# LIQUIDITY AND LIQUIDITY RISK OF UK EQUITY OPTIONS

**By**

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## Abstract

This doctoral thesis investigates the role of liquidity in potential channels of liquidity risk in the UK equity options market. It conjectures that liquidity risk channels are associated with market-wide factors of both the options market and the underlying stock market. It assesses whether the liquidity of individual stock options comoves with that of the options market only or with that of the stock market as well. It also assesses how the persistence of liquidity in the options market and the stock market affects option returns over time. Moreover, once the time variation of liquidity in the options market and in the stock market are analysed, this study forwards a rationale that option returns can be partly explained by the liquidity of an option, liquidity of the underlying stock, and different sources of liquidity risk, such as: the covariance of the liquidity and return of the option with the returns of the stock market; the covariance of the liquidity and return of the option with the liquidity of the options and stock markets; the covariance of the liquidity of the stock with returns of the stock market; and the covariance of the liquidity of the stock with the liquidity of the options and stock markets. The factor risk premia that include the standard market factor and liquidity risk factors are estimated using the standard two-pass Fama-MacBeth (1973) procedure.

This study uses UK equity options data on the most actively traded FTSE 100 stocks covering the period from 22 February 2008 to 31 December 2010. It documents new evidence of liquidity comovement between options and their underlying stock market, option return sensitivity to unexpected illiquidity in the options markets, and sources of liquidity risk being priced in equity options returns. It also confirms the already documented findings of Cao and Wei (2010) on liquidity comovement between options and their market, the size effect and the volatility effects in the liquidity comovement.

We find new evidence that the liquidity of options comoves with the liquidity of the underlying stock market. Although small in magnitude when compared to the liquidity comovement between options and their market, it still is significant across option portfolios. This suggests that liquidity of the underlying plays an important role in explaining liquidity in options as measured by the bid-ask spread. It is also evidence for the derivative hedge theory that the bid-ask spread in the derivatives market exist partly due to the bid-ask spreads in the underlying market. However, when we investigate the role of inventory risk, information asymmetry and derivative hedge theory in explaining the daily changes in option proportional bid-ask spreads, we find that information

asymmetry helps explain spreads in the option market, since both changes in option volume and open interest have positive relationships with the change in option spreads.

The thesis documents first time evidence on the sensitivity of option returns to expected and unexpected illiquidity in the options and stock markets. We find that the effect of expected illiquidity on option returns is significant and positive for calls only, whereas the effect of unexpected illiquidity on option returns is significant and negative for both calls and puts. For calls, the latter effect decreases in moneyness and maturity, and for puts, increases in maturity. We further document that generally option portfolios do not show strong sensitivity to the expected and unexpected illiquidity in the stock market. Only deep-in-the-money call options show significant effect of expected and unexpected illiquidity on their option returns. This could be mainly because deep-in-the-money calls act more like a stock as their delta is close to one. The implication is that option traders consider expected and unexpected illiquidity in the options market based on the type of option they are trading. They generally are little concerned about stock market illiquidity, probably because all options analysed are on the liquid FTSE 100 stocks.

The most important findings in the thesis relate to the pricing of option liquidity, stock liquidity and liquidty risk channels in the equity options market. We define option return as the return of a delta-hedged portfolio net of the risk-free rate. Based on this definition, we document that option liquidity affects option returns negatively for calls and puts. The relationship is significant for most moneyness portfolios of put options only. This suggests that on average option traders pay a premium for the expected liquidity of the option. We do not find evidence that stock liquidity affects delta-hedged option returns. This finding is contrary to that of Cetin et al. (2006) who report that when the underlying asset is not perfectly liquid, the liquidity cost of the asset is a significant component of the option price and the impact on the option price depends on its moneyness.

We further document new evidence that the different sources of liquidity risk are priced in equity options, and this depends on the type as well as the moneyness of the options. For calls, we document that liquidity comovement between options and their market, the sensitivity of option reutrns to the option market liquidity, the sensitivity of option liquidity to stock market return, and liquidity comovement between the stock market and the option market are priced. For puts, we document that liquidity comovement between options and their market, liquidity comovement between options and their underlying market and sensitivity of stock liquidity to stock returns are priced. Finally, we document that the premium related to various sources of liquidity risk is 0.515 pence for at-the-money calls and 0.318 pence for at-the-money puts. We conclude that although more sources of liquidity risk are priced in puts than in calls across all moneyness portfolios, the results suggest that the liquidity risk premium demanded by investors for calls is higher than that for puts. This suggests that calls are riskier than puts, as far as liquidity is concerned.

The overall results in this thesis on the UK equity options market, compared to the findings in the literature on equity options of other markets, indicate that option traders consider liquidity as an important determinant of option prices. Most importantly, liquidity of an option and the channels of liquidity risk related to liquidity comovement between options and their market, liquidity comovement between options and the stock market, sensitivity of option returns to option market liquidity, sensitivity of option liquidity to stock market return, and liquidity comovement between the stock and the options market, are priced in UK equity options.

# Dedication

To my caring parents ammie, Zainab Khatoon and baba, Muhammad Ali Shaikh

To my loving wife, Sadaf Bashir and adorable son, Ebrahiem Ahmed Shaikh.

To my brothers and sister and uncle, Abdul Khalique Shaikh.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Background

Liquidity plays an important role in the finance literature, especially in market microstructure, corporate finance, market efficiency and asset pricing. Studies on liquidity focus on its characteristics and pricing, but mainly in stocks and bonds. There is very little research on the liquidity of derivative securities, especially on equity options. Liquidity of an asset can be generally defined as how easy it is to trade an asset in the market. Liquidity is difficult to measure, however, and several proxies have been put forward. The most widely used measure of liquidity is the difference between the bid and ask quote price known as bid-ask spread. It is the cost of one round trip of buying and selling the asset at the current best bid and ask prices in the market. The market microstructure literature suggests that bid-ask spreads exist due to costs related to risks faced by the suppliers of liquidity. Market makers face three types of costs in the stock and derivative markets: order-processing, inventory holding and information asymmetry costs. In the derivatives market they face additional hedging costs when they trade underlying assets to keep their derivative positions hedged. Therefore, transaction costs may vary across stocks and their derivatives depending on the type of risks faced by the market maker for each stock and its derivatives.

Asset pricing theory suggests that, in complete markets with perfect information and no transaction costs, the return required by risk-averse investors on an asset depends on the asset's relative riskiness to the efficient market portfolio. According to the Capital Asset Pricing Model (CAPM), the required return of an asset is the risk-free rate plus the premium for the riskiness (beta) of the asset relative to the market portfolio. However, markets are not perfect, not least because there are trading frictions of which transaction costs are prominent. Accordingly, transaction costs affect asset prices and returns.

The interaction between market microstructure and asset pricing has been widely studied following the seminal work of Amihud and Mendelsen (1986). They were the first to show that the liquidity of a stock is priced in their returns in the cross-section, and present evidence that stocks with lower transaction costs, measured by the proportional bid-ask spread, earn lower returns. They report that the market expected return is increasing in stock illiquidity and has a concave relationship with stock illiquidity. This suggests that liquidity is an important determinant of asset prices.

According to the market microstructure literature, liquidity of an asset changes over time. For example, transaction costs as measured by bid-ask spreads have fixed and variable components. The fixed component is the order-processing costs and the variable component is due to costs arising from inventory imbalances and information asymmetries in the market. When a market maker faces deviations from the optimal inventory or higher information asymmetries, he adjusts the bid-ask spread accordingly. Therefore, bid-ask spreads change over time. This strand of the literature, which deals with the interaction between market microstructure and asset pricing, expands further to investigate changes in the liquidity of an asset over time and its effects on asset prices.

