast with α_1 estimates, β_1 estimates, which capture the duration dependency in the temporary price effect component, are significantly positive for all option moneyness categories. This finding is related to the fact that the increased inter-transaction time between trades implies a decrease in liquidity. In a relatively non-liquid market situation, the transaction costs increase, and thus the temporary price effect component and the options spread should increase. The overall patterns of *PI*, *TE*, *IS*, and γ across option moneyness are similar to those found in previous studies (Ahn, Kang, and Ryu, 2008, 2010). The *PI* and γ values show that the relative portion of informed trading increases with option moneyness, and a higher portion of the option spread is explained by informed trading as options move deeper into the money.

Although the results reported in Table 3 and the related discussions are clear, significant, and interesting, the effect of trade size should be considered when examining the role of trade duration because informed investors can coordinate large trades by adjusting trade frequency and size, two elements of liquidity. The DV-MRR model can accommodate this need. Table 4 presents the estimation results of the DV-MRR model by option moneyness for call and put options, respectively. All parameter estimates (α_0, α_1, α_2, β_0, β_1, β_2) shown in Table 4 are statistically significant. The table also reports the spread component measures of the DV-MRR model (PI=α_0+$\alpha_1\overline{lnT}$+$\alpha_2\sqrt{\overline{\mathrm{V}}}$, TE=β_0+$\beta_1\overline{lnT}$+$\beta_2\sqrt{\overline{\mathrm{V}}}$, IS=2(PI+TE), γ=PI/(PI+TE)) in terms of their relative values to options prices.[11]

[Table 4 around here]

Table 4 shows that α_1 estimates, which capture the information effects of trade duration, show the same patterns across option moneyness as those found in Table 3. This finding indicates that the informational roles of trade duration remain the same after controlling for size. α_2 estimates, which capture the information effects of trade size, are also significant and have positive values in all option moneyness categories. This finding indicates that large trades are more informed than smaller trades, and that large trades have greater permanent impacts on options prices and spreads. The negative values of β_2 estimates support the economy of scale. As the trade size increases, the order processing cost per trade decreases and the temporary price effect component per trade also decreases.[12]

The high t-values of the α_2 and β_2 estimates also justify incorporating trade size into the structural model. However, the results in Table 4 are not qualitatively different from those in Table 3, as supported by the D-MRR model. Therefore, for the analyses in the next section, we continue to employ the D-MRR model for simplicity.[13]

4.2 Intraday analysis

In previous sections, we analyze the information content of trade duration by measuring the effects of time between trades on intraday asset price formation. In this section, we consider that many microstructure studies have reported specific intraday patterns in microstructure variables. For example, the size and components of bid-ask spreads, the degree of informed trading, the proxies for liquidity, and the price impacts usually show L-shaped or U-shaped patterns, depending on the behavior of the market. Consistent with other financial markets, previous studies of the KOSPI 200 options market also report that microstructure variables exhibit systematic intraday patterns.

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[11] $\bar{V}$ denotes the average trade size in each futures series.

[12] Market microstructure theories explain that the permanent price impact component arises from information asymmetry among investors or the information embedded in the incoming trades. The temporary price effect component consists of the inventory holding costs and other trading costs such as the order-processing cost. In an order-driven market, the order processing cost is the most important part of the temporary price effect component.

[13] The results of the DV-MRR and D-MRR models provide the same indications; these will be provided upon request to the authors.

Considering this previous finding, we re-examine the information role of the trade duration based on the detailed intraday intervals to check for robustness.

Table 5 presents the estimation results of the D-MRR model with respect to the 17 intraday intervals of all continuous trading sessions (from 9:00 to 15:05).[14] We divide the trading sessions into 30-minute intervals, except that the beginning and ending intervals are set shorter because previous microstructure studies report that informed trading and/or liquidity are concentrated in these intervals (Admati and Pfleiderer, 1988; Ahn, Cai, Hamao, and Ho, 2002; Angelidis and Benos, 2009; Huang, 2004; Huang and Stoll, 1997; Madhavan, Richardson, and Roomans, 1997; Ryu 2011).

[Table 5 around here]

As Table 5 shows, most of the α_1 and β_1 estimates are highly significant and show the consistent patterns that are found in Tables 3 and 4. These confirming results indicate that our findings about the informational role of trade duration hold when considering the intraday intervals. Table 5 shows additional interesting findings. First, the liquidity, indicated by the number of trades per minute, the number of contracts per minute, and the reciprocal of the trade duration, shows clear U-shaped intraday patterns in all moneyness categories.[15] This finding indicates that the liquidity is more abundant at the beginning and end periods of each trading day than at mid-day, which is consistent with the findings of Admati and Pfleiderer (1988). Second, the permanent price impact component and the γ, which are important estimates related to the degree of informed trading, tend to increase around the end periods of each day and sharply increase after 14:50, which is the time when the continuous trading session of the KOSP 200 stock market closes. This result is in slight contrast with Ryu (2011), who reports that informed trading in the KOSPI 200 futures market is less concentrated after 14:50. We attribute this result to the traits of KOSPI 200 options trading. In the case of index options trading, the index futures are regarded as a liquid underlying asset. In other words, in the options market, simultaneous intraday trading, program trading, and arbitrage trading can be active as long as the intraday futures transactions are possible. Unlike the stock market, the end of the continuous trading session of the KOSPI 200 futures market is the same as that of the KOSPI 200 options market, 15:05. This end time encourages informed traders who want to implement strategic intraday trading to actively participate until 15:05. Another possibility is that informed investors are reluctant to hold overnight positions in the KOSPI 200 options market. If they are reluctant, the informed investors try to close their positions when the market closes. As a result, the concentration of informed trading at the end intervals becomes relatively high. Third, though we cannot find systematic

[14] For the intraday analysis, we exclude the trading dates on which the transaction begins at 10:00 or when the options contracts mature.

[15] To fairly measure the liquidity in each interval, we calculate the per-minute values by dividing the number of trades (contracts) by the length of each interval.

intraday patterns for the α_1 estimates in DOTM options, the α_1 estimates tend to increase with time in other options (see columns "*M3*," "*M4*," "*M5*," and "*M6*"). Considering that this kind of intraday pattern is also observed for options market liquidity, this result supports the possible association between the information content of trade duration and liquidity, which was explained in a previous section.

4.3 Informativeness of trade duration and options market variables

The previous section reports that the magnitudes of α_1 and β_1 estimates exhibit some intraday patterns, which might indicate that the information content of trade duration is related to other microstructure variables that show systematic intraday patterns. To investigate this possible association, we carry out the following regression analysis.

$$I_i = Const + Money_i + ln(\bar{T})_i + PI_i + \sqrt{\bar{V}}_i + TTM_i + Volatility_i + Intra\text{-}Dum_i + \varepsilon_i \quad (9)$$

In Equation (9), i denotes the i-th one-hour-long trading interval of each trading day in the pooling sample. There are 4,708 intervals in the call options sample and 6,209 intervals in the put options sample. In each interval, the D-MRR model is estimated, and options market variables such as moneyness, trade duration, price impact, trade size, time to maturity, and volatility are calculated. In the above regression equation, the dependent variable I is defined as an information measure, which represents the size of the information content of trade duration and is expressed as $\alpha_0+\alpha_1 lnT|_{T=90th\,percentile}^{T=10th\,percentile}$. The information measure is calculated based on the difference between the 10th and 90th percentiles of trade duration in each interval. ε denotes an error term, *Const* is a constant, $\bar{T}$ is the average trade duration, $\bar{V}$ is the average trade volume, *TTM* denotes the time to maturity, and *Intra-Dum* denotes a dummy variable that indicates the intraday interval of each trading day. *PI* is the average permanent price impact component, which equals $\alpha_0+\alpha_1 ln(\bar{T})$. *Volatility* represents the realized volatility that is calculated using five-minute log returns.

Table 6 shows the regression results for call options and put options, respectively. The table reports that all coefficients of explanatory variables are significantly estimated. We can interpret the implication of the variables on the information content of trade duration based on their signs. The negative signs of *Money* mean that the information content of trade duration is greater in OTM options than in ITM options. The positive signs of $ln(\bar{T})$ indicate that, if other options market trading activities are controlled, the informational role of trade duration becomes more significant and important as trading becomes slower. The negative sign of $\sqrt{\bar{V}}$ is also consistent with the implication of the signs of $ln(\bar{T})$. These results imply that there remains little room for trade duration to provide additional explanation when higher trading activities (i.e., fast trading and large trades) dominate the market.

[Table 6 around here]

Table 6 reports that the coefficients of the *PI* variable are positive and highly significant. This result indicates that the informational role of trade duration becomes more significant when informed trading is more concentrated. The positive signs of *Volatility* indicate that the information content of trade duration is greater when the market is more volatile. The signs of *TTM* are also positive, which indicates that the additional information role of trade duration is diminished as the maturity date approaches. This finding is plausible in that, as opposed to information-based trading, other trading motives such as unwinding and closing positions govern options trading near the maturity dates.

5. Conclusions

We examine the informational role of trade duration using the high-quality intraday dataset of KOSPI 200 options, which are the most actively traded and leading index derivatives in the world. Developing a structural market microstructure model which analyzes the real-time transaction data and incorporates the inter-transaction time between options trades, we find the following empirical results in the KOSPI 200 options market. Our empirical results indicate that the informational role of trade duration depends on option moneyness. We find that fast trading represents informed trading in the OTM options market, whereas slower trading is related to informed trading in the relatively less speculative and less liquid ITM options market. This informational role of trade duration becomes more important when informed trading is more concentrated, liquidity is relatively lower, there remain many days to maturity date, and the market is more volatile.

Our results provide trading implications for market practitioners and regulators. Considering that the trade duration conveys different information content across option moneyness, options investors have to make a judgment about the inter-transaction time. If fast (slower) trading governs in the OTM (ITM) options market, they may postpone submitting orders to avoid transacting with better informed traders and suffering losses. Our findings may guide regulators who often interrupt the market due to concerns about excessive trading and the severe money losses of uninformed domestic individual investors.[16] Recently, the Korean government and the KRX have attempted to regulate Korea's index derivatives market due to concerns about the irrational exuberance of individual investors. The current regulation system totally relies on the price movement of the derivatives asset, on which the

[16] It is known that the majority of individual investors are net losers in Korea's derivatives market (Ahn, Kang, and Ryu, 2008, 2010; Kang and Ryu, 2010; Kim and Ryu, 2012; Ryu, 2012*a*, 2012*b*, forthcoming-b, forthcoming-c,). To protect them from predatory informed investors (mainly consisting of foreign professional investors), the government and the KRX are working to design regulations and guidelines.

regulation authorities base their determinations of whether the market is overheated. However, this study demonstrates that trade duration should be considered as a useful trading indicator.

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Table 1. Trading volume by investor type

Note: This table shows the trading volume of KOSPI 200 options by investor type (domestic individuals, domestic institutions, and foreigners) for the sample period from January 2003 to June 2005. "Total" indicates the total trading volume of the index options. "Call options" and "Put options" indicate the trading volumes of call and put options, respectively. "*In contracts*" presents the number of contracts, and "*%*" indicates the percentage values. The source is the website of the Korea Exchange (www.krx.or.kr).

	Total		Call options		Put options	
	In contracts	%	In contracts	%	In contracts	%
Domestic individuals	6,584,231,687	51.21%	3,447,844,525	51.54%	3,136,387,162	50.85%
Domestic institution	4,733,585,562	36.82%	2,472,848,244	36.97%	2,260,737,318	36.65%
Foreigners	1,539,585,921	11.97%	768,370,039	11.49%	771,215,882	12.50%
Total	12,857,403,170	100%	6,689,062,808	100%	6,168,340,362	100%

Table 2: Summary statistics of the options data

Note: This table presents the number of trades ("*No. of trades*"), the number of contracts ("*No. of contracts*"), the contract-weighted average transaction price ("*Price*"), and the average duration between two consecutive trades ("*Duration*") for each moneyness category of each options series. The prices are measured in points, and the durations are measured in seconds. "*M1,*" "*M2,*" "*M3,*" "*M4,*" "*M5,*" and "*M6*" denote options for which moneyness values are 0.88~0.93, 0.93~0.96, 0.96~0.98, 0.98~1.0, 1.0~1.04, and 1.04~1.12, respectively. We define the moneyness metric of call (put) options as *S/K* (*K/S*), where *S* is the stock price and *K* is the strike price. The last rows ("*Avg.*") provide the average values. Panel A shows the results for call options, and Panel B shows the results for put options.