Chordia et al. (2000) postulate that changes over time in the liquidity of an asset with market-wide factors constitutes liquidity risk. The literature identifies three main sources of liquidity risk in the stock market. The first is the covariation of liquidity of a stock with market liquidity. This is referred to as liquidity commonality, or liquidity comovement. The second source is the covariation of the return of a stock with market liquidity, which is referred to as the stock return sensitivity to market liquidity. The third source of liquidity risk is the covariation of the liquidity of a stock with market return, and is referred to as the liquidity sensitivity to the market return. Chordia et al. (2000) were the first to document evidence of the first source of liquidity risk for New York Stock Exchange (NYSE) stocks. Amihud (2002) documents that market liquidity affects the returns of NYSE stocks, and Pastor and Stambaugh (2003) provide empirical support that asset returns are sensitive to changes in the liquidity of the market. Their findings constitute evidence of the second source of liquidity risk. Acharya and Pedersen (2005) find evidence of the third source of liquidity risk. They consider the return of an asset net of transaction costs (transaction costs being a measure of illiquidity) and derive the risk-return relationship. Their model suggests that asset's expected return is positively related to the expected illiquidity and the net-beta of that stock. They define net-beta to be proportional to the covariance of net return of asset and net return of the market. Net return is return excluding the illiquidity costs. They decompose this covariance into four components and suggest that the 'net beta' is decomposed into standard market beta, which is the covariance between asset return and market return, and three other betas representing three covariances that include exogenous liquidity costs of the asset or the market as one of the two variables. These three betas represent the three different sources of liquidity risk. The first relates to the covariance between the liquidity of an asset and the liquidity of the market (i.e., liquidity commonality or liquidity comovement). The second relates to the covariance between the return of the asset and the liquidity of the market (i.e., the return sensitivity to the market liquidity). The third relates to the covariance between the liquidity of the asset and the return of the market. Their empirical findings suggest that among these three the most important source of liquidity risk is the covariance of an asset's illiquidity with the stock market return, which relates to the third beta. They empirically find that 1.1% of the cross-sectional return is due to liqidity risk and 80% of this 1.1% is attributed to the sensitivity of liquidity to the market return. Evidence documented in the literature on stock markets suggests that, beside standard market risk, stock liquidity and the three sources of liquidity risk affect expected stock returns.

Derivatives differ from stocks and bonds because their payoff is dependent on the payoff of their underlying assets. In the Black-Scholes-Merton Model, the capital markets are perfect, where underlying asset returns follow a diffusion process and the payoff of an option can be replicated by basic assets and lending and borrowing. Using the no-arbitrage principle, options, therefore, are priced as redundant securities. However, when the perfect market assumption is relaxed, options are no longer priced as redundant securities. Supply and demand in imperfect markets, then, determines the price of these non-redundant securities. Moreover, there are other factors that affect option prices, such as stock market momentum (Amin et al., 2004), volatility (Bakshi and Kapadia, 2003a & 2003b; Goyal and Saretto, 2009; and Cao and Han, 2011), demand pressure (Garleanu et. al, 2009) and liquidity (Carr and Wu, 2009; Goyal and Saretto, 2009; and Deuskar et al., 2011).

Like stocks, the literature on options suggests that liquidity is an important determinant of option prices. Brenner et al. (2001) compares exchange traded and over-the-counter (OTC) FX options issued by the Bank of Israel. They find that OTC FX options are priced at a discount of 21% in comparison to similar exchange-traded FX options. They suggest the reason is that liquidity in the OTC options market is less than the liquidity of exchange traded options.

In the stock and bond markets, an illiquid asset provides a higher return. This higher return includes the premium for illiquidity of the asset as well as a premium for liquidity risk. However, in the options markets, the payoff of an option depends on the payoff of the underlying asset, and an option can be replicated by trading delta units of the underlying asset. When considering the transaction costs of the option and the underlying asset, it may be argued that illiquidity of both the option and the underlying asset become relevant for these options. In light of the inventory theory of market microstructure, when market makers cannot perfectly hedge their inventories, they will require a positive (negative) compensation for holding positive (negative) inventory of options. Due to selling (demand) pressure from end-users, market makers eventually hold net-positive (net-long) inventory, and holding positive or negative inventory is costly. To avoid inventory pile-up, market makers ex-ante will quote higher bid-ask spreads. Thus, they require an liquidity premium. Similarly, market makers in the options market trade in the underlying stock market to keep their positions delta-hedged. Therefore, they are affected by the bid-ask spreads in the underlying market. The hedging cost argument suggests that in order to hedge their option positions, market makers would incur trading costs in the underlying stock market, and therefore, they eventually pay a premium for the illiquidity in the underlying stock. To summarize these arguments, the effect of option illiquidity and the stock illiquidity on the option return would be positive and negative, respectively, in the cross-section. The positive effect of illiquidity of an option on the return of the option is referred as the 'Illiquidity Premium Hypothesis,' and the negative effect of illiquidity of the underlying asset on the return of the option is referred as the 'Hedging Cost Hypothesis'. Recently, the findings of Christoffersen (2015) support the above arguments by providing empirical evidence for the effect of option illiquidity and stock illiquidity on expected returns on Chicago Board Options Exchange (CBOE) equity options.

Liquidity not only comoves across assets in the stock market (Chordia et al, 2000; Huberman and Halka, 2001; Hasbrouck and Seppi, 2001) but it also comoves across options in the equity options market (Cao and Wei, 2010). Cao and Wei (2010) find that the liquidity of options comoves with the option market liquidity after accounting for liquidity in the stock market and other determinants of liquidity, for example, volatility. In particular, they observe volatility effects in liquidity comovement, whereby firms with higher volatility show strong liquidity commonality.

Liquidity risk is not only confined to the liquidity commonality in the options market, but because of the very nature of the option payoff, following the net-beta derivation of Acharya and Pedersen (2005), liquidity risk in the options market can be due to the covariation of option returns, option liquidity and stock liquidity with stock market return, option market liquidity and stock market liquidity. In light of the above discussion, there remain a few issues to investigate in order to understand whether liquidity of an option, liquidity of the stock of the option, and various sources of liquidity risk affect option returns. Moreover, the studies that investigate the liquidity effects in equity options are mostly on the CBOE equity options market. There are several equity options markets around the world whose data can be used to investigate the effects of liquidity on option prices, not only to verify the already documented results but also to contribute to the literature. This is carried out in this thesis. We investigate how liquidity of an option comoves with liquidity of the option and stock markets; how return of an option comoves with liquidity of the option and stock markets; and how liquidity of an option, liquidity of the stock of the option, and the various sources of liquidity risk affect returns of UK equity options. Moreover, our goal is to investigate these relationships for calls and puts separately, and over their moneyness and maturity portfolios.

In the equity options market, evidence of liquidity comovement between options and their market is documented by Cao and Wei (2010) for CBOE equity options. We argue that comovement of options liquidity arises from the liquidity of both the options market and their underlying stock market. The results show that Cao and Wei's (2010) evidence of liquidity comovement between options and their market is present in UK equity options. However, we also report new findings of liquidity comovement between UK equity options and their underlying stock market. We document that at-the-money (ATM) options show higher liquidity comovement with the underlying stock market than in-the-money (ITM) and out-the-money (OTM) options. Liquidity comovement is observed to be positive for all moneyness and maturity portfolios of calls, whereas for some put option portfolios there is a negative but insignificant liquidity comovement with their underlying stock market.

We contribute further to the literature by documenting evidence that option returns are sensitive to both the expected and unexpected components of the liquidity of the options and stock markets. We follow the methodology of Amihud (2002), and our results suggest that call option returns are sensitive to the expected and unexpected illiquidity in the options market, whereas put option returns are sensitive to the unexpected illiquidity in the options market only. The findings show that UK equity option return sensitivity to expected illiquidity in the option market varies for calls and puts and across moneyness and maturity portfolios.

Following the investigation of liquidity commonality and option return sensitivity, we investigate whether the liquidity of an option, the liquidity of the underlying stock of the option, and several sources of liquidity risk are priced in option returns. Christoffersen et al. (2015) document that expected option returns include an illiquidity premium and a hedging cost premium (negative premium for stock illiquidity). However, we present new evidence that different sources of liquidity risk are priced in the UK equity options market. We follow Bakshi et al. (2003a) to calculate the weekly delta-hedged net-gains as a measure of option return. When options are delta-hedged, we argue that the deviations from zero net-gain are due, at least in part, to the liquidity being priced in the options. We document evidence that for calls, the priced liquidity sources include the option return sensitivity to stock market liquidity, the option liquidity comovement with stock market excess return, and the liquidity comovement between the stock and options markets. For puts, we report evidence that the sources of liquidity risk that are priced are the liquidity comovement between options and their market, the liquidity comovement between options and the stock market, the option liquidity comovement with the stock excess return, and the option liquidity comovement with the stock market liquidity. We conclude that although liquidity risk is priced in equity options, the sources of liquidity risk that are priced differ for calls and puts and across their moneyness.

More specifically, our main contribution is as follows:

First, the analysis is performed on equity options of the most actively traded stocks trading on the NYSE Euronext LIFFE London Equity options market. There are mainly two benefits of this data set. First, data on options of such active stocks to study the liquidity effects on prices are rarely used. Second, this is the first study to investigate liquidity comovements and sources of liquidity risk using daily data on UK equity options market.

Second, we extend the work of Amihud (2002) to investigate the effect of expected and unexpected illiquidity in options and stock markets on option returns. In time-series, we find that option returns are sensitive to both the expected and unexpected illiquidity in the options market, but option returns are only sensitive to the unexpected (not the expected) illiquidity in the underlying stock market. This finding has implications for option traders. When options are sensitive to the unexpected illiquidity in the stock market, if ignored by traders might lead to inefficient strategies.

Third, this study is the first to investigate sources of liquidity risk other than liquidity commonality in the options market. We document that not all identified sources of liquidity risk are priced in all options. Rather, ATM options generally have more priced liquidity risk factors compared to OTM and ITM, suggesting liquidity risk is related to their moneyness.

Fourth, this study documents that delta-hedge gains are non-zero. They are positive for calls and negative for puts. The non-zero delta-hedged gains are related to the option illiquidity premium and to premia related to different sources of liquidity risk. For the first time in the literature, thesis documents that for calls the priced sources of liquidity risk are: the option return sensitivity to stock market liquidity, the option liquidity comovement with the stock market excess return, and the liquidity comovement between stocks and the options market. For puts, the sources of liquidity risk that have a significant premium are: the liquidity comovement between options and their market, the liquidity comovement between options and the stock market, the option liquidity comovement with the stock excess return, and the option liquidity comovement with stock market liquidity.

## 1.2 Institutional Background

This thesis investigates the role of liquidity in the UK equity options market using Euronext NYSE London International Financial Futures and Options Exchange (LIFFE) London equity options data.

The LIFFE is a futures and options exchange based in London. Following a merger with the London Traded Options Market (LTOM) in 1993, LIFFE added equity options to its product range. Following the takeover by Euronext in January 2002 and Euronext's merger with NYSE in April 2007, LIFFE is currently part of NYSE Euronext. NYSE LIFFE is the derivatives part of the European derivative market comprising the Amsterdam, Brussels, Lisbon, London and Paris markets. Equity options are traded on Amsterdam, Brussels, London and Paris exchanges only. The LIFFE CONNECT is the main trading platform of NYSE LIFFE. It is an anonymous electronic order-driven system that operates an open system architecture allowing users direct access via an Application Platform Interface (API). The NYSE LIFFE trading structure also includes the Euronext Liquidity Provider System (ELPS), through which a market maker can submit two-sided quotes of bid and ask prices. Market makers vetted to participate in the ELPS are required to provide liquidity by quoting simultaneously bid and ask prices at a maximum spread with a minimum quantity regulated by the exchange. In this market, the complete depth is visible to all participants including market makers.

## 1.3 Objectives of the Study

This thesis investigates the role of liquidity in potential channels (also referred to as 'sources') of liquidity risk in the equity options market. It conjectures that liquidity risk channels are associated with market-wide factors of both the options market and the underlying stock market. It assesses whether the liquidity of individual stock options comoves with that of the options market only or with that of the stock market as well. It also assesses how the persistence of liquidity affects option returns over time. Moreover, once the time variation of liquidity in the options market and in the stock market is analysed, this study forwards a rationale that option returns can be partly explained by the illiquidity of an option, illiquidity of the underlying stock and different sources of liquidity risk such as: covariance of the liquidity and return of the option with returns of the stock market; covariance of the liquidity and return of the option with the liquidity of the options and stock markets; covariance of the liquidity of the stock with returns of the stock market; and the covariance of the liquidity of the stock with the liquidity of the options and stock markets. The factor risk premia that include the standard market factor and liquidity risk factors are estimated with the two-pass Fama-MacBeth (1973) procedure.

This study uses UK equity options data covering the period from 22 February 2008 to 31 December 2010. The data is procured from NYSE Euronext LIFFE (London International Futures Exchange), where options on the FTSE 100 stocks are traded. These stocks are considered to be the most active on the London Stock Exchange, and collectively represent around 90% of the stock market capitalization. Therefore, the results related to the impact of illiquidity of either options, their underlying stocks, or the stock market are considered representative of equity option trading in the UK.

This thesis considers the following research questions:

- Does the liquidity of option portfolios comove with the liquidity of the options market, and is this comovement different for different types of options and their characteristics?
- Does the liquidity of option portfolios comove with the liquidity of the underlying stock market? Does this depend on the type and characteristics of the options? To our knowledge, this has not yet been researched in the literature.
- The literature identifies that inventory risk, information asymmetry and derivative hedge theories can explain the bid-ask spread. Which of these theories explain(s) variations in bid-ask spreads, particularly the comovement in spreads in the LIFFE equity options market?
- How does persistence in equity option liquidity affect option return? Are options sensitive to unexpected liquidity in the options and stock markets? Does this sensitivity depend on the moneyness and maturity characteristics of the options?
- Does liquidity of an option and its underlying stock affect that option’s returns? What are the potential sources of liquidity risk in the equity options market, and do they affect the return of individual options? What premia explain variations in option returns? Are they related to the illiquidity premium, hedging cost premium and/or premia for the sources of liquidity risk? The premia of potential sources of liquidity risk are being investigated for the first time in the literature on equity options. Importantly, this study is the first to explore premia related to liquidity of an option, liquidity of the underlying stock and different sources of liquidity risk in UK equity options.

The specific objectives of each empirical chapter of this study are presented next.

### 1.3.1 Specific Objectives of Chapter 4

Cao and Wei (2010) document liquidity comovement between options and their market. For a 1996-2010 sample of CBOE options, they find that options liquidity comoves with that of the options market. In the Black-Scholes-Merton economy, options can be replicated by positions in stocks and bonds. However, in the presence of trading frictions, options are not redundant. Thus, trading costs become important for options. Derivative hedge theory proposes that spreads in the options market are determined, at least partially, by the spreads in the underlying stock market when a market maker can completely hedge her option positions by deriving liquidity in the underlying stock market. Further, the primary motive of market makers in the options market is to provide liquidity. Therefore, liquidity comovement for an option may not only be due to liquidity in the options market but also to liquidity in the underlying stock market. In addition, liquidity comovement can have volatility effects. Cao and Wei (2010) find that firms show a volatility effect in liquidity commonality. In times of high volatility in the underlying market, the liquidity of options comoves with the liquidity of the option market. This can potentially separate the effect of the comovement of liquidity of the option that is due to liquidity of the underlying stock market from that which is due to liquidity of the options market, which is potentially another liquidity risk channel.

Chapter 4 poses the following questions:

- Is there evidence of liquidity comovement between UK options and their market? Is there evidence of liquidity comovement between options and the market of their underlying stocks?
- Does liquidity comovement differ across calls and puts and across moneyness and maturity characteristics? What are the implications of these differences?
- Are there any size and volatility effects in this liquidity comovement? It is plausible to expect that options of small firms have a higher liquidity comovement since small stocks are more affected by inventory risk and information asymmetry than large stocks (Cao and Wei, 2010).
- What are the possible explanations for liquidity comovement across different types of options and their characteristics? What are the possible explanations to variations in spreads across options in terms of inventory risk, information asymmetry and derivative hedge theories?

### 1.3.2 Specific Objectives of Chapter 5

In the Liquidity-adjusted Capital Asset Pricing Model of Acharya and Pedersen (2005), the return of an asset net of transaction costs is related to the illiquidity premium, the market risk premium and the liquidity risk premium. The liquidity risk premium in the stock market is further identified to be related to three main sources. One of these sources is the sensitivity of asset return to liquidity in the asset market.[1]

[1] The other two sources are: comovement between stock illiquidity and stock market return and comovement between stock return and stock market illiquidity.

Amihud (2002) investigates the time-series and cross-sectional effects of market liquidity on stock returns in the New York Stock Exchange. Following the methodology of Amihud (2002), we investigate the time-series effects of options market liquidity and stock market liquidity on returns of call and put option portfolios created by moneyness and maturity bands.