Panel A. Call options

	No. of trades						No. of contracts					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	879,889	834,441	637,166	627,466	621,200	80,809	90,442,068	71,069,717	51,054,462	39,805,920	19,266,491	1,356,643
2	701,341	934,005	882,533	654,799	678,379	101,490	93,776,866	101,095,410	81,990,515	38,683,925	27,693,637	1,668,685
3	237,467	597,266	886,240	750,898	852,584	55,761	40,412,902	79,245,821	91,179,275	64,589,461	38,413,681	829,879
4	567,927	1,014,885	1,184,004	1,111,940	870,921	69,143	73,419,813	107,956,089	105,827,237	81,494,291	35,234,876	907,381
5	244,606	735,422	948,228	1,219,444	903,332	51,190	26,705,083	73,027,200	83,058,159	88,683,415	32,507,496	562,722
6	1,056,165	1,390,172	1,437,782	1,045,300	746,094	64,411	81,832,537	105,064,185	84,719,730	47,169,023	19,433,545	570,122
7	497,229	1,036,236	1,062,148	1,052,749	874,881	56,077	50,873,040	89,815,012	68,572,983	48,615,385	21,148,019	532,740
8	382,316	979,740	1,249,602	1,439,666	928,427	56,572	42,054,729	92,125,018	83,189,208	73,286,831	17,676,076	539,642
9	238,667	814,409	1,117,491	1,532,956	1,086,665	40,016	23,873,173	68,418,058	77,177,305	81,273,279	24,743,639	458,729
10	168,141	732,690	1,136,164	1,620,338	1,068,820	46,842	16,763,523	61,615,096	72,124,033	74,688,957	23,179,869	436,960
Avg.	497,375	906,927	1,054,136	1,105,556	863,130	62,231	54,015,373	84,943,161	79,889,291	63,829,049	25,929,733	786,350

	Price						Duration					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	0.385	0.532	0.553	0.769	1.495	4.491	2.92	1.59	1.30	1.29	2.52	34.58
2	0.282	0.475	0.595	0.949	1.419	4.557	3.23	1.50	1.09	1.20	2.38	27.93
3	0.101	0.265	0.571	0.649	1.396	5.750	9.06	2.55	1.26	1.13	2.23	55.62
4	0.202	0.418	0.615	0.758	1.469	5.917	4.38	1.74	1.05	1.00	2.41	52.60
5	0.111	0.312	0.478	0.701	1.471	6.494	7.73	2.57	1.33	1.00	2.58	74.00
6	0.322	0.434	0.666	0.894	1.576	6.399	2.71	1.34	0.90	1.07	2.95	54.99

7	0.163	0.363	0.544	0.772	1.517	6.120	5.16	1.77	1.07	1.04	2.32	61.42
8	0.111	0.276	0.544	0.689	1.729	6.282	6.96	2.05	1.07	0.91	2.59	69.48
9	0.097	0.290	0.435	0.656	1.572	6.744	6.56	2.42	1.22	0.85	2.25	90.98
10	0.067	0.220	0.453	0.666	1.426	6.617	13.38	2.91	1.25	0.88	2.29	82.24
Avg.	0.184	0.359	0.545	0.750	1.507	5.937	6.21	2.04	1.15	1.04	2.45	60.38

Panel B. Put options

	No. of trades						No. of contracts					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	973,936	807,689	487,422	686,900	529,863	71,559	101,981,241	68,604,772	37,881,175	40,780,801	18,991,283	1,325,568
2	744,656	710,486	732,223	672,606	543,069	65,699	83,431,385	69,347,540	61,177,958	44,314,957	14,212,636	962,892
3	307,645	549,280	709,506	865,549	753,071	64,058	45,592,350	62,589,561	75,923,301	70,139,534	23,111,679	891,112
4	729,904	1,049,835	853,758	1,083,510	748,590	54,282	73,641,699	89,172,348	66,671,501	81,501,179	19,812,800	686,967
5	473,052	795,039	927,337	1,136,641	793,232	41,800	43,734,160	65,514,397	67,947,882	72,857,255	21,667,005	437,431
6	1,440,072	1,352,452	1,095,541	985,759	801,941	93,765	99,599,109	85,456,237	61,901,497	50,300,274	21,232,305	1,163,907
7	910,791	1,184,495	811,456	957,595	573,521	45,345	62,171,167	67,764,833	44,153,092	39,733,889	11,296,574	573,223
8	857,091	1,107,284	936,737	1,065,231	777,001	30,782	67,345,854	67,942,460	50,003,329	55,916,063	13,788,257	402,489
9	408,698	768,368	1,007,956	1,376,763	928,181	27,052	33,748,922	56,994,186	59,465,898	60,575,080	20,430,498	397,773
10	392,829	960,230	1,034,207	1,490,200	1,028,119	36,711	35,243,635	63,626,039	61,449,332	63,260,133	22,035,120	446,737
Avg.	723,867	928,516	859,614	1,032,075	747,659	53,105	64,648,952	69,701,237	58,657,497	57,937,917	18,657,816	728,810

	Price						Duration					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	0.419	0.582	0.616	0.791	1.463	5.155	2.26	1.46	1.43	1.36	3.08	41.82
2	0.323	0.450	0.607	0.684	1.746	4.952	2.87	1.57	1.22	1.23	3.06	46.66
3	0.132	0.317	0.461	0.711	1.554	5.386	7.68	2.46	1.51	1.01	2.52	52.11
4	0.251	0.464	0.580	0.667	1.744	6.212	3.76	1.64	1.20	1.03	2.98	70.99
5	0.161	0.374	0.532	0.697	1.618	6.357	6.37	2.19	1.34	1.05	2.94	80.93
6	0.467	0.623	0.730	0.781	1.650	6.666	1.89	1.21	1.10	1.09	2.83	41.63
7	0.332	0.539	0.604	0.754	1.587	6.144	2.94	1.46	1.16	1.19	3.61	79.15

8	0.286	0.486	0.580	0.612	1.759	6.511	3.62	1.58	1.33	1.21	3.25	112.43
9	0.179	0.335	0.510	0.681	1.339	7.037	6.99	2.46	1.25	0.93	2.71	112.22
10	0.160	0.375	0.474	0.703	1.286	6.641	6.54	2.16	1.25	0.91	2.65	96.33
Avg.	0.271	0.454	0.569	0.708	1.575	6.106	4.49	1.82	1.28	1.10	2.96	73.43

Table 3. Estimation results of the duration-dependent (D-MRR) model

Note: Estimating the D-MRR model for each moneyness category of each options series, this table presents the permanent-impact-related estimates (the duration-independent parameter α_0, the duration-related parameter α_1, and the permanent price impact component PI=α_0+$\alpha_1\overline{lnT}$), the temporary-effect-related estimates (the duration-independent parameter β_0, the duration-related parameter β_1, and the temporary price effect component TE=β_0+$\beta_1\overline{lnT}$), the model-implied spread (IS=2(PI+TE)), and the proportion of the permanent impact component in IS (γ=PI/(PI+TE)). $\overline{lnT}$ denotes the average log time between two consecutive trades. "*M1,*" "*M2,*" "*M3,*" "*M4,*" "*M5,*" and "*M6*" denote options for which moneyness values are 0.88~0.93, 0.93~0.96, 0.96~0.98, 0.98~1.0, 1.0~1.04, and 1.04~1.12, respectively. We define the moneyness metric of call (put) options as S/K (K/S), where S is the stock price and K is the strike price. All estimated coefficients are measured in points, and PI, TE, and IS are measured in percentage of options prices. γ values are presented in percentage. t-statistics are in parentheses. The last row ("*Avg.*") provides the average values. Panel A shows the results for call options, and Panel B shows the results for put options.

Panel A. Call options

	α0 (Coefficient x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.060	(83.4)	0.069	(77.4)	0.065	(58.1)	0.074	(53.4)	0.130	(35.3)	-0.071	(1.1)
2	0.058	(75.6)	0.059	(82.6)	0.059	(74.5)	0.098	(74.6)	0.117	(42.8)	-0.048	(1.2)
3	0.034	(31.1)	0.036	(55.9)	0.043	(78.5)	0.069	(73.6)	0.084	(47.7)	0.001	(0.0)
4	0.045	(62.6)	0.049	(84.6)	0.054	(94.0)	0.073	(91.8)	0.106	(42.2)	-0.138	(2.2)
5	0.036	(34.2)	0.040	(67.2)	0.049	(80.7)	0.062	(90.8)	0.095	(40.0)	-0.415	(5.0)
6	0.066	(87.8)	0.063	(90.6)	0.070	(97.8)	0.102	(80.5)	0.154	(33.9)	-0.040	(0.4)
7	0.051	(64.3)	0.052	(101.5)	0.063	(101.2)	0.079	(88.5)	0.119	(55.4)	-0.420	(4.4)
8	0.048	(53.7)	0.047	(96.4)	0.057	(109.1)	0.077	(105.7)	0.147	(61.2)	-0.212	(2.8)
9	0.028	(24.9)	0.040	(76.4)	0.053	(97.2)	0.063	(102.2)	0.112	(66.0)	-0.021	(0.2)
10	0.017	(15.2)	0.033	(59.6)	0.043	(89.2)	0.065	(106.5)	0.110	(68.0)	0.247	(3.6)
Avg.	0.044	(53.3)	0.049	(79.2)	0.055	(88.0)	0.076	(86.8)	0.117	(49.3)	-0.112	(1.4)

	α1 (Coefficient x100)											
Series	M1		M2		M3		M4		M5		M6	
1	-0.015	(60.9)	-0.011	(32.8)	-0.005	(6.4)	0.009	(8.4)	0.051	(17.7)	0.347	(18.7)
2	-0.017	(64.4)	-0.012	(40.3)	-0.009	(19.8)	-0.001	(1.3)	0.048	(21.7)	0.322	(23.2)
3	-0.010	(28.3)	-0.013	(50.2)	-0.012	(47.1)	-0.011	(27.7)	0.031	(22.2)	0.313	(18.2)
4	-0.016	(54.1)	-0.015	(62.6)	-0.009	(33.7)	-0.003	(4.9)	0.059	(27.3)	0.487	(25.3)
5	-0.012	(30.0)	-0.013	(52.7)	-0.011	(41.1)	-0.006	(14.0)	0.055	(25.0)	0.560	(21.8)
6	-0.016	(63.0)	-0.011	(36.3)	-0.009	(15.2)	0.011	(6.9)	0.105	(26.1)	0.608	(20.6)
7	-0.018	(52.4)	-0.016	(67.9)	-0.014	(42.3)	-0.003	(5.0)	0.057	(28.1)	0.583	(18.4)
8	-0.018	(45.2)	-0.016	(70.8)	-0.013	(50.0)	-0.011	(26.3)	0.059	(23.8)	0.546	(24.4)
9	-0.011	(20.6)	-0.014	(58.2)	-0.013	(53.1)	-0.011	(27.2)	0.058	(27.6)	0.464	(17.2)
10	-0.006	(12.3)	-0.014	(53.0)	-0.013	(57.1)	-0.010	(33.3)	0.051	(28.2)	0.353	(17.2)
Avg.	-0.014	(43.1)	-0.013	(52.5)	-0.011	(36.6)	-0.004	(12.4)	0.057	(24.8)	0.458	(20.5)

	β0 (Coefficient x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.340	(305.6)	0.330	(258.6)	0.352	(230.9)	0.343	(209.6)	0.303	(97.8)	0.009	(0.2)
2	0.348	(276.6)	0.341	(308.3)	0.356	(317.6)	0.332	(207.2)	0.304	(114.5)	0.066	(2.0)
3	0.433	(240.9)	0.400	(336.3)	0.363	(388.9)	0.342	(277.3)	0.285	(139.0)	-0.367	(6.7)
4	0.376	(261.0)	0.351	(354.7)	0.333	(341.3)	0.335	(295.9)	0.275	(115.8)	-0.681	(11.6)
5	0.402	(183.2)	0.372	(308.2)	0.345	(326.1)	0.338	(328.3)	0.272	(114.0)	-0.763	(10.3)
6	0.322	(293.9)	0.324	(307.6)	0.335	(330.2)	0.314	(206.2)	0.244	(71.7)	-0.565	(5.8)
7	0.330	(186.5)	0.320	(304.4)	0.301	(271.9)	0.306	(224.8)	0.243	(99.3)	-0.309	(3.3)
8	0.354	(165.7)	0.326	(293.7)	0.306	(307.2)	0.306	(275.2)	0.194	(71.8)	-0.387	(5.7)
9	0.444	(218.9)	0.345	(269.5)	0.311	(270.7)	0.314	(292.6)	0.229	(111.3)	-0.334	(4.0)

	β1 (Coefficient x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.015	(81.3)	0.014	(57.1)	0.011	(29.3)	0.014	(25.6)	0.022	(16.9)	0.062	(5.8)
2	0.015	(80.1)	0.014	(66.5)	0.012	(43.5)	0.013	(25.2)	0.034	(28.1)	0.062	(8.6)
3	0.009	(34.2)	0.011	(63.2)	0.012	(66.0)	0.011	(39.8)	0.032	(35.2)	0.087	(9.6)
4	0.012	(68.1)	0.014	(82.8)	0.013	(66.1)	0.014	(42.6)	0.040	(34.5)	0.086	(8.8)
5	0.009	(36.6)	0.011	(67.6)	0.013	(67.0)	0.012	(46.6)	0.032	(32.1)	0.082	(6.6)
6	0.016	(85.3)	0.015	(79.1)	0.017	(57.7)	0.020	(35.2)	0.049	(31.5)	0.041	(2.4)
7	0.012	(66.2)	0.015	(97.0)	0.017	(80.2)	0.017	(48.2)	0.032	(34.6)	-0.001	(0.1)
8	0.012	(57.2)	0.015	(97.1)	0.016	(88.7)	0.016	(62.6)	0.036	(37.7)	0.019	(1.4)
9	0.005	(27.3)	0.011	(74.0)	0.015	(83.1)	0.013	(61.9)	0.030	(37.1)	0.018	(1.2)

10	0.458	(210.5)	0.382	(288.9)	0.334	(310.5)	0.306	(287.7)	0.227	(102.5)	-0.390	(4.4)	0.004	(17.2)	0.009	(65.4)	0.012	(77.5)	0.014	(72.1)	0.027	(36.7)	0.022	(1.5)
Avg.	0.381	(234.3)	0.349	(303.0)	0.334	(309.5)	0.324	(260.5)	0.258	(103.8)	-0.372	(5.0)	0.011	(55.4)	0.013	(75.0)	0.014	(65.9)	0.014	(46.0)	0.033	(32.4)	0.048	(4.6)

	Permanent price impact component (%Price)						Temporary price effect component (%Price)						Implied spread (%Price)						γ (%)					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	0.070	0.089	0.102	0.115	0.154	0.328	0.972	0.673	0.670	0.476	0.232	0.064	2.085	1.524	1.545	1.184	0.773	0.783	6.7	11.7	13.2	19.5	40.0	83.7
2	0.071	0.080	0.076	0.101	0.144	0.270	1.357	0.770	0.630	0.372	0.257	0.068	2.858	1.699	1.411	0.946	0.801	0.677	5.0	9.4	10.7	21.3	35.8	79.8
3	0.041	0.033	0.042	0.080	0.102	0.258	4.526	1.599	0.672	0.555	0.247	0.007	9.135	3.265	1.428	1.270	0.698	0.530	0.9	2.0	5.8	12.6	29.2	97.2
4	0.045	0.054	0.065	0.091	0.143	0.357	1.995	0.897	0.574	0.469	0.235	-0.048	4.079	1.901	1.277	1.120	0.757	0.617	2.2	5.6	10.1	16.3	37.8	115.6
5	0.063	0.052	0.065	0.077	0.131	0.343	3.799	1.261	0.763	0.506	0.224	-0.058	7.725	2.626	1.657	1.166	0.709	0.571	1.6	3.9	7.9	13.2	36.8	120.2
6	0.114	0.104	0.087	0.131	0.218	0.421	1.088	0.802	0.537	0.382	0.212	-0.059	2.404	1.811	1.248	1.026	0.860	0.724	9.5	11.5	13.9	25.5	50.8	116.4
7	0.079	0.069	0.079	0.096	0.142	0.382	2.193	0.952	0.598	0.427	0.195	-0.052	4.544	2.042	1.353	1.046	0.674	0.662	3.5	6.8	11.6	18.4	42.1	115.6
8	0.075	0.073	0.073	0.092	0.144	0.386	3.436	1.268	0.602	0.473	0.149	-0.047	7.022	2.682	1.350	1.130	0.586	0.677	2.1	5.5	10.8	16.3	49.3	113.9
9	0.058	0.057	0.079	0.077	0.126	0.340	4.721	1.251	0.760	0.500	0.174	-0.036	9.557	2.616	1.678	1.155	0.599	0.607	1.2	4.4	9.5	13.4	41.9	111.9
10	0.051	0.041	0.056	0.080	0.132	0.294	6.989	1.807	0.772	0.483	0.188	-0.043	14.080	3.697	1.657	1.125	0.639	0.503	0.7	2.2	6.8	14.2	41.2	117.1
Avg.	0.067	0.065	0.072	0.094	0.144	0.338	3.108	1.128	0.658	0.464	0.211	-0.020	6.349	2.386	1.460	1.117	0.710	0.635	3.3	6.3	10.0	17.1	40.5	107.1