We investigate two main research questions. The first relates to the sensitivity of option return to liquidity in the options market. The second relates to the sensitivity of option return to liquidity in the stock market. The relationship of liquidity in the stock market with option returns is important because option payoff depends on the price of the underlying stock.

Further, since liquidity is persistent (Amihud, 2002), expected and unexpected components of liquidity can be separated by, say, an autoregressive (AR) model that captures persistence. Two hypotheses are developed to investigate the time-series effects on option returns of illiquidity in the options market and illiquidity in the stock market:

- Hypothesis One: expected illiquidity in the options market has a positive effect on the contemporaneous option excess return. This is the direct implication of the persistence in liquidity. When markets are liquid, persistence would partly imply that markets will be liquid in the next period.

- Hypothesis Two: unexpected illiquidity in the options market has a negative effect on the contemporaneous option excess return. Unexpected illiquidity can be estimated as the residual from the AR(p) specification used to describe the persistence in market illiquidity.

These two hypotheses are also investigated for illiquidity of the underlying stock market, and tested separately for calls and puts and their portfolios based on moneyness and maturity.

To investigate these research questions and hypotheses, the methodology of French et al. (1987) and Amihud (2002) is used. Our approach is different in the sense that Amihud (2002) investigates the time-series impact of market liquidity on market returns, while in

Chapter 5 we investigate the time-series impact of illiquidity of the options and stock markets on returns of portfolios of call and put options based on moneyness.

### 1.3.3 Specific Objectives of Chapter 6

Recently, Christoffersen et al. (2015) investigates how liquidity of an option and its underlying stock affect option returns in the CBOE options market. They find that option illiquidity affects option returns positively and stock illiquidity affects option returns negatively. The positive impact of option illiquidity suggests that investors require premium to hold an illiquid portfolio of options. The negative impact of stock illiquidity suggests that potentially investors in options want to hedge their option positions in the underlying market by trading the underlying stock, for which they are willing to forgo a part of their expected option return in the form of a premium for higher illiquidity in the stock market.

In the stock and bond markets, an illiquid asset provides a higher return. This higher return includes the premium for the illiquidity of the asset as well as a premium for liquidity risk. However, in options markets, the payoff of an option depends on the payoff of the underlying asset, and the option can be replicated by trading delta units of the underlying stock. Therefore, illiquidity in both the options and the underlying stock market become relevant.

Chapter 6 has the following specific aims:

- Identify the sources of liquidity risk that potentially affect option prices.
- Quantify option portfolio returns by implementing a delta-hedged portfolio strategy such that the hedged portfolio should earn zero net-gains. Moreover, provide a rationale for any non-zero delta-hedged net-gains.
- Investigate the sign and magnitude of the different sources of liquidity risk that are important in explaining cross-sectional variations in option returns.
- Investigate which sources of liquidity risk are important for calls and puts, and whether investors consider different sources of liquidity risk important for different moneyness portfolios.

In order to investigate these issues, the analysis in this chapter employs the delta-hedging portfolio strategy of Bakshi et al. (2003) to measure option portfolio returns, and uses the proportional bid-ask spread as a measure of illiquidity for both options and stocks. In addition, to investigate the risk premia associated with these liquidity variables and liquidity risk channels, the Fama-MacBeth (1973) two-pass procedure is used in their cross-sectional analysis.

The derivative market is a net-zero supply market. It is possible that the premia related to the liquidity of the option, the liquidity of the underlying stock, or the liquidity risk channels to have different signs for puts or calls or for different moneyness portfolios. There is no theoretical model that predicts the signs for the following sources of liquidity risk: the covariance of liquidity and returns of the option with the returns of the stock market; the covariance of liquidity and returns of the option with the liquidity of the option and stock markets; the covariance of the liquidity of a stock with the returns of the stock market; or the covariance of the liquidity of a stock with the liquidity of the options and stock markets. Therefore, we use the Fama-MacBeth (1973) two-pass regression procedure to investigate which of these sources of liquidity risk are important for equity options, and whether they differ across puts and calls and their moneyness.

## 1.4 Organization of the Thesis

Chapter 2 provides a review of the literature related to liquidity comovements, sensitivity of stock market returns to stock market liquidity, and liquidity risk channels and their pricing in the stock market. It also provides a review of the theoretical and empirical findings in the literature on liquidity comovement in the derivative market with a particular focus on the sparse evidence documented on the equity options market. The review of relevant literature, however, is not restricted to Chapter 2, and subsequent empirical chapters contain reviews of specifically relevant background and motivational literature. Chapter 3 describes data sources, data, variables for the empirical analyses and the descriptive statistics of data. This thesis contains three empirical chapters. Chapter 4 is the first empirical chapter and provides an investigation into liquidity comovement between options and their market, as well as liquidity comovement between options and their underlying stock market. Chapter 5 is the second empirical chapter. It investigates the role of persistence in liquidity in affecting option returns over time. Chapter 6 is the third empirical chapter and investigates the pricing of the liquidity of an option, the liquidity of the underlying stock and the different sources of liquidity risk in equity options. The delta-hedging strategy is used to quantify option returns that are hedged to sources of risk other than liquidity, and which are then used to test for any deviations due to illiquidity. Finally, Chapter 7 provides general conclusions of each empirical chapter, and provides contributions, limitations and recommendations for further research.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

This thesis investigates the sources of liquidity comovements and the pricing of the liquidity of equity options trading on the NYSE Euronext LIFFE London equity options market. This chapter provides a review of the literature on the following: the role of liquidity in financial markets, the market microstructure theories forwarded to explain bid-ask spreads in the stock and options markets, liquidity comovement in the stock market, liquidity comovement in the options market, the sensitivity of market return to market liquidity, and the pricing of liquidity in the stock and options markets. This chapter also discusses the literature relating to the calculation of option returns and the pricing of liquidity risk in the stock and equity options markets.

The thesis employs the methodology used by Cao and Wei (2010) to investigate liquidity comovements in the equity options market, liquidity comovement between options and their market and the liquidity comovement between options and their underlying stock market. Cao and Wei (2010) use the time-series market model to investigate whether changes in the liquidity of options over time comove with changes in the liquidity of the whole option market. To investigate the sensitivity of option returns to liquidity of the equity options market as well as the sensitivity of option returns to liquidity of the stock market, the thesis employs the methodology of Amihud et al. (2002). In order to investigate premia relating to the liquidity of an option, the liquidity of a stock and various sources of liquidity risk, the Fama-MacBeth (1973) methodology is used.

The next section (2.2) presents an overview of the literature on liquidity. It highlights the different aspects of liquidity investigated in the literature. Section 2.3 discusses relevant market microstructure theories. Section 2.4 reviews the literature on liquidity comovement in the stock market. The liquidity comovement in the stock market is commonly referred to in the literature as liquidity commonality. Section 2.5 provides a review of the literature on liquidity comovement in the derivatives markets. Subsection 2.5.1 reviews the literature on liquidity comovement between options and their market.

Subsection 2.5.2 reviews the literature on liquidity comovement between options and the underlying stock market. Section 2.6 discusses the literature on return sensitivity to market liquidity. Section 2.7 reviews studies related to empirical and theoretical models of pricing liquidity risk. Section 2.8 discusses the literature on using option strategies to quantify option hedged returns.

## 2.2 Overview of the Literature on Liquidity

Liquidity has gained much attention in the literature. Several articles have examined liquidity characteristics and pricing but mainly in stocks and bonds. There has been less research on derivative securities such as options. The literature on liquidity can be broadly divided into two main streams. The first focuses on liquidity as an individual asset phenomenon, and the second focuses on the impact of liquidity on asset pricing.