Panel B. Put options

	α0 (Coefficient x100)												α1 (Coefficient x100)											
Series	M1		M2		M3		M4		M5		M6		M1		M2		M3		M4		M5		M6	
1	0.062	(85.0)	0.071	(70.6)	0.101	(56.3)	0.102	(64.3)	0.128	(33.5)	-0.164	(2.1)	-0.014	(57.5)	-0.009	(19.9)	0.003	(3.3)	0.013	(12.8)	0.076	(25.0)	0.431	(20.5)
2	0.055	(77.5)	0.060	(69.2)	0.058	(57.4)	0.076	(66.0)	0.166	(43.2)	-0.233	(3.6)	-0.015	(61.0)	-0.011	(31.0)	-0.008	(13.9)	-0.006	(8.8)	0.043	(17.3)	0.411	(21.8)
3	0.036	(35.3)	0.051	(61.1)	0.051	(73.0)	0.073	(84.8)	0.143	(55.2)	-0.516	(5.4)	-0.011	(32.2)	-0.016	(53.3)	-0.013	(45.2)	-0.013	(35.9)	0.019	(12.6)	0.447	(16.6)
4	0.049	(76.5)	0.056	(90.9)	0.067	(82.0)	0.070	(81.3)	0.136	(38.3)	-0.398	(4.9)	-0.016	(61.5)	-0.012	(43.5)	-0.009	(23.8)	-0.007	(11.8)	0.057	(20.9)	0.637	(25.4)
5	0.055	(47.7)	0.051	(63.0)	0.059	(71.9)	0.074	(82.2)	0.108	(38.9)	-0.273	(2.9)	-0.015	(44.6)	-0.014	(51.5)	-0.011	(33.0)	-0.007	(16.1)	0.056	(22.0)	0.577	(20.3)
6	0.083	(110.6)	0.093	(92.1)	0.090	(85.4)	0.118	(77.3)	0.178	(47.0)	-0.025	(0.4)	-0.016	(59.4)	-0.012	(26.0)	0.005	(5.0)	0.023	(13.6)	0.104	(30.4)	0.690	(28.9)
7	0.055	(92.7)	0.066	(104.6)	0.066	(78.3)	0.098	(95.9)	0.154	(41.4)	-0.208	(2.3)	-0.015	(63.6)	-0.014	(51.7)	-0.012	(27.2)	-0.001	(1.4)	0.075	(25.2)	0.585	(22.0)
8	0.055	(91.1)	0.065	(100.8)	0.077	(85.6)	0.080	(70.9)	0.155	(46.8)	-0.034	(0.2)	-0.015	(62.0)	-0.011	(39.0)	-0.009	(19.5)	0.008	(6.3)	0.070	(20.6)	0.608	(15.6)
9	0.044	(51.4)	0.047	(78.6)	0.056	(94.8)	0.079	(112.6)	0.126	(60.1)	-0.096	(0.7)	-0.012	(34.8)	-0.014	(54.4)	-0.013	(48.7)	-0.013	(37.1)	0.059	(25.7)	0.535	(13.4)
10	0.035	(41.4)	0.049	(82.2)	0.056	(86.3)	0.069	(103.8)	0.120	(58.2)	0.206	(2.1)	-0.012	(33.1)	-0.013	(54.4)	-0.012	(41.3)	-0.008	(21.4)	0.057	(25.4)	0.458	(16.0)
Avg.	0.053	(70.9)	0.061	(81.3)	0.068	(77.1)	0.084	(83.9)	0.141	(46.3)	-0.174	(2.0)	-0.014	(51.0)	-0.013	(42.5)	-0.008	(24.4)	-0.001	(10.0)	0.061	(22.5)	0.538	(20.0)

	β0 (Coefficient x100)												β1 (Coefficient x100)											
Series	M1		M2		M3		M4		M5		M6		M1		M2		M3		M4		M5		M6	
1	0.335	(308.2)	0.322	(225.0)	0.347	(183.2)	0.342	(177.0)	0.298	(74.5)	0.078	(1.1)	0.015	(75.2)	0.014	(48.7)	0.000	(0.4)	0.012	(19.5)	0.036	(22.8)	0.032	(2.4)
2	0.346	(283.0)	0.335	(245.7)	0.343	(260.1)	0.364	(248.4)	0.226	(63.1)	-0.268	(5.3)	0.014	(76.7)	0.014	(56.6)	0.010	(29.3)	0.008	(19.2)	0.039	(28.8)	0.075	(7.5)
3	0.410	(220.7)	0.352	(252.6)	0.343	(295.7)	0.337	(305.7)	0.237	(94.2)	0.554	(4.5)	0.010	(40.8)	0.014	(62.4)	0.013	(61.0)	0.011	(41.6)	0.029	(31.1)	-0.101	(3.6)
4	0.336	(244.5)	0.317	(282.6)	0.308	(244.8)	0.342	(290.6)	0.213	(72.4)	-0.887	(11.4)	0.013	(78.2)	0.014	(76.0)	0.014	(54.9)	0.009	(28.2)	0.037	(30.9)	0.080	(6.2)
5	0.375	(194.1)	0.346	(275.9)	0.324	(253.0)	0.326	(250.0)	0.240	(87.4)	-0.753	(8.8)	0.011	(51.4)	0.012	(66.6)	0.013	(57.5)	0.011	(35.7)	0.031	(29.5)	0.060	(4.3)

6	0.290	(276.1)	0.290	(214.8)	0.298	(211.3)	0.307	(165.1)	0.263	(78.1)	-0.675	(9.3)	0.017	(83.7)	0.018	(58.2)	0.022	(44.7)	0.022	(29.7)	0.044	(30.3)	0.065	(5.6)
7	0.300	(237.9)	0.284	(264.9)	0.292	(200.6)	0.290	(190.2)	0.220	(59.3)	-0.680	(8.9)	0.015	(89.9)	0.018	(93.1)	0.016	(60.5)	0.017	(41.5)	0.032	(24.0)	0.021	(1.6)
8	0.282	(210.0)	0.274	(217.1)	0.265	(178.8)	0.283	(173.0)	0.203	(62.8)	-0.824	(5.3)	0.016	(92.8)	0.017	(85.0)	0.017	(59.8)	0.018	(38.3)	0.031	(25.5)	0.047	(1.8)
9	0.293	(123.1)	0.310	(226.8)	0.294	(244.8)	0.286	(245.1)	0.218	(84.8)	-0.652	(5.2)	0.011	(53.6)	0.013	(74.2)	0.016	(80.1)	0.014	(64.5)	0.025	(27.0)	0.035	(1.6)
10	0.365	(171.4)	0.298	(239.5)	0.295	(230.2)	0.295	(255.4)	0.197	(77.1)	-0.600	(5.2)	0.009	(45.0)	0.013	(78.9)	0.014	(74.0)	0.014	(60.5)	0.025	(30.4)	0.047	(2.2)
Avg.	0.333	(226.9)	0.313	(244.5)	0.311	(230.2)	0.317	(230.0)	0.231	(75.4)	-0.471	(5.4)	0.013	(68.7)	0.015	(70.0)	0.014	(52.2)	0.014	(37.9)	0.033	(28.0)	0.036	(3.0)

	Permanent price impact component (%Price)						Temporary price effect component (%Price)						Implied spread (%Price)						γ (%)					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	0.076	0.093	0.171	0.156	0.191	0.360	0.877	0.597	0.564	0.458	0.253	0.044	1.906	1.379	1.469	1.229	0.890	0.808	8.0	13.5	23.3	25.4	43.0	89.1
2	0.064	0.088	0.073	0.097	0.149	0.321	1.171	0.804	0.594	0.551	0.178	0.013	2.471	1.782	1.334	1.298	0.655	0.668	5.2	9.8	11.0	15.0	45.5	96.1
3	0.042	0.056	0.059	0.075	0.118	0.273	3.330	1.200	0.797	0.498	0.193	0.019	6.744	2.512	1.712	1.145	0.622	0.584	1.2	4.5	6.9	13.1	38.0	93.4
4	0.056	0.074	0.089	0.090	0.143	0.415	1.459	0.739	0.573	0.533	0.165	-0.083	3.030	1.627	1.324	1.247	0.615	0.663	3.7	9.1	13.5	14.5	46.5	125.0
5	0.119	0.067	0.078	0.092	0.132	0.380	2.490	0.988	0.648	0.489	0.185	-0.074	5.217	2.110	1.454	1.163	0.632	0.611	4.6	6.3	10.8	15.9	41.6	124.3
6	0.122	0.120	0.133	0.191	0.217	0.415	0.680	0.509	0.451	0.432	0.206	-0.062	1.604	1.259	1.169	1.244	0.847	0.708	15.2	19.1	22.7	30.6	51.3	117.4
7	0.076	0.078	0.078	0.128	0.190	0.421	0.994	0.581	0.524	0.418	0.178	-0.094	2.141	1.318	1.206	1.091	0.736	0.654	7.1	11.9	13.0	23.4	51.6	128.8
8	0.088	0.095	0.109	0.149	0.157	0.495	1.099	0.620	0.502	0.501	0.146	-0.088	2.374	1.430	1.222	1.301	0.605	0.815	7.4	13.3	17.8	22.9	51.9	121.5
9	0.105	0.070	0.074	0.092	0.166	0.382	1.777	0.995	0.621	0.446	0.193	-0.067	3.764	2.131	1.390	1.077	0.718	0.631	5.6	6.6	10.7	17.2	46.3	121.1
10	0.067	0.073	0.084	0.084	0.166	0.369	2.393	0.851	0.665	0.443	0.185	-0.056	4.920	1.848	1.497	1.054	0.703	0.627	2.7	7.8	11.2	16.0	47.3	117.7
Avg.	0.081	0.081	0.095	0.116	0.163	0.383	1.627	0.788	0.594	0.477	0.188	-0.045	3.417	1.740	1.378	1.185	0.702	0.677	6.1	10.2	14.1	19.4	46.3	113.4

Table 4. Estimation results of the duration- and volume-dependent (DV-MRR) model

Note: Estimating the DV-MRR model for each moneyness category of each options series, this table presents the permanent-impact-related estimates (the duration- and volume-independent parameter α_0, the duration-related parameter α_1, the volume-related parameter α_2, and the permanent price impact component $PI=\alpha_0+\alpha_1\overline{lnT}+\alpha_2\sqrt{\overline{V}}$), the temporary-effect-related estimates (the duration- and volume-independent parameter β_0, the duration-related parameter β_1, and the volume-related parameter β_2, and the temporary price effect component $TE=\beta_0+\beta_1\overline{lnT}+\beta_2\sqrt{\overline{V}}$), the model-implied spread (IS=2(PI+TE)), and the proportion of the permanent impact components in IS ($\gamma=PI/(PI+TE)$). $\overline{lnT}$ denotes the average log time between two consecutive trades. "*M1,*" "*M2,*" "*M3,*" "*M4,*" "*M5,*" and "*M6*" denote options for which moneyness values are 0.88~0.93, 0.93~0.96, 0.96~0.98, 0.98~1.0, 1.0~1.04, and 1.04~1.12, respectively. We define the moneyness metric of call (put) options as S/K (K/S), where S is the stock price and K is the strike price. All estimated coefficients are measured in points, and PI, TE, and IS are measured in percentage of options prices. γ values are presented in percentage. t-statistics are in parentheses. The last row ("*Avg.*") provides the average values. Panel A shows the results for call options, and Panel B shows the results for put options.

Panel A. Call options

	α0 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.003	(3.2)	0.014	(14.1)	0.008	(7.0)	0.003	(1.8)	-0.029	(6.7)	-0.518	(7.6)
2	-0.002	(2.2)	0.001	(1.0)	0.002	(2.5)	0.014	(9.3)	-0.016	(5.2)	-0.437	(9.5)
3	-0.003	(2.7)	-0.009	(11.8)	-0.009	(14.0)	0.018	(18.3)	-0.024	(11.8)	-0.532	(7.1)
4	-0.006	(6.4)	-0.004	(6.4)	0.000	(0.6)	0.010	(12.1)	-0.009	(3.2)	-0.462	(6.0)
5	-0.005	(4.2)	-0.006	(8.3)	0.003	(3.8)	0.008	(11.8)	-0.011	(4.5)	-0.810	(8.0)
6	0.014	(18.2)	0.020	(26.1)	0.013	(16.5)	0.038	(27.7)	0.042	(8.7)	-0.635	(5.1)
7	-0.008	(7.9)	-0.003	(4.7)	0.014	(19.1)	0.019	(18.7)	0.007	(2.8)	-0.668	(5.9)
8	-0.013	(9.8)	-0.010	(15.2)	-0.001	(1.4)	0.016	(20.2)	0.010	(3.6)	-0.627	(6.8)
9	-0.010	(6.9)	-0.007	(10.6)	0.006	(8.5)	0.009	(13.1)	0.001	(0.5)	-0.542	(4.2)
10	-0.008	(5.6)	-0.015	(20.0)	-0.002	(3.7)	0.016	(23.0)	0.007	(3.5)	-0.030	(0.3)
Avg.	-0.004	(2.4)	-0.002	(3.6)	0.003	(3.8)	0.015	(15.6)	-0.002	(1.2)	-0.526	(6.1)

	α1 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	-0.012	(51.9)	-0.008	(25.2)	-0.001	(1.8)	0.014	(12.4)	0.055	(18.6)	0.374	(20.2)
2	-0.012	(49.0)	-0.008	(29.2)	-0.004	(10.6)	0.004	(5.0)	0.052	(23.2)	0.342	(24.5)
3	-0.005	(16.9)	-0.008	(31.8)	-0.008	(34.1)	-0.007	(19.6)	0.038	(26.5)	0.351	(20.0)
4	-0.009	(33.8)	-0.011	(49.7)	-0.007	(25.1)	0.000	(0.4)	0.062	(28.2)	0.509	(26.3)
5	-0.007	(19.9)	-0.009	(39.2)	-0.008	(29.7)	-0.002	(5.6)	0.058	(26.2)	0.590	(22.5)
6	-0.014	(58.7)	-0.008	(27.5)	-0.007	(11.4)	0.011	(7.4)	0.106	(26.5)	0.667	(23.8)
7	-0.012	(36.8)	-0.012	(53.5)	-0.011	(35.0)	-0.001	(0.9)	0.059	(28.4)	0.596	(18.7)
8	-0.010	(25.6)	-0.012	(53.1)	-0.009	(37.1)	-0.007	(17.7)	0.064	(25.4)	0.566	(25.0)
9	-0.008	(15.1)	-0.011	(43.8)	-0.009	(38.8)	-0.006	(15.6)	0.059	(28.1)	0.502	(17.8)
10	-0.004	(9.2)	-0.009	(32.7)	-0.010	(44.7)	-0.007	(22.4)	0.055	(29.8)	0.367	(17.3)
Avg.	-0.009	(31.7)	-0.010	(38.6)	-0.007	(26.8)	0.000	(5.6)	0.061	(26.1)	0.487	(21.6)

	α2 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	

1	0.009	(93.9)	0.009	(78.0)	0.009	(74.6)	0.012	(68.8)	0.036	(70.5)	0.111	(14.4)
2	0.007	(79.6)	0.008	(105.6)	0.009	(92.2)	0.014	(65.4)	0.028	(76.8)	0.098	(17.7)
3	0.003	(27.8)	0.005	(62.7)	0.008	(90.9)	0.008	(71.2)	0.021	(87.4)	0.126	(13.2)
4	0.006	(57.9)	0.008	(95.6)	0.009	(100.8)	0.011	(82.3)	0.024	(71.2)	0.081	(7.7)
5	0.006	(32.4)	0.008	(77.4)	0.008	(79.4)	0.010	(99.2)	0.023	(73.3)	0.102	(7.1)
6	0.010	(97.2)	0.009	(105.6)	0.011	(94.8)	0.014	(70.5)	0.028	(47.0)	0.137	(5.0)
7	0.009	(60.4)	0.010	(102.7)	0.010	(81.4)	0.013	(75.3)	0.029	(71.5)	0.082	(4.3)
8	0.008	(43.4)	0.009	(95.7)	0.011	(105.8)	0.012	(99.7)	0.038	(74.4)	0.135	(7.6)
9	0.006	(25.3)	0.008	(71.7)	0.009	(84.1)	0.012	(116.9)	0.029	(76.8)	0.128	(6.6)
10	0.004	(16.5)	0.008	(61.8)	0.009	(83.4)	0.011	(94.6)	0.028	(78.8)	0.087	(4.5)
Avg.	0.007	(53.4)	0.008	(85.7)	0.009	(88.8)	0.012	(84.4)	0.029	(72.8)	0.109	(8.8)

	β0 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.386	(373.3)	0.372	(310.7)	0.395	(275.6)	0.403	(259.9)	0.414	(126.4)	0.300	(5.6)
2	0.394	(348.2)	0.385	(369.2)	0.402	(375.8)	0.395	(241.9)	0.398	(144.7)	0.342	(9.5)
3	0.465	(323.5)	0.444	(438.7)	0.406	(467.3)	0.382	(323.1)	0.366	(181.2)	-0.117	(2.1)
4	0.435	(368.7)	0.398	(439.8)	0.376	(402.7)	0.387	(355.3)	0.368	(148.2)	-0.527	(8.3)
5	0.444	(244.1)	0.419	(387.7)	0.380	(376.5)	0.378	(377.9)	0.348	(138.2)	-0.563	(7.4)
6	0.362	(345.1)	0.352	(340.1)	0.377	(365.9)	0.371	(240.9)	0.332	(90.2)	-0.555	(5.3)
7	0.388	(240.8)	0.360	(350.8)	0.334	(302.1)	0.351	(255.8)	0.322	(124.1)	-0.115	(1.1)
8	0.425	(241.4)	0.370	(349.8)	0.345	(335.9)	0.350	(322.4)	0.283	(96.0)	-0.163	(2.3)
9	0.467	(274.6)	0.393	(331.3)	0.335	(297.1)	0.345	(319.1)	0.310	(139.0)	-0.016	(0.2)
10	0.479	(268.6)	0.438	(394.3)	0.363	(344.4)	0.336	(315.7)	0.293	(119.3)	-0.277	(2.5)
Avg.	0.425	(302.8)	0.393	(371.2)	0.371	(354.3)	0.370	(301.2)	0.343	(130.7)	-0.169	(1.4)

	β1 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.015	(84.6)	0.014	(56.9)	0.010	(27.3)	0.013	(24.0)	0.019	(14.4)	0.049	(4.6)
2	0.015	(81.9)	0.014	(65.9)	0.011	(39.8)	0.012	(23.1)	0.030	(25.9)	0.048	(6.6)
3	0.007	(28.2)	0.010	(56.6)	0.012	(67.6)	0.011	(37.7)	0.030	(33.4)	0.071	(8.0)
4	0.011	(61.0)	0.014	(85.4)	0.013	(66.7)	0.013	(41.5)	0.036	(31.6)	0.077	(7.8)
5	0.007	(31.3)	0.011	(64.6)	0.012	(67.5)	0.011	(45.6)	0.028	(28.8)	0.075	(6.1)
6	0.016	(89.2)	0.016	(81.0)	0.016	(55.4)	0.019	(33.6)	0.046	(29.6)	0.056	(3.6)
7	0.011	(60.8)	0.016	(99.3)	0.017	(81.5)	0.016	(47.0)	0.029	(32.2)	-0.009	(0.4)
8	0.010	(48.5)	0.014	(96.6)	0.016	(91.8)	0.015	(61.4)	0.034	(35.5)	0.011	(0.8)
9	0.005	(23.9)	0.011	(70.9)	0.015	(86.3)	0.013	(62.8)	0.028	(34.9)	0.001	(0.0)
10	0.003	(14.6)	0.008	(54.8)	0.012	(81.2)	0.014	(73.3)	0.025	(35.2)	0.019	(1.2)
Avg.	0.010	(52.4)	0.013	(73.2)	0.013	(66.5)	0.014	(45.0)	0.031	(30.1)	0.040	(3.8)

	β2 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	-0.007	(108.7)	-0.007	(89.9)	-0.007	(82.1)	-0.011	(73.9)	-0.025	(60.3)	-0.078	(13.6)
2	-0.005	(90.5)	-0.007	(115.3)	-0.007	(100.0)	-0.011	(71.0)	-0.019	(69.1)	-0.069	(13.1)
3	-0.002	(33.3)	-0.003	(72.9)	-0.006	(105.2)	-0.007	(79.5)	-0.016	(85.0)	-0.060	(8.4)

4	-0.003	(71.8)	-0.006	(110.1)	-0.007	(115.5)	-0.009	(91.5)	-0.018	(70.6)	-0.040	(5.3)
5	-0.003	(39.0)	-0.005	(88.5)	-0.006	(94.6)	-0.008	(110.6)	-0.018	(68.9)	-0.064	(5.6)
6	-0.007	(109.1)	-0.007	(125.3)	-0.009	(105.5)	-0.012	(85.7)	-0.021	(49.8)	-0.014	(0.5)
7	-0.004	(73.8)	-0.006	(120.1)	-0.007	(100.1)	-0.010	(86.3)	-0.021	(68.0)	-0.070	(5.4)
8	-0.003	(53.1)	-0.005	(108.7)	-0.008	(104.1)	-0.009	(107.7)	-0.025	(62.0)	-0.078	(5.7)
9	-0.002	(31.3)	-0.005	(87.6)	-0.006	(96.2)	-0.009	(130.0)	-0.021	(72.6)	-0.089	(5.8)
10	-0.002	(20.2)	-0.004	(75.3)	-0.006	(103.1)	-0.008	(112.9)	-0.018	(64.6)	-0.042	(2.5)
Avg.	-0.004	(63.1)	-0.005	(99.4)	-0.007	(100.6)	-0.009	(94.9)	-0.020	(67.1)	-0.060	(6.6)

	Permanent Price Impact Component (%Price)						Temporary Price Effect Component (%Price)					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	0.164	0.150	0.158	0.160	0.187	0.356	0.919	0.624	0.624	0.443	0.208	0.044
2	0.201	0.153	0.135	0.137	0.180	0.290	1.307	0.716	0.587	0.347	0.232	0.055
3	0.238	0.135	0.098	0.125	0.134	0.280	4.521	1.612	0.635	0.521	0.225	-0.002
4	0.195	0.139	0.123	0.135	0.171	0.369	2.090	0.858	0.531	0.439	0.214	-0.053
5	0.336	0.170	0.139	0.131	0.157	0.357	3.892	1.258	0.714	0.463	0.198	-0.065
6	0.246	0.199	0.136	0.165	0.241	0.433	1.025	0.731	0.494	0.356	0.194	-0.054
7	0.369	0.192	0.143	0.137	0.165	0.393	2.268	0.896	0.553	0.395	0.178	-0.061
8	0.452	0.218	0.139	0.139	0.167	0.401	3.751	1.239	0.552	0.439	0.133	-0.056
9	0.404	0.170	0.160	0.134	0.145	0.355	4.728	1.268	0.698	0.451	0.160	-0.047
10	0.392	0.211	0.130	0.128	0.156	0.303	7.054	1.899	0.728	0.442	0.172	-0.048
Avg.	0.300	0.174	0.136	0.139	0.170	0.354	3.156	1.110	0.612	0.430	0.191	-0.029

	Implied Spread (%Price)						γ (%)					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	2.165	1.548	1.564	1.206	0.791	0.800	15.1	19.4	20.2	26.5	47.3	89.0
2	3.017	1.739	1.444	0.969	0.823	0.691	13.3	17.6	18.7	28.4	43.6	84.0
3	9.517	3.494	1.467	1.292	0.719	0.557	5.0	7.7	13.4	19.3	37.4	100.7
4	4.571	1.995	1.308	1.147	0.770	0.631	8.5	14.0	18.9	23.5	44.4	116.9
5	8.456	2.857	1.707	1.188	0.710	0.583	8.0	11.9	16.3	22.1	44.2	122.3
6	2.542	1.861	1.261	1.043	0.870	0.759	19.3	21.4	21.6	31.7	55.3	114.1
7	5.275	2.176	1.391	1.065	0.686	0.665	14.0	17.7	20.5	25.8	48.2	118.2
8	8.406	2.913	1.381	1.155	0.600	0.689	10.7	14.9	20.1	24.0	55.6	116.3
9	10.266	2.876	1.716	1.170	0.611	0.618	7.9	11.8	18.6	22.9	47.6	115.1
10	14.892	4.222	1.716	1.140	0.656	0.511	5.3	10.0	15.2	22.5	47.5	118.6
Avg.	6.911	2.568	1.495	1.138	0.724	0.650	10.7	14.7	18.3	24.7	47.1	109.5

Panel B. Put options

	α0 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	-0.005	(5.6)	0.008	(7.2)	0.038	(20.0)	0.019	(11.8)	-0.019	(4.4)	-0.666	(7.8)
2	-0.004	(5.1)	0.008	(8.8)	0.003	(3.2)	0.010	(8.2)	-0.011	(2.3)	-0.654	(8.6)
3	-0.005	(4.7)	-0.002	(2.2)	-0.005	(6.7)	0.008	(8.6)	0.014	(4.6)	-1.125	(10.1)
4	-0.011	(13.8)	0.000	(0.2)	0.012	(13.0)	0.007	(8.1)	-0.014	(3.4)	-0.682	(6.5)
5	0.010	(8.1)	-0.009	(10.6)	0.007	(8.3)	0.014	(15.3)	-0.012	(4.1)	-0.665	(5.3)

6	0.024	(28.2)	0.032	(30.3)	0.028	(22.2)	0.041	(26.0)	0.030	(6.7)	-0.294	(3.3)
7	0.001	(1.3)	0.007	(9.6)	0.010	(10.4)	0.037	(30.9)	0.006	(1.3)	-0.493	(4.6)
8	-0.012	(16.1)	0.003	(3.9)	0.023	(22.2)	0.022	(18.4)	0.002	(0.5)	-0.335	(1.7)
9	-0.013	(11.0)	-0.011	(14.6)	-0.001	(1.5)	0.021	(25.6)	0.024	(8.9)	-0.324	(1.6)
10	-0.014	(11.8)	-0.004	(6.4)	0.008	(11.5)	0.010	(13.2)	0.034	(13.1)	-0.219	(1.4)
Avg.	-0.003	(3.0)	0.003	(2.6)	0.012	(10.3)	0.019	(16.6)	0.005	(2.1)	-0.546	(5.1)

	α1 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	-0.005	(5.6)	0.008	(7.2)	0.038	(20.0)	0.019	(11.8)	-0.019	(4.4)	-0.666	(7.8)
2	-0.004	(5.1)	0.008	(8.8)	0.003	(3.2)	0.010	(8.2)	-0.011	(2.3)	-0.654	(8.6)
3	-0.005	(4.7)	-0.002	(2.2)	-0.005	(6.7)	0.008	(8.6)	0.014	(4.6)	-1.125	(10.1)
4	-0.011	(13.8)	0.000	(0.2)	0.012	(13.0)	0.007	(8.1)	-0.014	(3.4)	-0.682	(6.5)
5	0.010	(8.1)	-0.009	(10.6)	0.007	(8.3)	0.014	(15.3)	-0.012	(4.1)	-0.665	(5.3)
6	0.024	(28.2)	0.032	(30.3)	0.028	(22.2)	0.041	(26.0)	0.030	(6.7)	-0.294	(3.3)
7	0.001	(1.3)	0.007	(9.6)	0.010	(10.4)	0.037	(30.9)	0.006	(1.3)	-0.493	(4.6)
8	-0.012	(16.1)	0.003	(3.9)	0.023	(22.2)	0.022	(18.4)	0.002	(0.5)	-0.335	(1.7)
9	-0.013	(11.0)	-0.011	(14.6)	-0.001	(1.5)	0.021	(25.6)	0.024	(8.9)	-0.324	(1.6)
10	-0.014	(11.8)	-0.004	(6.4)	0.008	(11.5)	0.010	(13.2)	0.034	(13.1)	-0.219	(1.4)
Avg.	-0.003	(3.0)	0.003	(2.6)	0.012	(10.3)	0.019	(16.6)	0.005	(2.1)	-0.546	(5.1)