As an individual characteristic, asset liquidity is considered as the ease with which an investor is able to trade the asset in the market. The term liquidity is vague and is not defined precisely. However, the market microstructure literature suggests several measures to quantify liquidity of an asset. These proxies are defined in the context of various liquidity models. One such proxy stems from defining liquidity as the cost of trading that is different from the intrinsic value of a security. In general, there are fixed and variable costs. Fixed costs mainly comprise the fees charged by brokers or dealers. Lower fixed costs per transaction charged by a broker or a dealer imply higher liquidity. Market makers in mediated markets supply immediacy (an aspect of liquidity) at a cost. Therefore, the ask price for buying is different from the bid price for selling. The difference is called the bid-ask spread, or simply the spread. There is a vast literature that empirically analyses the bid-ask spread in stock and bond markets. In general, this literature reports that these costs arise from inventory risk and information asymmetry. Stoll (1978a), Amihud and Mendelson (1980) and Grossman and Miller (1988) suggest that the bid-ask spread arises from inventory risk, which is due to the lack of diversification. Glosten and Milgrom (1985) find that the bid-ask spreads are due to the costs of being uninformed. Theoretical work by Kyle (1985) and empirical work by Glosten and Harris (1988) suggest that the price impact of a trade, which they define as the variable component of trading costs, captures the liquidity effects of asymmetric information. One aspect of liquidity is immediacy. There are three different dimensions of liquidity that are used to quantify costs of immediacy: depth, breadth and resiliency. Depth refers to the incremental quantity available for sale at a price that slightly exceeds the current market price. Depth is used to determine the costs of immediacy by looking at the magnitude of price movement when a large quantity of a buy or a sell order of that security is absorbed in the market. A higher depth indicates a market where large quantities of stocks can be bought or sold without affecting the price by much. Breadth relates to the number of market participants. A large number implies that no individual can assume a monopolistic role or can significantly affect the market. Therefore, a market with a large number of participants is referred to as a broad market. Resiliency relates to the propensity of the market to absorb price shocks quickly.

Liquidity has also been investigated from the perspective of trading mechanisms in terms of their influence on the costs of individual transactions (e.g., Madhavan, 1992). There are mainly two distinguishing features of trading mechanisms. The first is whether the trading system is continuous or periodic. An order in a continuous system is executed as soon as its submitted, while it is accumulated for later execution with other orders in a periodic system. The second distinguishing feature is whether the trading mechanism is quote-driven or order-driven. A quote-driven system, also called a continuous dealer market, depends on competitive dealers posting bid-ask price quotes. In this system, submitted orders are not delayed but executed with market makers. In an order-driven system, all market participants are required to submit their orders and a matching process determines prices. Order-driven systems are either continuous or periodic. Currently, most trading systems are complex hybrids of order-driven and quote-driven systems. Some stock exchanges open trading with an auction and then switch to a dealer market or an order-driven market. In the stock market, Madhavan (1992) compares and contrasts a quote-driven system with an order-driven system that can operate continuously or periodically (a batch market). He models trading as a game where order quantities and beliefs are determined endogenously and players act strategically. He shows that the periodic system is more costly due to traders’ costs of information acquisition because there are no price quotes to observe. In the equity options market, however, Vijh (1990) examines the trade-off between market depth and market spread across the Chicago Board Options Exchange (CBOE) and the New York Stock Exchange (NYSE). Although CBOE and NYSE are both predominantly dealer markets, CBOE is a multiple dealer market where more than one dealer makes the market in one stock and NYSE is, on the main, a single dealer market where only one specialist is assigned to each stock to make the market in that stock. He finds that CBOE is a highly liquid market in that large trades can be absorbed without a major change in the prevailing price. He explains that this is due to the large number of dealers competing in each stock.

The above discussion suggests that liquidity has different dimensions and can be measured by different variables. Since the objective in this thesis is to investigate liquidity comovements and pricing of liquidity risk in the UK equity options market, we procured data from Euronext NYSE LIFFE. The options data provides only end-of-day data files with bid and ask prices. We can measure liquidity mainly by using bid and ask prices. This measure also coincides with how liquidity is usually measured in the asset pricing literature. Therefore, this thesis uses mainly the proportional bid-ask spread, defined as a spread expressed as a percentage of the bid-ask midpoint, in all empirical analyses. In Chapter 4, we also use, for options, the percentage bid-ask spread, which is spread of an option as a percentage of the underlying stock price.

Previously liquidity was thought to be only a characteristic of an asset, but after the seminal work on the interaction between market microstructure and asset pricing done by Amihud and Mendelson (1986), liquidity is confirmed to be an important factor considered by the traders in determining asset prices. Amihud and Mendelsen (1986) are the first to study the impact of liquidity as measured by the bid-ask spread expressed as s percentage of the stock price on expected excess returns of NYSE stocks from 1960 to 1979. Their main findings are that the relationship between excess return and stock betas is linear and that between excess returns and the proportional bid-ask spread is concave. They show that less liquid stocks are priced lower and consequently require a premium for expected return. Similarly, Longstaff (2000) suggests that a lack of tradability (proxy for liquidity) will mean securities trade at lower prices. He derives an upper bound for this discount and suggests that trading frictions lead to substantial implied liquidity premia.

Transaction costs, volume and other market microstructure phenomena have common underlying determinants. Some parts of transaction costs co-vary over time (Wood et al., 1985). As such, liquidity of an asset as measured by transaction costs should comove over time with market-wide factors. Chordia et al. (2000), Huberman and Halka (2001), and Hasbrouk and Seppi (2001) purport this idea. These market-wide factors include the risks of accumulating inventory by liquidity providers, information asymmetry, and market volatility. One of the main sources of liquidity comovement is inventory risk; that is, trading activity having an inter-temporal response to general price variations across the whole market (Chordia et al., 2000). For a liquidity provider, trading volume is a main component of inventory risk. Changes in trading volume will most likely induce comovement in the optimal levels of inventory. To avoid inventory risk, the dealer may increase the bid-ask spread.[2] Therefore, the variations in trading volume may lead to variations in the levels of optimal inventory. This in turn causes changes in the bid-ask spread, quoted depth, and other liquidity measures of individual assets. The other potential sources of liquidity comovement include programme trading and investing styles of institutional investors. Programme trading of simultaneous large orders and investing styles of the institutional investors put common pressures on dealer inventories. These could cause correlated patterns across trading and thus, dealers' response to the changes in the optimal level of inventories could be correlated. Such correlated patterns across trading may underlay comovements in liquidity and perhaps prices.

Liquidity comovement is also investigated in the derivative markets. The two main studies are Cao and Wei (2010) on the CBOE equity options market and Deusker et al. (2011) on the over-the-counter (OTC) Euro (€) interest rate market. Cao and Wei (2010) document evidence for liquidity commonality between options and their market. However, for an option, liquidity in the underlying stock market may also be important. Cho and Engle (1999) suggest that an important determinant of option trading costs is underlying stock market activity as they suggest that investors' primary concern is hedging when trading in the derivative market. The more difficult it is for market makers to hedge their net positions by deriving liquidity in the underlying market, the greater is the spread in the derivative market. Therefore, the spread in the option market is related to the spread in the underlying stock market (Cho and Engle, 1999). In support of this argument, Cao and Wei (2010) find a positive correlation in the proportional bid-ask spread between equity options and stock markets.

It is important to understand how market microstructure theories explain the bid-ask spread. These explanations further help us understand which theories could explain the changes in liquidity (the bid-ask spreads) in the equity options market. The related

[2] If trade volume increases, dealers also face a trade-off between decreasing the spread due to the increased trading intensity and increasing the spread due to possible information asymmetry accompanying the large volume. The dealers have to balance between the inventory and information asymmetry risks and therefore, the result could also be a decrease in spread rather than increase in spread (in case the enhanced liquidity overrides the information asymmetry).

theories that can help explain bid-ask spreads in the stock and option markets are inventory management, information asymmetry and derivative hedging. These are discussed next.

## 2.3 Role of Liquidity in Market Microstructure

Liquidity is at the core of microstructure theories that deal with the arrival of orders, revision of quotes, and transaction prices. One dimension of liquidity is the cost of immediacy in executing orders. When traders are able to buy or sell stocks quickly at lower costs and at a price not too different from previous observed price, the market is considered more liquid. Moreover, liquidity is hard to measure because normal price movements are not easily distinguishable from those resulting from large orders. The bid-ask spread is therefore one of the most common proxies because it captures round-trip average costs of traded normal quantities (Cho and Engle, 1999).

In Section 2.3.1, we present the two most common theories of market microstructure used to explain bid-ask spreads, and in Section 2.3.2, we discuss the empirical explanaitons of bid-ask spread in the market microstructure.