	α2 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.010	(111.1)	0.010	(90.2)	0.010	(56.4)	0.014	(66.3)	0.031	(48.0)	0.115	(12.3)
2	0.008	(91.7)	0.008	(85.8)	0.010	(82.4)	0.012	(79.0)	0.041	(59.2)	0.124	(12.8)
3	0.004	(36.4)	0.007	(70.0)	0.008	(82.7)	0.011	(97.9)	0.027	(63.5)	0.166	(16.0)
4	0.009	(86.5)	0.009	(91.7)	0.009	(73.7)	0.011	(103.4)	0.036	(74.6)	0.082	(5.0)
5	0.007	(46.3)	0.011	(92.9)	0.010	(79.3)	0.012	(100.2)	0.030	(70.3)	0.119	(6.3)
6	0.012	(110.2)	0.012	(99.7)	0.012	(67.0)	0.016	(76.5)	0.035	(46.7)	0.075	(4.9)
7	0.011	(94.5)	0.013	(114.4)	0.012	(88.8)	0.014	(61.0)	0.040	(55.3)	0.080	(5.7)
8	0.012	(101.7)	0.012	(102.2)	0.011	(73.0)	0.012	(76.3)	0.044	(64.8)	0.063	(2.8)
9	0.009	(51.3)	0.011	(88.5)	0.012	(96.4)	0.013	(83.2)	0.027	(65.8)	0.044	(2.1)
10	0.007	(38.1)	0.011	(92.4)	0.011	(89.7)	0.014	(96.8)	0.025	(47.8)	0.098	(4.5)
Avg.	0.009	(76.8)	0.011	(92.8)	0.011	(78.9)	0.013	(84.1)	0.034	(59.6)	0.097	(7.2)

	β0 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.384	(362.3)	0.367	(266.3)	0.401	(212.4)	0.407	(206.3)	0.406	(94.9)	0.345	(4.9)
2	0.390	(345.1)	0.372	(287.3)	0.397	(320.9)	0.415	(284.7)	0.349	(93.7)	0.033	(0.6)
3	0.451	(291.6)	0.399	(311.2)	0.385	(346.4)	0.385	(355.5)	0.323	(124.3)	0.890	(6.7)
4	0.398	(318.4)	0.354	(330.6)	0.353	(287.5)	0.393	(347.3)	0.321	(102.6)	-0.684	(7.3)
5	0.429	(260.2)	0.400	(347.9)	0.357	(284.6)	0.362	(281.9)	0.327	(113.3)	-0.492	(5.3)
6	0.332	(310.8)	0.332	(234.4)	0.351	(239.3)	0.369	(187.1)	0.362	(90.0)	-0.448	(6.3)
7	0.337	(271.4)	0.318	(296.8)	0.324	(222.8)	0.337	(217.7)	0.296	(71.6)	-0.575	(7.3)
8	0.331	(252.1)	0.303	(246.1)	0.305	(207.7)	0.332	(206.8)	0.295	(80.8)	-0.581	(3.6)

9	0.384	(174.5)	0.356	(270.7)	0.323	(273.3)	0.324	(274.8)	0.278	(80.3)	-0.383	(2.6)
10	0.442	(260.7)	0.332	(272.1)	0.316	(253.4)	0.330	(278.2)	0.251	(93.1)	-0.206	(1.5)
Avg.	0.388	(284.7)	0.353	(286.3)	0.351	(264.8)	0.365	(264.0)	0.321	(94.5)	-0.210	(2.2)

	β1 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	0.015	(78.6)	0.013	(48.9)	-0.001	(1.6)	0.011	(17.2)	0.032	(20.6)	0.020	(1.5)
2	0.014	(77.5)	0.014	(55.4)	0.013	(41.5)	0.007	(16.7)	0.034	(25.8)	0.063	(6.2)
3	0.008	(33.3)	0.014	(64.2)	0.013	(61.7)	0.011	(41.4)	0.028	(30.5)	-0.117	(4.1)
4	0.013	(75.8)	0.015	(79.0)	0.014	(54.0)	0.009	(26.7)	0.033	(28.1)	0.070	(5.3)
5	0.010	(44.8)	0.012	(65.6)	0.013	(59.1)	0.011	(37.1)	0.028	(26.6)	0.049	(3.5)
6	0.018	(88.4)	0.018	(58.9)	0.020	(42.4)	0.020	(27.4)	0.039	(27.0)	0.053	(4.6)
7	0.016	(93.3)	0.018	(97.9)	0.017	(62.2)	0.016	(40.6)	0.029	(21.6)	0.015	(1.1)
8	0.016	(93.1)	0.018	(89.9)	0.017	(59.7)	0.017	(37.2)	0.028	(23.5)	0.035	(1.3)
9	0.009	(42.8)	0.013	(75.4)	0.016	(84.7)	0.014	(65.6)	0.024	(26.6)	0.021	(0.9)
10	0.006	(30.1)	0.014	(85.7)	0.015	(79.9)	0.014	(62.3)	0.024	(29.4)	0.027	(1.3)
Avg.	0.012	(65.8)	0.015	(72.1)	0.014	(54.4)	0.013	(37.2)	0.030	(26.0)	0.024	(2.2)

	β2 (Coefficient.x100)											
Series	M1		M2		M3		M4		M5		M6	
1	-0.007	(129.4)	-0.008	(99.7)	-0.009	(61.8)	-0.012	(71.5)	-0.022	(47.8)	-0.068	(9.6)
2	-0.006	(99.5)	-0.006	(97.5)	-0.007	(91.7)	-0.009	(83.3)	-0.027	(52.3)	-0.087	(11.2)
3	-0.002	(42.2)	-0.005	(85.9)	-0.006	(95.6)	-0.008	(101.3)	-0.019	(61.8)	-0.093	(11.3)
4	-0.005	(96.9)	-0.008	(114.8)	-0.008	(87.1)	-0.009	(112.0)	-0.024	(59.5)	-0.063	(4.4)
5	-0.004	(57.0)	-0.006	(103.3)	-0.007	(93.1)	-0.009	(108.9)	-0.021	(63.1)	-0.085	(5.2)
6	-0.009	(134.0)	-0.010	(110.9)	-0.011	(88.7)	-0.013	(86.0)	-0.023	(43.8)	-0.062	(6.1)
7	-0.007	(114.0)	-0.009	(125.9)	-0.009	(98.9)	-0.010	(70.8)	-0.021	(38.5)	-0.031	(2.9)
8	-0.007	(113.5)	-0.008	(119.3)	-0.008	(89.4)	-0.009	(86.1)	-0.026	(46.3)	-0.070	(4.0)
9	-0.004	(58.0)	-0.007	(102.7)	-0.008	(109.3)	-0.009	(90.4)	-0.016	(33.2)	-0.074	(3.5)
10	-0.003	(50.0)	-0.007	(108.8)	-0.007	(106.0)	-0.010	(94.4)	-0.015	(42.6)	-0.114	(5.6)
Avg.	-0.005	(89.5)	-0.007	(106.9)	-0.008	(92.2)	-0.010	(90.5)	-0.021	(48.9)	-0.075	(6.4)

	Permanent Price Impact Component (%Price)						Temporary Price Effect Component (%Price)					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	0.178	0.154	0.222	0.204	0.227	0.389	0.813	0.543	0.513	0.420	0.230	0.028
2	0.176	0.168	0.126	0.146	0.176	0.345	1.123	0.745	0.580	0.516	0.162	-0.004
3	0.218	0.164	0.141	0.128	0.142	0.300	3.369	1.167	0.741	0.459	0.178	0.004
4	0.217	0.158	0.146	0.145	0.164	0.424	1.498	0.669	0.530	0.493	0.150	-0.093
5	0.312	0.181	0.147	0.148	0.154	0.393	2.586	0.975	0.591	0.435	0.168	-0.085
6	0.215	0.185	0.177	0.238	0.242	0.424	0.617	0.447	0.411	0.391	0.190	-0.067
7	0.202	0.156	0.144	0.167	0.218	0.437	0.933	0.526	0.472	0.392	0.164	-0.100
8	0.245	0.182	0.163	0.197	0.177	0.505	1.058	0.547	0.464	0.469	0.134	-0.099
9	0.289	0.196	0.150	0.135	0.190	0.388	2.071	0.961	0.560	0.414	0.181	-0.079
10	0.246	0.186	0.169	0.134	0.193	0.381	2.662	0.793	0.593	0.401	0.171	-0.071
Avg.	0.230	0.173	0.158	0.164	0.188	0.399	1.673	0.737	0.545	0.439	0.173	-0.057

	Implied Spread (%Price)						γ (%)					
Series	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	1.983	1.395	1.469	1.248	0.914	0.835	18.0	22.1	30.2	32.7	49.6	93.2
2	2.599	1.826	1.413	1.324	0.676	0.681	13.6	18.4	17.9	22.0	52.0	101.2
3	7.174	2.660	1.764	1.174	0.641	0.609	6.1	12.3	16.0	21.9	44.4	98.5
4	3.430	1.654	1.352	1.275	0.628	0.661	12.6	19.1	21.5	22.7	52.3	128.2
5	5.797	2.312	1.474	1.166	0.643	0.617	10.8	15.7	19.9	25.3	47.8	127.5
6	1.664	1.264	1.175	1.257	0.864	0.712	25.9	29.2	30.1	37.9	56.1	118.9
7	2.270	1.364	1.232	1.118	0.763	0.674	17.8	22.9	23.3	29.9	57.0	129.7
8	2.606	1.459	1.252	1.331	0.622	0.812	18.8	24.9	26.0	29.6	57.0	124.5
9	4.720	2.313	1.420	1.098	0.741	0.618	12.3	16.9	21.1	24.5	51.1	125.6
10	5.815	1.958	1.525	1.070	0.728	0.621	8.4	19.0	22.2	25.0	52.9	122.8
Avg.	3.806	1.820	1.408	1.206	0.722	0.684	14.4	20.1	22.8	27.2	52.0	117.0

Table 5. Intraday analysis

Note: This table shows the number of trades ("*No. of trades*") and the number of contracts ("*No. of contracts*") for 17 intraday intervals. Estimating the D-MRR model for each intraday interval, this table also reports the permanent-impact-related estimates (the duration-independent parameter α_0, the duration-related parameter α_1, and the permanent price impact component $PI=\alpha_0+\alpha_1\overline{lnT}$), the temporary-effect-related estimates (the duration-independent parameter β_0, the duration-related parameter β_1, and the temporary price effect component $TE=\beta_0+\beta_1\overline{lnT}$), and the proportion of the permanent impact component in *IS* ($\gamma=PI/(PI+TE)$). $\overline{lnT}$ denotes the average log time between two consecutive trades in a futures series. The two trading volume measures are presented both in raw values ("*raw*") and in per-minute values ("*per min.*"). All estimates are presented in points, and *PI*, *TE*, and *IS* are measured in percentage of options prices. *t*-statistics are shown in parentheses. Panel A shows the results for call options, and Panel B shows the results for put options.

Panel A. Call options

	Number of trades											
	M1		M2		M3		M4		M5		M6	
Interval	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.
09:00-09:15	628,734	41,916	1,455,877	97,058	1,640,106	109,340	1,498,328	99,889	822,523	54,835	58,489	3,899
09:15-09:30	446,208	29,747	1,093,306	72,887	1,268,648	84,577	1,205,146	80,343	653,900	43,593	46,049	3,070
09:30-10:00	720,219	24,007	1,796,694	59,890	2,117,874	70,596	2,045,815	68,194	1,093,597	36,453	76,829	2,561
10:00-10:30	620,511	20,684	1,554,991	51,833	1,847,842	61,595	1,803,538	60,118	950,699	31,690	62,353	2,078
10:30-11:00	554,072	18,469	1,398,240	46,608	1,666,443	55,548	1,631,507	54,384	848,929	28,298	54,524	1,817
11:00-11:30	482,077	16,069	1,213,501	40,450	1,461,658	48,722	1,475,469	49,182	785,675	26,189	47,726	1,591
11:30-12:00	447,256	14,909	1,105,090	36,836	1,313,764	43,792	1,286,113	42,870	694,038	23,135	43,958	1,465
12:00-12:30	402,300	13,410	1,027,683	34,256	1,206,996	40,233	1,191,602	39,720	664,886	22,163	38,620	1,287
12:30-13:00	469,325	15,644	1,173,631	39,121	1,428,412	47,614	1,426,217	47,541	779,684	25,989	43,028	1,434
13:00-13:30	468,892	15,630	1,231,433	41,048	1,498,160	49,939	1,516,361	50,545	844,643	28,155	46,228	1,541
13:30-14:00	497,984	16,599	1,292,403	43,080	1,586,568	52,886	1,616,775	53,893	901,061	30,035	51,026	1,701
14:00-14:30	538,968	17,966	1,416,820	47,227	1,765,301	58,843	1,775,327	59,178	1,005,131	33,504	57,677	1,923
14:30-14:45	295,708	19,714	769,098	51,273	945,392	63,026	945,624	63,042	543,963	36,264	29,337	1,956
14:45-14:50	103,009	20,602	249,118	49,824	314,475	62,895	308,018	61,604	177,561	35,512	8,477	1,695
14:50-14:55	99,553	19,911	253,519	50,704	306,111	61,222	305,090	61,018	166,652	33,330	8,416	1,683
14:55-15:00	103,771	20,754	253,989	50,798	301,936	60,387	299,268	59,854	166,397	33,279	8,853	1,771

15:00-15:05	131,942	26,388	348,252	69,650	418,061	83,612	397,380	79,476	217,070	43,414	12,022	2,404