### 2.3.1 Theoretical Discussion

The two most common theories of market microstructure that are used to explain bid-ask spreads are inventory management and information asymmetry (Huberman and Halka, 2001). Under models of both theories, market makers are compensated by the spread between ask and bid quotes. The reasons of maintaining a spread in competitive markets vary across both theories. Inventory-based explanations focus on inventory risk exposure of the market maker. Since market makers are providers of liquidity and, in general, do not want to accumulate inventory, they are assumed to be risk-averse. The market maker either has bounds on the amount of inventory to be held (Amihud and Mendelson, 1980), or a desired target inventory level and a cost of deviating from it (Ho and Stoll, 1983). Market makers quote two prices, bid and ask, which determine the stochastic arrival rates of buyers and sellers, and adjust these prices dynamically to optimize their inventory levels. They charge the spread to compensate themselves for undesired inventory risk. Whenever a market maker completes an order that causes his inventory to deviate from optimal or target levels, he adjusts either or both the bid/ask quotes to attract the desired type of order to re-optimize his inventory position. The more the order imbalance accumulates, the wider the bid-ask spread he quotes. In Stoll's (1989) model, the spread is an increasing function of trade, volatility and risk aversion. Moreover, the bid-ask spread is independent of the inventory level.

Unlike inventory models, market makers are not assumed to be risk-averse in information asymmetry models. They can be risk neutral. Information asymmetry models view the market as consisting of three types of traders: those with private information (informed traders), those with life-cycle needs to trade (liquidity traders), and market makers. Since market makers do not possess private information, they are at an informational disadvantage. They, however, perform an important function of proving liquidity to the market, and should earn a fair return on their capital. They trade with both liquidity (uninformed) and informed traders. They will, therefore, lose by trading with informed traders, but compensate by trading more often with the uninformed or by widening the spread. The theory suggests that variable trading costs arise only because of the presence of informed traders, and their profits are made at the expense of uninformed liquidity traders. These costs, which are covered by the spread, are called adverse-selection costs, and according to Cho and Engle (1999) they exist for a risk neutral as well as competitive market maker (Copeland and Galai, 1983; Glosten and Milgrom, 1985; and Easley and O'Hara, 1987). Copeland and Galai (1983) formalize the idea in a one period model. They maximize the profit of a market maker under asymmetric information and show that nothing more than asymmetric information is required to induce spreads. In their model, spreads increase with price and volatility, and decrease with market activity, depth, continuity, and the degree of competition. The consequence is that spreads are lower when volume (number of transactions) is higher. However, Ibrahim and Kalaitzoglou (2016) suggest that a higher volume may not necessarily be related to a lower spread. They present evidence that higher volume increases the adverse selection (asymmetric information) component and decreases the liquidity cost component of the spread, but at different rates. The net effect will determine whether the spread increases or decreases, which will depend on the relative magnitude between those two forces. Transactions signal information (Glosten and Milgrom, 1985 and Easley and O'Hara, 1987). A buying order would result in an increase in the spread because according to the dynamic model of Glosten and Milgrom (1985) the market maker would increase the value of the asset and the opposite will be true for the selling order. Size of the trade also is interpreted as a type of signal. Informed traders prefer larger size. Easley and O' Hara (1987) in their model consider that market makers adjust prices and spreads according to the size of a large order that they would take on aas a signal of informed trading.

### 2.3.1 Empirical Discussion

There are several papers which explain the spread in inventory models such as Lee, Mucklow, and Ready (1993), Hasbrouck and Sofianos (1993) and George and Longstaff (1993). For example, for the NYSE stocks, Lee, Mucklow, and Ready (1993) provide evidence that the spread is positively related to the trading volume. Hasbrouck and Sofianos (1993) show that the participation of NYSE specialist in trades is generally accompanied by a bigger and qauicker effects on spreads than when they do not participate. Madhavan and Smidt (1993) report that the revisions in the bid-ask quotes are positively related to the order imbalances. In the options market, George and Longstaff (1993) study spreads of the S&P100 index options. They classify them based on the inventory cost and show that the differences in the cross section of the spreads should be related to the cost-related variables.

Trading volume is also used as a measure of liquidity. It features in different market microstructure models to indicate inventory risk and information asymmetry in a market. Harris and Raviv (1993) suggest that high trading volume reflects mainly high liquidity (uninformed) trading and therefore, market liquidity is higher. Due to high trading volume in the market, risk of an order imbalance for a market maker is lower. Thus, high trading volume suggests low inventory risk. Another argument for low inventory risk is high volume due to many traders (market participants) buying and selling securities. However, in the Easley and O'Hara's (1992) model, specialists use trading volume to infer the presence of informed traders. Lee, Mucklow and Ready (1993) investigate the effect of volume on quoted liquidity. Using a time-series regression model, they find that quoted depth decreases and spreads widen in response to abnormally high trading volume in the market. They suggest that when trades differ in size, the combination of a smaller quoted depth and a wider quoted spread is sufficient to infer a decrease in quoted liquidity consistent with the model of Easley and O' Hara (1992).

In the equity options market, trading volume and open interest are used as proxies for inventory risk (Cao and Wei, 2010). According to inventory risk theory, as discussed above, a higher trading volume decreases the risk of an order imbalance and, consequently, a market maker will face lower inventory risk. This implies a negative relationship between option spreads and option trading volume as opposed to what Lee, Mucklow and Ready (1993) find. Recently, Ibrahim and Kalaitzoglou (2016) suggest that the sign of the relationship between trading volume and the spread depends on the net-effect between the increase in information asymmetry and the decrease in the liquidity cost components of the spread that accompany an increase in volume. Open interest is defined as the number of option contracts that are open or not yet delivered on a particular day. An increase in open interest implies that market makers are facing an order imbalance. According to inventory risk theory, an increase in the order imbalance will lead to an increase in inventory risk and, therefore, the relationship between option spreads and option open interest is expected to be positive. Individual trading activity is associated with information asymmetry. Jones et al. (1994) suggest that the number of trades is a better indicator of information asymmetry than the dollar volume of trading. They show that volume has a lower impact on volatility than has trading frequency.

Bid-ask spreads in the options market may be determined not only by the activity in the options market but also by the activity in the underlying asset market. In this regard, Cho and Engle (1999) propose a derivative hedge theory that highlights how liquidity in the underlying market is related to hedging risk in the derivatives market. A market maker in derivatives can observe liquidity in both the derivative and underlying markets. Further, he can use both while hedging his derivatives position in the stock market, which is a deeper market. According to Cho and Engle (1999), when the derivative's market maker is able to hedge all his positions, he will not be exposed to the risks of either inventory or information in that market. From liquidity perspective, when the market maker executes a trade with an informed trader but he hedges perfectly, he will not be with informed traders and hedges his position perfectly, the informed trade will not affect him as derivative market liquidity will be a function of the asset market instead of activity in the derivatives market. Therefore, the presence of the informed traders in the asset market will imply that the spreads will be wide in the asset as well as derivative market. The argument follows that the spreads in the derivatives market exist because of the difficulty to perfectly hedge inventory positions, due to the illiquidity of the underlying asset market.[3]

[3] The argument that the spreads in the derivative market are due to the investors being unable to hedge in the underlying market assumes that the derivative has a tradable underlying asset with synchronous trading hours. This is true in the case of equity options market but may not be the case in other derivative markets where both a tradable underlying asset and synchronous trading hours may not be present.

Having discussed how inventory, information asymmetry and derivative hedge theories explain changes in bid-ask spreads, we contribute to the literature by investigating which theories explain changes in option spreads. In the next section, we review the literature on changes in the liquidity of an asset with that of the market, which is referred to in the literature by liquidity comovement or liquidity commonality.

## 2.4 Liquidity Comovement in the Stock Market

It is documented that liquidity of a security is relaed to order flow (Tinic, 1972; Menyah and Paudyal, 1996).

However, liquidity comovement (or liquidity commonality) refers to the idea that liquidity of a security covaries with market-wide factors such as returns, liquidity and volatility of the overall market. In the literature, several explanations are forwarded for the comovement of the liquidity of an asset with that of the whole market. One such explanation is that liquidity costs have a common component across stocks in the market (Hasbrouck and Seppi, 2001). Another explanation is that some securities act as substitutes for others (Huberman and Halka, 2001). Further, when liquidity is measured by transaction costs such as the bid-ask spread, a plausible reason that would give rise to commonality in liquidity is trading activity. If increased trading activity indicates superior information, a market maker in dealer markets will evaluate his optimal inventory (Galariotis and Giouvris, 2007), which in turn might cause the comovement in the bid-ask spread. This would imply that a common liquidity component is related to inventory or information asymmetry risk.

Comovement in liquidity may have interesting implications for markets. Chordia et al. (2000) note that stocks with higher average liquidity costs require a higher return. There might also be additional compensation that investors may demand for stocks that are more sensitive to shocks in market-wide liquidity. During times when a market experiences a negative liquidity shock, and stock liquidity is sensitive to market liquidity, then investors would be expected to require higher returns for less liquid stocks, which suggests a required premium for liquidity commonality.

Chordia et al. (2000) were the first to investigate liquidity commonality in the stock market. They investigate commonality in liquidity of 1,169 NYSE stocks over the 253 trading days of 1992. They employ several proxies to measure liquidity: quoted or effective spread, proportional quoted or effective spread, and quoted depth. Their approach focuses on how the daily changes in liquidity of each stock covary with the daily changes in the liquidity of the stock market. They measure market liquidity by the average liquidity of all the stocks in the market. Their market model time-series regression results provide evidence of comovement in liquidity. They report that changes in stock liquidity are positively related to change sin market liquidity. The percentage quoted spread has a significant liquidity comovement coefficient of 0.791 with an average adjusted-$R^2$ of less than two percent for all the individual stock regressions. They further investigate the source of this liquidity comovement and find that market-wide dollar volume (proxy for inventory risk), average dollar size of a transaction (proxy for asymmetric information/informed trading), and the total number of trades for a stock affect changes in the liquidity of that stock. They suggest that an increase in market-wide dollar volume represents a decrease in inventory risk, whereas an increase in the number of transactions suggests the opposite in inventory risk. The increase in the number of transactions can be interpreted as an attempt by an informed trader to strategically break up large trades into smaller ones in order to hide information. The same is reported by Barclay and Warner (1993) and further suggest that the practice is more prominent in medium-sized trades.

Hasbrouck and Seppi (2001) and Huberman and Halka (2001) also find evidence of liquidity comovement across stocks by employing approaches different from that adopted by Chordia et al. (2000). Hasbrouck and Seppi (2001) document a component of liquidity that is systematic and time-varying. They argue that this component of liquidity is not explained by inventory or asymmetric information aspects. Huberman and Halka (2001) study the constituents of the DJIA index during 1994. Their goal is to investigate whether liquidity has a systematic component and any variables that might be correlated with it. They employ principal component and canonical correlation analyses on the following liquidity variables: log quote slope, log spread, and quote slope.[4] They investigate the levels of liquidity over 15-minute intervals after standardizing the data by removing time-of-day effects where they exist. They find weak evidence of liquidity comovement and report that one common factor explains 13% of the total variation in the log quote slope,

[4] Log quote slope is measured as $\frac{\log\left(\frac{A_k}{B_k}\right)}{\log\ (N_k^A)+\log(N_k^B)}$. Where, $A_k$and $B_k$ are ask and bid quote prices of record k, and $N_k^A$ and $N_k^B$ are the number of shares posted at ask and bid quotes, respectively.

11.83% of the total variation in the log spread, and 10.75% of the total variation in the quote slope. They report the common factors in liquidity are weak.

Coughenour and Saad (2004) were the first to investigate the economic sources of liquidity comovement. They consider the specialist structure of the New York Stock Exchange (NYSE) and show that liquidity comovement arises because each NYSE stock specialist firm provides liquidity for many stocks simultaneously. These specialists provide liquidity in the market from the same capital pool, and share inventory and profit information, which leads to comovement in liquidity across the market. They estimate the degree of comovement of individual stock liquidity with the liquidity of the NYSE market portfolio and, separately, with the specialist portfolio. They find evidence that average market liquidity beta (liquidity comovemnt between stocks and the stock market) for the stock specialist portfolio has a range from 0.66 to 0.80 across the four different measures of liquidity used; a results that is comparable to the findings of Chordia et al. (2000). Coughenour and Saad (2004) report a mean adjusted-$R^2$ of around 22% which is much higher than the 1.4% reported by Chordia et al. (2000). They argue that these differences are mainly due to the different aggregation periods used, as aggregation periods include intervals of morning, midday and afternoon. After aggregating at daily intervals, the beta coefficients are slightly lower ranging from 0.60 to 0.71 and the mean adjusted-$R^2$ is 2.9% to 3.9%, which is comparable to the figure reported by Chordia et al. (2000). This suggests that changes in liquidity of a stock can be explained by changes in the liquidity of the stock market, but the $R^2$ depends on the aggregation interval. With daily intervals, the coefficient of liquidity comovement (or liquidity beta) is smaller than for shorter intervals. The conflicting evidence on liquidity comovement documented for example by Chordia et al. (2000) and Hasbrouck and Seppi (2001) may be due to the intervalling effect of the aggregation of liquidity. Chordia et al. (2000) use daily measure of liquidity whereas Hasbrouck and Seppi (2001) use similar measure but estimated over a 15 minutes interval. Hillier et al., (2007) propose that delays in the adjustment of spreads to new information could help explain the conflicting findings for the liquidity commonality. They suggest that short interval used in measuring liquidity in the study by Hasbrouck and Seppi (2001) may explain the documented weak evidence of liquidity commonality. Hillier et al. (2007) for the LSE stocks for the sample from 22 December 1993 to 31 July 2003 show that sensitivity of liquidity comovement in securities increases with the interval over which changes in spread are measured. Moreover, they also show that the intervalling effect is more pronounced with the size of the security.

Studies in order-driven markets also document evidence of the commonality in liquidity. In a limit order market, comovement of liquidity supply and demand may be related. When a trader submits either a market order (thus being a liquidity taker) or a limit order (being a liquidity provider), and if choices of the order types are correlated across stocks, this may result in liquidity commonality (Chordia et al., 2000). Domowitz and Wang (2002) support this conjecture using simulations of the limit order book for two hypothetical stocks and actual limit order book data from the Australian Stock Exchange for the period 22 February 2000 to 31 December 2000. They study the causes of commonality in liquidity and returns, and evaluate the asset pricing implications by showing a link between liquidity commonality and return comovement. Their simulation results show that comovements in supply and demand may be a cause of liquidity commonality. This supply demand comovement is a channel through which the type of order (market versus limit order) plays an important role, and return comovement is mainly caused by order-flow (size and direction) comovement. Moreover, they suggest that when stock returns are negatively correlated, liquidity comovement for such stocks can be positive and may pose a problem to diversification strategies. Corwin and Lipson (2011) confirm the results of Domowitz and Wang (2002) using electronic order flow data for a sample of NYSE-listed stocks. They find that both the common order flow and the common order type by the type of trader matter for liquidity. The type of traders include program traders, institutional traders, retail traders, and exchange members. They do not separately include the common factor of order type in their regressions, so they cannot determine what the incremental explanatory power is for disaggregating trader type, or whether the comovement of order types is mainly due to a specific group of traders. For order flow, they show that comovement is mainly due to program traders, so the common factor of order type might as well be. Also, since the order flow factor explains some fraction of liquidity (albeit mild), program traders play a role. This evidence suggests that algorithm traders might have a significant influence on liquidity commonality, as they usually operate across many different stocks and have correlated strategies, or their strategies involve buying and selling many different stocks at the same time (e.g., statistical arbitrage), therefore taking liquidity across many different stocks simultaneously.

Bauer (2004) investigates liquidity commonality in a pure order-driven market from 03/05/2002 to 31/07/2002 on 19 stocks traded on the Swiss Stock Exchange (SWX).

Through principal component analysis he finds three or four common factors are able to explain part of the variation in liquidity, which is higher than what is found for quote-driven markets (see Huberman and Halka (2001)). He further reports that liquidity is affected by these common factors across orders and quoted quantities of all sizes. The proportion of liquidity variation that these common factors explain varies over the trading day. Moreover, they report that cross-sectional liquidity is significantly affected by market-wide liquidity and market-wide volatility, and these two variables are responsible for a fifth of the variation in the cost of liquidity whereas they are responsible for only 6% of depth.