	Number of contracts											
	M1		M2		M3		M4		M5		M6	
Interval	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.
09:00-09:15	72,646,198	4,843,080	126,864,067	8,457,604	104,416,988	6,961,133	61,455,880	4,097,059	18,776,234	1,251,749	812,533	54,169
09:15-09:30	52,133,305	3,475,554	95,609,241	6,373,949	78,046,157	5,203,077	47,923,154	3,194,877	15,082,929	1,005,529	639,358	42,624
09:30-10:00	81,591,120	2,719,704	152,959,162	5,098,639	129,453,499	4,315,117	82,480,415	2,749,347	25,099,990	836,666	1,025,636	34,188
10:00-10:30	68,529,172	2,284,306	131,940,359	4,398,012	112,253,838	3,741,795	70,959,703	2,365,323	21,378,753	712,625	810,749	27,025
10:30-11:00	60,452,898	2,015,097	118,848,751	3,961,625	99,874,660	3,329,155	64,119,184	2,137,306	18,900,638	630,021	704,707	23,490
11:00-11:30	52,887,213	1,762,907	104,318,268	3,477,276	90,045,946	3,001,532	58,563,747	1,952,125	17,613,979	587,133	604,771	20,159
11:30-12:00	49,911,318	1,663,711	95,195,517	3,173,184	80,669,803	2,688,993	50,346,416	1,678,214	15,169,881	505,663	570,022	19,001
12:00-12:30	44,661,726	1,488,724	88,198,283	2,939,943	73,636,228	2,454,541	47,361,208	1,578,707	15,012,931	500,431	490,230	16,341
12:30-13:00	51,978,561	1,732,619	98,300,618	3,276,687	84,929,944	2,830,998	55,604,912	1,853,497	17,281,843	576,061	558,271	18,609
13:00-13:30	51,283,297	1,709,443	102,451,272	3,415,042	90,296,306	3,009,877	59,616,840	1,987,228	18,951,827	631,728	609,950	20,332
13:30-14:00	56,139,701	1,871,323	108,533,108	3,617,770	95,232,920	3,174,431	62,184,884	2,072,829	19,478,806	649,294	656,825	21,894
14:00-14:30	61,751,977	2,058,399	119,908,052	3,996,935	107,075,697	3,569,190	70,037,140	2,334,571	22,202,823	740,094	752,078	25,069
14:30-14:45	34,237,472	2,282,498	65,969,857	4,397,990	58,338,667	3,889,244	37,139,836	2,475,989	11,963,010	797,534	384,014	25,601
14:45-14:50	12,520,766	2,504,153	22,435,894	4,487,179	19,890,663	3,978,133	12,163,005	2,432,601	3,958,383	791,677	111,688	22,338
14:50-14:55	11,965,379	2,393,076	23,442,044	4,688,409	19,423,755	3,884,751	12,007,175	2,401,435	3,751,492	750,298	109,104	21,821
14:55-15:00	12,703,421	2,540,684	23,520,034	4,704,007	19,486,419	3,897,284	12,060,530	2,412,106	3,671,912	734,382	107,524	21,505
15:00-15:05	16,058,729	3,211,746	32,041,713	6,408,343	26,852,845	5,370,569	16,080,797	3,216,159	4,815,561	963,112	159,241	31,848

	α0 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	0.051	(59.2)	0.054	(99.3)	0.070	(114.1)	0.115	(116.2)	0.199	(59.0)	0.266	(2.9)
09:15-09:30	0.053	(50.2)	0.056	(86.8)	0.074	(102.2)	0.121	(104.8)	0.210	(54.1)	0.182	(1.6)
09:30-10:00	0.053	(64.8)	0.054	(113.4)	0.070	(131.6)	0.112	(138.1)	0.185	(65.3)	0.121	(1.4)
10:00-10:30	0.054	(61.6)	0.056	(105.7)	0.072	(123.5)	0.114	(130.0)	0.188	(57.1)	0.125	(1.2)

10:30-11:00	0.055	(58.2)	0.056	(99.8)	0.074	(117.9)	0.118	(123.2)	0.194	(52.5)	0.184	(1.4)
11:00-11:30	0.056	(54.3)	0.058	(92.8)	0.075	(109.4)	0.119	(115.7)	0.194	(49.7)	0.159	(1.2)
11:30-12:00	0.057	(52.8)	0.059	(88.6)	0.076	(103.4)	0.123	(108.3)	0.207	(47.7)	0.031	(0.2)
12:00-12:30	0.058	(50.5)	0.060	(85.9)	0.078	(100.7)	0.124	(103.7)	0.198	(43.3)	0.119	(0.7)
12:30-13:00	0.056	(54.6)	0.059	(92.7)	0.077	(109.8)	0.123	(114.6)	0.194	(45.1)	0.255	(1.7)
13:00-13:30	0.056	(54.5)	0.058	(94.4)	0.076	(111.5)	0.121	(117.5)	0.190	(44.4)	0.053	(0.4)
13:30-14:00	0.056	(55.6)	0.058	(96.7)	0.076	(115.2)	0.121	(122.9)	0.192	(45.9)	0.149	(1.0)
14:00-14:30	0.055	(58.0)	0.058	(101.5)	0.075	(120.5)	0.119	(126.6)	0.183	(46.2)	0.098	(0.7)
14:30-14:45	0.058	(42.2)	0.062	(74.3)	0.082	(88.8)	0.131	(90.8)	0.208	(34.9)	0.074	(0.4)
14:45-14:50	0.072	(25.4)	0.078	(43.0)	0.099	(51.5)	0.160	(49.2)	0.288	(24.1)	1.169	(2.8)
14:50-14:55	0.073	(25.2)	0.078	(42.4)	0.098	(50.4)	0.160	(49.6)	0.304	(23.7)	0.184	(0.5)
14:55-15:00	0.072	(25.7)	0.077	(42.8)	0.098	(49.8)	0.160	(48.7)	0.307	(24.4)	0.966	(2.7)
15:00-15:05	0.067	(28.3)	0.071	(48.8)	0.091	(58.6)	0.148	(56.3)	0.274	(25.6)	0.413	(1.1)

	α1 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	-0.014	(45.6)	-0.012	(40.0)	-0.006	(11.1)	0.016	(15.9)	0.145	(41.0)	0.531	(19.3)
09:15-09:30	-0.014	(36.5)	-0.012	(31.5)	-0.004	(7.2)	0.017	(15.4)	0.149	(35.9)	0.587	(16.9)
09:30-10:00	-0.014	(48.9)	-0.012	(43.5)	-0.006	(14.4)	0.015	(17.4)	0.140	(45.1)	0.591	(22.3)
10:00-10:30	-0.014	(46.4)	-0.012	(40.0)	-0.005	(11.4)	0.016	(16.6)	0.149	(41.0)	0.638	(20.5)
10:30-11:00	-0.014	(44.0)	-0.011	(36.0)	-0.004	(8.3)	0.017	(15.9)	0.154	(38.0)	0.607	(16.5)
11:00-11:30	-0.014	(40.2)	-0.011	(32.3)	-0.003	(4.5)	0.018	(16.1)	0.160	(37.2)	0.643	(16.8)
11:30-12:00	-0.015	(40.1)	-0.011	(30.9)	-0.002	(3.6)	0.020	(15.7)	0.165	(37.2)	0.678	(16.0)
12:00-12:30	-0.014	(37.2)	-0.011	(28.0)	-0.002	(3.4)	0.021	(15.4)	0.169	(35.0)	0.661	(14.8)
12:30-13:00	-0.014	(39.9)	-0.011	(31.2)	-0.003	(4.1)	0.021	(17.5)	0.168	(37.0)	0.615	(15.2)
13:00-13:30	-0.014	(40.8)	-0.011	(32.9)	-0.002	(4.0)	0.022	(18.3)	0.164	(36.2)	0.662	(17.3)
13:30-14:00	-0.014	(42.2)	-0.011	(34.4)	-0.002	(3.6)	0.022	(19.2)	0.162	(37.5)	0.613	(16.0)
14:00-14:30	-0.014	(44.9)	-0.012	(37.2)	-0.003	(5.3)	0.022	(20.3)	0.163	(39.8)	0.637	(17.5)
14:30-14:45	-0.014	(31.6)	-0.011	(23.8)	-0.001	(0.8)	0.026	(16.2)	0.182	(31.1)	0.691	(12.4)

14:45-14:50	-0.014	(16.5)	-0.011	(10.1)	0.004	(2.4)	0.041	(12.8)	0.222	(21.2)	0.484	(4.5)
14:50-14:55	-0.015	(17.4)	-0.011	(11.3)	0.005	(2.7)	0.040	(12.4)	0.223	(20.8)	0.768	(7.5)
14:55-15:00	-0.015	(17.4)	-0.011	(10.8)	0.005	(2.6)	0.041	(12.4)	0.218	(21.8)	0.537	(5.9)
15:00-15:05	-0.015	(19.9)	-0.012	(14.7)	0.001	(1.0)	0.035	(13.2)	0.208	(23.0)	0.669	(6.7)

	β0 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	0.355	(269.4)	0.346	(409.0)	0.338	(399.4)	0.324	(291.3)	0.246	(68.5)	-0.376	(4.1)
09:15-09:30	0.354	(226.2)	0.345	(353.1)	0.337	(350.2)	0.324	(256.6)	0.245	(59.6)	-0.425	(3.9)
09:30-10:00	0.351	(279.9)	0.340	(432.4)	0.332	(434.9)	0.319	(333.0)	0.238	(80.5)	-0.531	(6.3)
10:00-10:30	0.348	(260.6)	0.339	(402.4)	0.331	(403.1)	0.318	(310.5)	0.236	(72.4)	-0.689	(6.4)
10:30-11:00	0.349	(248.1)	0.339	(382.4)	0.331	(383.1)	0.318	(289.7)	0.234	(66.0)	-0.612	(5.4)
11:00-11:30	0.347	(230.8)	0.339	(356.5)	0.332	(356.1)	0.320	(275.1)	0.235	(63.7)	-0.662	(5.6)
11:30-12:00	0.347	(223.5)	0.339	(339.0)	0.333	(339.0)	0.319	(253.7)	0.226	(55.7)	-0.676	(5.1)
12:00-12:30	0.346	(208.9)	0.338	(323.5)	0.331	(321.4)	0.320	(242.9)	0.231	(55.0)	-0.704	(4.8)
12:30-13:00	0.345	(224.5)	0.337	(347.9)	0.330	(346.9)	0.316	(259.4)	0.224	(56.9)	-0.678	(5.0)
13:00-13:30	0.346	(228.4)	0.338	(357.2)	0.330	(354.2)	0.316	(266.6)	0.230	(62.5)	-0.553	(4.7)
13:30-14:00	0.347	(235.3)	0.338	(366.5)	0.329	(362.4)	0.314	(273.7)	0.221	(61.3)	-0.554	(5.0)
14:00-14:30	0.348	(245.5)	0.337	(381.0)	0.328	(380.3)	0.313	(284.7)	0.222	(64.8)	-0.596	(5.7)
14:30-14:45	0.350	(181.2)	0.341	(284.2)	0.332	(281.0)	0.320	(207.4)	0.228	(45.5)	-0.695	(4.4)
14:45-14:50	0.348	(101.0)	0.343	(157.8)	0.342	(157.0)	0.333	(104.9)	0.220	(20.5)	-0.436	(1.4)
14:50-14:55	0.352	(102.5)	0.343	(157.7)	0.342	(156.3)	0.333	(105.1)	0.214	(18.8)	-0.594	(1.7)
14:55-15:00	0.351	(103.4)	0.343	(158.4)	0.342	(152.7)	0.335	(105.2)	0.216	(18.9)	-0.813	(2.5)
15:00-15:05	0.353	(120.0)	0.344	(190.2)	0.340	(188.5)	0.333	(126.5)	0.219	(23.2)	-0.901	(3.1)

	β1 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	0.013	(58.6)	0.014	(77.1)	0.016	(59.6)	0.020	(35.5)	0.056	(32.9)	0.079	(4.2)
09:15-09:30	0.013	(48.0)	0.014	(64.2)	0.016	(49.3)	0.020	(30.0)	0.055	(27.4)	0.067	(3.0)

09:30-10:00	0.013	(63.3)	0.014	(89.6)	0.016	(71.6)	0.019	(44.2)	0.049	(34.6)	0.075	(4.6)
10:00-10:30	0.014	(60.4)	0.015	(81.7)	0.016	(65.5)	0.019	(40.4)	0.049	(30.8)	0.097	(4.7)
10:30-11:00	0.014	(57.3)	0.014	(75.9)	0.016	(59.8)	0.020	(38.3)	0.050	(29.1)	0.091	(4.2)
11:00-11:30	0.014	(52.7)	0.014	(68.7)	0.016	(53.9)	0.020	(35.2)	0.050	(27.7)	0.087	(3.7)
11:30-12:00	0.014	(50.8)	0.015	(65.5)	0.016	(49.5)	0.020	(32.1)	0.054	(27.4)	0.093	(3.5)
12:00-12:30	0.014	(47.7)	0.015	(62.4)	0.016	(47.5)	0.021	(31.2)	0.053	(26.8)	0.113	(4.0)
12:30-13:00	0.014	(52.5)	0.015	(68.3)	0.016	(53.3)	0.021	(35.3)	0.053	(28.7)	0.100	(3.9)
13:00-13:30	0.014	(52.5)	0.015	(70.0)	0.016	(55.1)	0.021	(36.2)	0.049	(27.3)	0.069	(3.0)
13:30-14:00	0.014	(55.0)	0.015	(72.9)	0.016	(57.3)	0.021	(38.5)	0.051	(30.2)	0.077	(3.5)
14:00-14:30	0.014	(57.7)	0.015	(77.1)	0.016	(61.9)	0.021	(40.3)	0.050	(31.6)	0.073	(3.5)
14:30-14:45	0.014	(40.5)	0.015	(51.8)	0.017	(39.5)	0.022	(26.7)	0.056	(23.2)	0.104	(3.2)
14:45-14:50	0.015	(20.5)	0.015	(23.7)	0.017	(17.3)	0.025	(12.3)	0.073	(14.3)	0.062	(0.9)
14:50-14:55	0.015	(20.9)	0.016	(24.3)	0.017	(16.6)	0.025	(12.4)	0.081	(15.0)	0.104	(1.5)
14:55-15:00	0.015	(21.2)	0.016	(24.1)	0.017	(16.8)	0.025	(12.2)	0.080	(14.9)	0.177	(2.7)
15:00-15:05	0.015	(24.9)	0.015	(30.4)	0.017	(21.4)	0.024	(14.5)	0.076	(17.3)	0.183	(3.2)

	Permanent Price Impact Component (%Price)						Temporary Price Effect Component (%Price)					
Interval	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
09:00-09:15	0.144	0.115	0.116	0.141	0.218	0.409	2.004	1.063	0.634	0.373	0.172	-0.009
09:15-09:30	0.163	0.125	0.121	0.145	0.228	0.431	1.990	1.060	0.610	0.365	0.172	-0.024
09:30-10:00	0.147	0.115	0.111	0.136	0.216	0.435	1.894	1.025	0.601	0.365	0.169	-0.035
10:00-10:30	0.148	0.119	0.117	0.138	0.224	0.463	1.834	1.014	0.604	0.360	0.167	-0.043
10:30-11:00	0.151	0.121	0.119	0.143	0.230	0.461	1.824	1.011	0.593	0.361	0.165	-0.034
11:00-11:30	0.153	0.127	0.127	0.147	0.236	0.487	1.784	1.028	0.613	0.368	0.167	-0.044
11:30-12:00	0.156	0.131	0.129	0.151	0.244	0.500	1.816	1.034	0.609	0.362	0.162	-0.043
12:00-12:30	0.166	0.135	0.131	0.154	0.247	0.503	1.868	1.033	0.598	0.366	0.167	-0.032
12:30-13:00	0.162	0.127	0.126	0.152	0.243	0.495	1.862	0.993	0.590	0.359	0.163	-0.037
13:00-13:30	0.156	0.126	0.128	0.153	0.242	0.499	1.819	0.996	0.600	0.362	0.166	-0.040
13:30-14:00	0.154	0.124	0.125	0.150	0.238	0.478	1.840	0.993	0.587	0.353	0.159	-0.034

14:00-14:30	0.148	0.123	0.124	0.151	0.236	0.489	1.874	0.998	0.594	0.359	0.160	-0.044
14:30-14:45	0.174	0.141	0.144	0.166	0.261	0.522	1.936	1.037	0.614	0.365	0.165	-0.037
14:45-14:50	0.259	0.197	0.185	0.208	0.330	0.570	2.064	1.087	0.640	0.375	0.171	-0.028
14:50-14:55	0.255	0.202	0.186	0.207	0.339	0.624	2.094	1.138	0.648	0.375	0.176	-0.022
14:55-15:00	0.254	0.202	0.191	0.212	0.333	0.572	2.129	1.150	0.664	0.384	0.173	-0.004
15:00-15:05	0.230	0.178	0.168	0.193	0.308	0.583	2.126	1.132	0.645	0.379	0.170	-0.017

	Implied Spread (%Price)						γ (%)					
Interval	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
09:00-09:15	2.944	1.823	1.428	1.032	0.781	0.797	6.7	9.8	15.5	27.4	55.9	102.3
09:15-09:30	2.903	1.775	1.384	1.013	0.794	0.814	7.6	10.6	16.5	28.4	57.0	105.9
09:30-10:00	2.750	1.683	1.334	1.002	0.756	0.804	7.2	10.1	15.5	27.1	56.1	108.6
10:00-10:30	2.733	1.687	1.346	1.010	0.766	0.855	7.5	10.5	16.2	27.7	57.3	110.2
10:30-11:00	2.759	1.682	1.357	1.011	0.779	0.904	7.6	10.7	16.7	28.4	58.2	107.9
11:00-11:30	2.809	1.727	1.396	1.034	0.788	0.933	7.9	11.0	17.2	28.6	58.5	109.9
11:30-12:00	2.835	1.748	1.412	1.041	0.820	0.957	7.9	11.2	17.5	29.5	60.1	109.4
12:00-12:30	2.886	1.766	1.417	1.040	0.805	0.925	8.2	11.6	18.0	29.6	59.6	106.7
12:30-13:00	2.797	1.717	1.392	1.019	0.791	0.920	8.0	11.4	17.6	29.7	59.9	108.1
13:00-13:30	2.809	1.725	1.396	1.017	0.779	0.920	7.9	11.2	17.5	29.7	59.3	108.8
13:30-14:00	2.750	1.731	1.396	1.032	0.786	0.929	7.7	11.1	17.6	29.9	59.8	107.6
14:00-14:30	2.810	1.747	1.402	1.028	0.750	0.919	7.3	11.0	17.3	29.6	59.6	109.9
14:30-14:45	3.026	1.842	1.470	1.081	0.796	1.001	8.2	12.0	19.0	31.3	61.3	107.7
14:45-14:50	3.501	2.064	1.621	1.174	0.952	1.036	11.2	15.3	22.4	35.6	65.9	105.1
14:50-14:55	3.477	2.081	1.624	1.149	0.951	1.131	10.8	15.1	22.3	35.6	65.9	103.7
14:55-15:00	3.494	2.110	1.646	1.172	0.950	1.201	10.7	14.9	22.3	35.6	65.8	100.7
15:00-15:05	3.478	2.065	1.544	1.146	0.909	1.030	9.7	13.6	20.7	33.7	64.4	102.9

Panel B. Put options

	Number of trades

Interval	M1		M2		M3		M4		M5		M6	
	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.
09:00-09:15	1,102,911	73,527	1,480,245	98,683	1,324,875	88,325	1,274,420	84,961	723,458	48,231	48,712	3,247
09:15-09:30	803,712	53,581	1,141,466	76,098	1,056,816	70,454	1,041,439	69,429	583,583	38,906	39,181	2,612
09:30-10:00	1,327,071	44,236	1,892,933	63,098	1,753,348	58,445	1,779,776	59,326	1,024,835	34,161	66,753	2,225
10:00-10:30	1,132,904	37,763	1,655,598	55,187	1,559,834	51,994	1,577,478	52,583	895,487	29,850	52,709	1,757
10:30-11:00	1,024,543	34,151	1,495,522	49,851	1,407,276	46,909	1,417,721	47,257	811,122	27,037	45,765	1,526
11:00-11:30	900,213	30,007	1,323,154	44,105	1,265,928	42,198	1,288,311	42,944	744,891	24,830	42,428	1,414
11:30-12:00	823,500	27,450	1,181,099	39,370	1,125,100	37,503	1,130,583	37,686	658,198	21,940	38,618	1,287
12:00-12:30	766,683	25,556	1,091,393	36,380	1,053,974	35,132	1,054,342	35,145	598,746	19,958	35,745	1,192
12:30-13:00	873,658	29,122	1,272,440	42,415	1,230,735	41,025	1,247,442	41,581	721,938	24,065	40,330	1,344
13:00-13:30	900,565	30,019	1,320,957	44,032	1,278,668	42,622	1,341,252	44,708	767,753	25,592	41,686	1,390
13:30-14:00	963,540	32,118	1,407,404	46,913	1,357,577	45,253	1,438,193	47,940	809,041	26,968	42,377	1,413
14:00-14:30	1,069,401	35,647	1,552,080	51,736	1,512,179	50,406	1,590,550	53,018	890,996	29,700	48,709	1,624
14:30-14:45	559,217	37,281	829,525	55,302	814,380	54,292	836,187	55,746	476,154	31,744	24,247	1,616
14:45-14:50	188,798	37,760	276,197	55,239	267,992	53,598	271,246	54,249	159,154	31,831	7,036	1,407
14:50-14:55	187,293	37,459	274,857	54,971	269,054	53,811	264,589	52,918	155,449	31,090	7,422	1,484
14:55-15:00	188,472	37,694	273,750	54,750	253,735	50,747	257,777	51,555	155,379	31,076	7,702	1,540
15:00-15:05	253,864	50,773	365,769	73,154	343,672	68,734	347,701	69,540	194,907	38,981	9,686	1,937

Interval	Number of contracts											
	M1		M2		M3		M4		M5		M6	
	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.	raw	per min.
09:00-09:15	92,293,479	6,152,899	95,957,707	6,397,180	72,193,732	4,812,915	46,575,794	3,105,053	14,056,783	937,119	890,456	59,364
09:15-09:30	67,228,197	4,481,880	72,173,108	4,811,541	55,426,224	3,695,082	36,696,904	2,446,460	11,289,451	752,630	711,517	47,434
09:30-10:00	108,403,408	3,613,447	117,472,339	3,915,745	90,852,081	3,028,403	64,128,276	2,137,609	19,898,222	663,274	1,137,419	37,914
10:00-10:30	91,718,285	3,057,276	101,210,994	3,373,700	80,040,383	2,668,013	55,991,254	1,866,375	17,008,637	566,955	889,418	29,647

10:30-11:00	82,664,963	2,755,499	91,008,315	3,033,611	72,680,650	2,422,688	50,278,392	1,675,946	15,545,192	518,173	734,068	24,469
11:00-11:30	73,158,235	2,438,608	81,909,033	2,730,301	66,460,455	2,215,349	46,189,127	1,539,638	14,252,818	475,094	705,712	23,524
11:30-12:00	66,904,215	2,230,141	74,094,292	2,469,810	59,037,854	1,967,928	40,399,708	1,346,657	12,884,241	429,475	621,419	20,714
12:00-12:30	62,207,235	2,073,575	68,625,137	2,287,505	55,601,672	1,853,389	37,643,496	1,254,783	11,405,733	380,191	584,643	19,488
12:30-13:00	69,882,885	2,329,430	78,216,533	2,607,218	64,094,493	2,136,483	44,023,641	1,467,455	13,590,229	453,008	649,934	21,664
13:00-13:30	72,823,495	2,427,450	81,886,429	2,729,548	66,495,238	2,216,508	47,262,525	1,575,418	14,295,403	476,513	669,126	22,304
13:30-14:00	77,563,823	2,585,461	87,671,327	2,922,378	71,387,102	2,379,570	51,847,317	1,728,244	15,274,368	509,146	671,246	22,375
14:00-14:30	87,499,674	2,916,656	97,654,755	3,255,159	80,474,022	2,682,467	57,778,552	1,925,952	16,170,472	539,016	796,305	26,544
14:30-14:45	47,262,544	3,150,836	52,457,128	3,497,142	43,019,656	2,867,977	30,217,528	2,014,502	8,564,460	570,964	378,401	25,227
14:45-14:50	17,426,084	3,485,217	18,346,156	3,669,231	14,141,542	2,828,308	9,307,408	1,861,482	2,941,222	588,244	104,976	20,995
14:50-14:55	16,940,890	3,388,178	18,379,815	3,675,963	14,274,247	2,854,849	8,820,570	1,764,114	2,817,972	563,594	108,833	21,767
14:55-15:00	17,070,415	3,414,083	18,579,980	3,715,996	13,610,466	2,722,093	8,730,141	1,746,028	2,795,362	559,072	116,711	23,342
15:00-15:05	23,094,894	4,618,979	24,527,097	4,905,419	18,098,774	3,619,755	12,143,272	2,428,654	3,560,982	712,196	147,769	29,554

Interval	α0 (Coefficient.x100)											
	M1		M2		M3		M4		M5		M6	
09:00-09:15	0.059	(71.8)	0.069	(88.7)	0.084	(88.7)	0.128	(106.3)	0.230	(58.0)	0.460	(4.6)
09:15-09:30	0.063	(61.7)	0.073	(77.9)	0.089	(79.7)	0.133	(96.6)	0.238	(44.3)	0.524	(4.6)
09:30-10:00	0.060	(83.3)	0.069	(105.7)	0.084	(106.2)	0.123	(128.3)	0.211	(58.6)	0.306	(3.4)
10:00-10:30	0.062	(76.4)	0.072	(98.1)	0.086	(99.5)	0.126	(118.9)	0.218	(58.0)	0.462	(4.3)
10:30-11:00	0.063	(71.9)	0.073	(93.1)	0.087	(94.4)	0.128	(112.4)	0.218	(55.5)	0.431	(3.4)
11:00-11:30	0.064	(66.3)	0.074	(86.5)	0.089	(88.3)	0.130	(106.8)	0.225	(53.1)	0.432	(2.9)
11:30-12:00	0.063	(62.0)	0.075	(80.7)	0.090	(82.5)	0.133	(99.2)	0.229	(47.4)	0.439	(2.6)
12:00-12:30	0.064	(59.6)	0.076	(77.2)	0.091	(79.8)	0.135	(96.1)	0.231	(46.5)	0.469	(3.0)
12:30-13:00	0.063	(65.0)	0.074	(85.0)	0.088	(87.3)	0.131	(105.9)	0.220	(44.1)	0.168	(1.1)
13:00-13:30	0.064	(67.0)	0.074	(86.7)	0.088	(89.1)	0.130	(111.1)	0.224	(47.9)	0.335	(2.4)
13:30-14:00	0.063	(69.6)	0.074	(89.8)	0.088	(92.0)	0.129	(115.0)	0.215	(46.1)	0.401	(2.8)
14:00-14:30	0.062	(73.3)	0.072	(94.4)	0.085	(96.8)	0.127	(118.1)	0.213	(48.3)	0.260	(1.9)
14:30-14:45	0.066	(49.2)	0.077	(63.9)	0.094	(68.3)	0.139	(85.8)	0.253	(39.5)	0.724	(3.4)

14:45-14:50	0.087	(27.1)	0.098	(33.1)	0.119	(34.1)	0.178	(47.2)	0.338	(24.9)	1.357	(3.6)
14:50-14:55	0.085	(26.7)	0.098	(32.9)	0.116	(34.2)	0.180	(47.3)	0.348	(20.7)	1.497	(3.4)
14:55-15:00	0.085	(26.8)	0.098	(32.5)	0.120	(33.1)	0.182	(45.1)	0.348	(21.2)	1.744	(4.0)
15:00-15:05	0.077	(31.0)	0.090	(38.6)	0.111	(40.0)	0.164	(53.3)	0.316	(25.9)	1.561	(4.7)

	α1 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	-0.014	(44.9)	-0.011	(27.4)	0.001	(1.0)	0.021	(18.1)	0.158	(41.6)	0.635	(19.7)
09:15-09:30	-0.014	(35.9)	-0.010	(20.8)	0.003	(2.9)	0.021	(16.5)	0.159	(30.3)	0.663	(18.8)
09:30-10:00	-0.014	(51.2)	-0.010	(31.6)	0.001	(0.8)	0.017	(18.7)	0.146	(39.6)	0.669	(23.5)
10:00-10:30	-0.014	(46.1)	-0.010	(27.9)	0.002	(2.4)	0.020	(19.3)	0.150	(40.8)	0.665	(20.7)
10:30-11:00	-0.014	(43.0)	-0.010	(25.8)	0.002	(2.8)	0.020	(18.4)	0.154	(40.3)	0.694	(18.7)
11:00-11:30	-0.013	(38.8)	-0.010	(24.2)	0.002	(3.1)	0.022	(18.6)	0.156	(38.3)	0.687	(15.6)
11:30-12:00	-0.013	(35.8)	-0.010	(21.5)	0.003	(2.9)	0.022	(17.6)	0.160	(35.1)	0.711	(14.3)
12:00-12:30	-0.013	(34.5)	-0.010	(19.8)	0.002	(2.3)	0.022	(17.4)	0.166	(37.2)	0.679	(14.6)
12:30-13:00	-0.013	(39.1)	-0.010	(22.6)	0.002	(2.8)	0.022	(19.0)	0.163	(33.4)	0.756	(16.2)
13:00-13:30	-0.013	(39.3)	-0.010	(23.3)	0.002	(3.0)	0.021	(19.0)	0.156	(34.7)	0.705	(17.4)
13:30-14:00	-0.013	(41.3)	-0.010	(24.2)	0.002	(2.6)	0.020	(19.1)	0.160	(35.9)	0.700	(16.8)
14:00-14:30	-0.013	(44.6)	-0.010	(26.4)	0.001	(1.7)	0.020	(20.3)	0.157	(38.5)	0.703	(18.1)
14:30-14:45	-0.013	(28.2)	-0.010	(16.4)	0.004	(3.3)	0.026	(17.3)	0.171	(33.0)	0.634	(11.3)
14:45-14:50	-0.014	(14.0)	-0.007	(4.9)	0.012	(4.8)	0.037	(12.2)	0.207	(23.2)	0.527	(5.5)
14:50-14:55	-0.014	(13.7)	-0.007	(5.2)	0.014	(5.5)	0.038	(12.2)	0.218	(16.8)	0.550	(5.2)
14:55-15:00	-0.014	(13.7)	-0.007	(5.0)	0.014	(5.2)	0.039	(12.8)	0.216	(17.4)	0.538	(5.0)
15:00-15:05	-0.013	(17.0)	-0.008	(7.2)	0.010	(4.7)	0.035	(13.0)	0.204	(25.4)	0.469	(5.5)

	β0 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	0.325	(271.4)	0.317	(317.6)	0.313	(223.9)	0.309	(210.5)	0.217	(48.5)	-0.922	(9.3)
09:15-09:30	0.322	(224.1)	0.316	(275.1)	0.311	(193.8)	0.310	(190.5)	0.214	(42.0)	-1.167	(8.9)

09:30-10:00	0.319	(295.5)	0.309	(349.1)	0.305	(260.5)	0.302	(252.4)	0.209	(59.5)	-0.909	(9.8)
10:00-10:30	0.317	(268.1)	0.308	(321.6)	0.303	(236.8)	0.301	(228.3)	0.203	(53.2)	-1.012	(9.7)
10:30-11:00	0.316	(249.2)	0.308	(304.5)	0.304	(222.7)	0.304	(218.0)	0.207	(51.3)	-1.180	(8.4)
11:00-11:30	0.316	(231.1)	0.309	(286.1)	0.305	(207.1)	0.304	(208.6)	0.204	(46.3)	-1.122	(8.1)
11:30-12:00	0.317	(220.1)	0.310	(271.6)	0.305	(191.1)	0.304	(191.7)	0.207	(43.2)	-1.144	(7.6)
12:00-12:30	0.316	(209.3)	0.310	(262.3)	0.305	(183.7)	0.305	(183.6)	0.200	(39.6)	-1.174	(7.0)
12:30-13:00	0.316	(226.5)	0.307	(279.0)	0.304	(203.9)	0.303	(203.1)	0.201	(43.8)	-1.025	(7.2)
13:00-13:30	0.314	(228.2)	0.307	(286.0)	0.303	(206.6)	0.302	(210.8)	0.196	(43.8)	-1.114	(7.4)
13:30-14:00	0.315	(239.3)	0.307	(296.3)	0.303	(214.7)	0.302	(220.5)	0.194	(44.9)	-1.260	(8.5)
14:00-14:30	0.314	(250.0)	0.307	(309.8)	0.303	(229.4)	0.299	(226.6)	0.186	(45.4)	-0.968	(7.2)
14:30-14:45	0.321	(178.3)	0.312	(227.7)	0.307	(155.6)	0.307	(160.0)	0.180	(28.8)	-1.271	(5.8)
14:45-14:50	0.327	(87.5)	0.319	(118.5)	0.309	(63.8)	0.316	(76.7)	0.195	(14.9)	-1.802	(4.4)
14:50-14:55	0.330	(88.5)	0.320	(116.5)	0.311	(66.2)	0.312	(74.0)	0.175	(12.4)	-1.994	(4.7)
14:55-15:00	0.330	(88.7)	0.319	(118.0)	0.309	(61.9)	0.314	(73.4)	0.176	(13.0)	-2.395	(5.3)
15:00-15:05	0.331	(110.2)	0.320	(142.7)	0.309	(80.2)	0.313	(91.7)	0.188	(16.6)	-1.559	(5.3)

	β1 (Coefficient.x100)											
Interval	M1		M2		M3		M4		M5		M6	
09:00-09:15	0.014	(67.5)	0.016	(60.1)	0.019	(38.1)	0.022	(34.0)	0.052	(26.6)	0.135	(6.9)
09:15-09:30	0.014	(54.9)	0.016	(48.7)	0.019	(31.4)	0.021	(29.1)	0.053	(22.3)	0.182	(6.6)
09:30-10:00	0.014	(77.8)	0.016	(72.9)	0.019	(47.6)	0.021	(42.7)	0.044	(28.3)	0.114	(5.9)
10:00-10:30	0.015	(71.0)	0.017	(66.2)	0.019	(44.4)	0.022	(39.3)	0.046	(27.1)	0.132	(6.3)
10:30-11:00	0.015	(66.5)	0.017	(61.5)	0.019	(41.1)	0.022	(36.2)	0.046	(25.6)	0.164	(5.6)
11:00-11:30	0.015	(60.7)	0.017	(56.0)	0.020	(37.7)	0.022	(33.9)	0.047	(23.9)	0.161	(5.6)
11:30-12:00	0.014	(56.6)	0.016	(50.6)	0.019	(34.1)	0.022	(32.3)	0.048	(22.7)	0.153	(4.9)
12:00-12:30	0.014	(54.0)	0.017	(48.3)	0.020	(33.0)	0.023	(30.5)	0.048	(22.0)	0.166	(4.7)
12:30-13:00	0.015	(60.5)	0.017	(55.4)	0.019	(36.8)	0.022	(33.9)	0.046	(22.6)	0.128	(4.3)
13:00-13:30	0.015	(61.9)	0.017	(57.0)	0.019	(38.3)	0.022	(36.1)	0.048	(25.2)	0.144	(4.6)
13:30-14:00	0.015	(64.1)	0.017	(59.1)	0.019	(39.9)	0.022	(37.5)	0.046	(25.3)	0.175	(5.8)

14:00-14:30	0.015	(69.3)	0.017	(64.2)	0.019	(42.9)	0.022	(40.1)	0.048	(27.7)	0.123	(4.4)
14:30-14:45	0.014	(43.2)	0.017	(39.0)	0.020	(26.8)	0.023	(26.3)	0.057	(21.9)	0.196	(4.2)
14:45-14:50	0.014	(18.6)	0.017	(17.4)	0.023	(10.6)	0.029	(13.0)	0.066	(12.0)	0.330	(4.0)
14:50-14:55	0.014	(18.0)	0.018	(17.5)	0.022	(10.4)	0.029	(13.4)	0.070	(11.6)	0.343	(4.3)
14:55-15:00	0.014	(18.4)	0.017	(17.5)	0.022	(10.4)	0.029	(12.6)	0.072	(12.3)	0.411	(5.1)
15:00-15:05	0.014	(22.9)	0.017	(21.5)	0.021	(13.0)	0.026	(15.1)	0.066	(13.9)	0.262	(4.8)

	Permanent Price Impact Component (%Price)						Temporary Price Effect Component (%Price)					
Interval	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
09:00-09:15	0.142	0.129	0.146	0.160	0.241	0.457	1.330	0.782	0.568	0.356	0.149	-0.059
09:15-09:30	0.157	0.136	0.150	0.161	0.248	0.468	1.295	0.752	0.542	0.346	0.149	-0.061
09:30-10:00	0.138	0.123	0.137	0.152	0.233	0.466	1.237	0.718	0.530	0.349	0.145	-0.064
10:00-10:30	0.143	0.128	0.144	0.158	0.240	0.492	1.223	0.716	0.529	0.348	0.143	-0.065
10:30-11:00	0.148	0.130	0.147	0.158	0.244	0.521	1.231	0.711	0.532	0.348	0.145	-0.069
11:00-11:30	0.155	0.135	0.153	0.165	0.249	0.529	1.250	0.729	0.545	0.352	0.145	-0.063
11:30-12:00	0.156	0.139	0.157	0.168	0.260	0.549	1.261	0.735	0.549	0.353	0.150	-0.070
12:00-12:30	0.161	0.143	0.158	0.168	0.260	0.531	1.281	0.740	0.551	0.352	0.143	-0.068
12:30-13:00	0.152	0.136	0.152	0.162	0.254	0.528	1.247	0.722	0.544	0.347	0.142	-0.068
13:00-13:30	0.156	0.137	0.153	0.162	0.249	0.532	1.249	0.726	0.546	0.347	0.140	-0.072
13:30-14:00	0.151	0.136	0.152	0.163	0.252	0.536	1.224	0.730	0.546	0.353	0.140	-0.072
14:00-14:30	0.149	0.134	0.148	0.162	0.242	0.523	1.256	0.740	0.553	0.352	0.133	-0.063
14:30-14:45	0.175	0.150	0.169	0.180	0.265	0.561	1.338	0.771	0.566	0.361	0.133	-0.060
14:45-14:50	0.264	0.214	0.231	0.226	0.330	0.570	1.487	0.818	0.579	0.361	0.145	-0.052
14:50-14:55	0.257	0.214	0.230	0.225	0.339	0.632	1.482	0.827	0.583	0.350	0.137	-0.067
14:55-15:00	0.258	0.217	0.237	0.231	0.337	0.681	1.489	0.838	0.586	0.355	0.138	-0.080
15:00-15:05	0.230	0.195	0.208	0.213	0.315	0.574	1.509	0.837	0.564	0.360	0.140	-0.059

	Implied Spread (%Price)						γ (%)					
Interval	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6

09:00-09:15	2.944	1.823	1.428	1.032	0.781	0.797	9.7	14.2	20.4	31.0	61.8	114.7
09:15-09:30	2.903	1.775	1.384	1.013	0.794	0.814	10.8	15.3	21.7	31.8	62.5	115.1
09:30-10:00	2.750	1.683	1.334	1.002	0.756	0.804	10.0	14.6	20.5	30.3	61.6	115.9
10:00-10:30	2.733	1.687	1.346	1.010	0.766	0.855	10.5	15.1	21.3	31.2	62.6	115.1
10:30-11:00	2.759	1.682	1.357	1.011	0.779	0.904	10.8	15.5	21.6	31.2	62.7	115.2
11:00-11:30	2.809	1.727	1.396	1.034	0.788	0.933	11.0	15.6	21.9	31.9	63.2	113.5
11:30-12:00	2.835	1.748	1.412	1.041	0.820	0.957	11.0	15.9	22.2	32.2	63.5	114.6
12:00-12:30	2.886	1.766	1.417	1.040	0.805	0.925	11.2	16.1	22.3	32.3	64.6	114.7
12:30-13:00	2.797	1.717	1.392	1.019	0.791	0.920	10.9	15.9	21.8	31.9	64.2	114.8
13:00-13:30	2.809	1.725	1.396	1.017	0.779	0.920	11.1	15.8	21.8	31.8	64.0	115.7
13:30-14:00	2.750	1.731	1.396	1.032	0.786	0.929	11.0	15.7	21.7	31.5	64.3	115.4
14:00-14:30	2.810	1.747	1.402	1.028	0.750	0.919	10.6	15.3	21.1	31.5	64.5	113.8
14:30-14:45	3.026	1.842	1.470	1.081	0.796	1.001	11.6	16.3	23.0	33.3	66.5	112.0
14:45-14:50	3.501	2.064	1.621	1.174	0.952	1.036	15.1	20.7	28.5	38.5	69.5	110.0
14:50-14:55	3.477	2.081	1.624	1.149	0.951	1.131	14.8	20.5	28.3	39.1	71.2	111.8
14:55-15:00	3.494	2.110	1.646	1.172	0.950	1.201	14.7	20.6	28.8	39.4	70.9	113.4
15:00-15:05	3.478	2.065	1.544	1.146	0.909	1.030	13.2	18.9	26.9	37.1	69.2	111.5

Table 6. Regression analysis

Note: This table shows the estimation results of regression analysis, which demonstrate the relationship between the information content of trade duration and other trading- and options-related variables. The estimated coefficients of the regression and their corresponding *t*-statistics are reported. To construct the sample data for the regression analysis, the D-MRR model is estimated, and the trading- and options-related variables are measured per each one-hour-long trading interval of each trading day.

The dependent variable is the information measure of trade duration ($\left|I_T = \alpha_0 + \alpha_1 lnT|_{T=90t\quad pct}^{T=10t\quad pct}\right|$). Explanatory variables are average option moneyness ("*Moneyness*"), average trade duration ($ln(\bar{T})$), average permanent price impact component ("PI=α_0+$\alpha_1 ln(\bar{T})$"), square root of the average trade volume ("$\sqrt{\bar{V}}$"), time to maturity ("*TTM*"), high-low volatility of each interval ("*Volatility*"), and the intraday dummy variable that indicates the intraday interval of each trading day ("*Intra-Dum*"). "*Obs.*" denotes the number of sample observations, and "*Adj.* R^2" denotes the adjusted *R*-squared value.

	Call options		Put options	
	Coef.	T-statistics	Coef.	T-statistics
Const.	8.2E-03	(8.94)	1.5E-02	(19.00)
Moneyness	-1.0E-02	(-10.66)	-1.7E-02	(-20.39)
ln(T)	1.8E-04	(5.82)	1.4E-04	(4.78)
PI	5.9E-03	(73.28)	6.1E-03	(78.49)
sqrt(V)	-4.9E-05	(-5.47)	-6.7E-05	(-7.99)
TTM	4.0E-05	(14.20)	3.2E-05	(11.94)
Volatility	9.0E-05	(20.02)	8.3E-05	(19.30)
Intraday dummy	1.6E-05	(2.74)	1.9E-05	(3.59)
Obs.	4708		6209	
Adj. R2	0.686		0.659	