Fabre and Frino (2004) investigate the commonality in liquidity for stocks trading on the Australian Stock Exchange (ASX) using transaction and quote data for the year 2000. Although they find evidence of commonality in liquidity for ASX stocks, it is not significant as observed in other markets (e.g, NYSE). They find the size effect in the commonality in liquidity to be significant. This size effect is slightly different from that reported by Chordia et al. (2000) who find it when liquidity is measured by the bid-ask spread but not when liquidity is measured by depth.

Brockman et al. (2007) study liquidity commonality across 47 stock markets. Using intraday spread and depth data, they report that liquidity changes at firm-level are significantly affected by those at the exchange level. They find exceptionally strong commonality in liquidity for emerging Asian exchanges and very low commonality in liquidity for Latin American exchanges. Through a cross-exchange analysis, they also report a ‘distinct global component in bid-ask spreads and depths’. They further show that local and global sources of liquidity commonality explain approximately 39% and 19% of a firm’s total liquidity commonality respectively. They find that both domestic and U.S. macroeconomic announcements drive commonality in liquidity at both exchange and global levels.

Other work on liquidity commonality in stock markets includes Sadka (2006) and Korajczyk and Sadka (2008) for US stocks and, Kyaw (2006) more recently, Gregoriou et al. (2010) and Foran et al. (2015) for UK stocks trading on the London Stock Exchange (LSE). Sadka (2006) investigates liquidity risk components by decomposing firm-level liquidity into fixed and variable price effects that can explain the price-momentum and post-earnings-announcement drift (PEAD) anomalies in asset pricing.[5] As suggested by Lesmond et al. (2004), momentum and PEAD strategies involve frequent costly trading that may reduce profitability. Sadka (2006), however, investigates whether the returns of these strategies are associated with time variation in liquidity as documented by Chordia et al. (2000) and others. He shows that the variable component demands a premium of 6.5%, while the fixed component is not priced.

Korajczyk and Sadka (2008) estimate latent factor models for each set of liquidity measures. They find that for each individual measure of liquidity there is a liquidity comovement across assets and these common factors are correlated across measures of risk. Since there are alternative measures of liquidity used in the literature, some measures could have systematic and asset specific components of liquidity. Systematic components of different liquidity meausres could also be correlated with each other when these different liquidity measures estimate the same facet of liquidity or measure different facets of liquidity which are correlated.

In the UK equity market, Kyaw (2006) investigates existence of liquidity commonality and the effect of aggregate liquidity on a stock's liquidity using data on 733 LSE stocks from 22 December 1993 to 31 July 2003. She reports four main findings in her empirical analysis. First, there is a positive relation between the changes in stock's liquidity and the changes in market-wide liquidity. Second, liquidity commonality is more pronounced for large stocks than small stocks. Third, liquidity of large stocks is an important market determinant since it affects the liquidity of other large stocks and significantly affects the liquidity of small stocks.

In the UK equity market, Gregoriou et al. (2010) investigate liquidity comovement using data on LSE stocks from 10 October 2005 to 10 June 2009. Like Chordia et al. (2000), they investigate liquidity commonality using the time-series market model and shed some light on its determinants. Their empirical findings provide strong support for Fernando et al.'s (2008) argument that liquidity shocks that result in a financial crisis are permanent and systematic. Fernando et al. (2008) explain that due to negative shocks, liquidity in an

[5] The price-momentum anomaly is relates to abnormal returns unexplained by measures of risk of zero-cost portfolios that are long in winner stocks (stocks that out-performed in the past) and short in loser stocks (stocks that under-performed during the same period) (Jagadeesh and Titman, 2001). The post-earnings-announcement-drift anomaly suggests that firms with good-news (high unexpected earnings) perform better than those with bad-news (low unexpected earnings). This is due to the fact that investors underreact tot the earnings announcements and this induces continuations in returns.

order-driven market decreases because large number of market makers withdraw from the exchange following large order imbalances. Gregoriou et al. (2010) observe that evidence of liquidity comovement is more apparent after the credit crunch. They proxy trading activity by the number of trades and trading volume in pounds. They present evidence that in the UK equity market the liquidity comovement between the market portfolio and financial companies is mainly due to trading activity around the 2007 crisis. They report that the mean change in concurrent market liquidity ranges from 0.1030 to 0.9052, and 80% of the stocks in the sample have a positive and significant coefficient. Moreover, they report an average $R^2$ above 5%, which is higher than the 1.4% reported by Chordia et al. (2000) for NYSE stocks. For the credit crisis subsample, they report that the concurrent liquidity coefficient is significant for all stock regressions, and the average R-square also increases to more than 10%. The plausible reason for FTSE 100 stocks showing stronger liquidity comovement than NYSE stocks is that FTSE 100 stocks are the largest and most heavily traded in the UK whereas Chordia et al.'s (2000) 1169 US-firm sample was more mixed. Galariotis and Giouvris (2007) report that the average NYSE or NASDAQ firm size is lower than the normal market size in LSE. It is probably due to this that stronger liquidity comovement for LSE stocks is observed. The finding of stronger liquidity comovement in the post crisis period is consistent with the proposition of Brockman and Chung (2002) that stronger commonality for big firms can be generated by investor behaviour. When a market is under stress, investors holding shares of big firms seek to liquidate their stocks at the lowest possible cost, whereas the share price of small firms with higher levels of information asymmetry will decrease drastically in bear market causing an increase in the component of their costs that are associated with liquidity, which explains the higher liquidity comovement in big firms.

Another recent study on liquidity commonality in the UK equity market is Foran et al. (2015). They use daily data from January 1991 to December 2013, with 1274 stocks in 1991 rising to 2,240 stocks in 2006. They first investigate the commonality in liquidity, and then examine whether its systematic risk commands a premium in the cross-section of returns. They find that liquidity shocks to individual stocks are related to those of the market, which is evidence for liqiuidity commonality. Using principal component analysis, they extract systematic or market liquidity factors and provide evidence that these command a positive risk premium. Their result is counter-intuitive because a positive risk premium to systematic liquidity implies that illiquid stocks underperform liquid stocks or the former provide smaller returns than the later. It is contrary to what conventional wisdom suggests, which is that in a positive supply market an investor requires a higher return for a stock with a higher bid-ask spread compared to a similar stock with a lower bid-ask spread. For US markets, Amihud and Mendelsen (1986) and Acharya and Pedersen (2005) find that stocks with higher proportional bid-ask spread (illiquid stocks) have higher returns compared to stocks with lower proportional bid-ask spread. Foran et al. (2015) explain that their finding may be because of the differences between US and UK market structures. For example, NASDAQ in the US moved from a quote driven to a hybrid mechanism that includes an order book and NYSE is a hybrid structure with specialists who obliged to provide some stability to stocks assigned to them. However, in the UK, the London Stock Exchange (LSE) operates two main mechanisms: the Stock Exchange Electronic Trading Service (SETS) and the Stock Exchange Automated Quotation System (SEAQ). SETS is a pure order book for liquid stocks and SEAQ is a quote-driven system for less liquid stocks that are supported by market makers.

The above discussion suggests that whether investors pay or receive a premium for illiuqidity also depends on the market structure, even though stocks in the stock market are in positive supply. This is what one would expect in a zero-supply market, where the expected premium for illiquidity of an asset would depend on the net-supply of that asset in the market. Accordingly, this is important for a portfolio manager who seeks to diversify his portfolio by adding stocks that provide diversification benefits. In the mean-variance setup of Markowitz, low or negative return correlations across stocks provide diversification benefits under the assumption of a frictionless market (for example, no transaction costs). In this case, the diversification benefits result from first (mean) and second (variance and covariance) moments of returns. Although a diversification strategy considers the return levels and return interactions among securities, empirical evidence suggests that realizing returns would not be possible in the presence of frictions, such as transaction costs. For example, Brennan and Subrahmanyam (1996) report that a significant premium is associated with fixed and variable transaction costs.

Domowitz and Wang (2002) argue that for diversification purposes, investors choose stocks with negative return correlations (or small positive correlations), but it is likely that the liquidity of the chosen stocks comoves with other stocks. If liquidity of one stock dries up, it is possible that liquidity of other stocks also dries up. The cases of the market-wide crisis of the 1987 crash and the sell-off when the markets opened after the 9/11 attacks are examples when systematic liquidity broke down. Moreover, when there is a liquidity shock in the market, an investor holding a diversified portfolio would not be able to sell the securities immediately, as liquidity of all stocks in the portfolio may decrease simultaneously. He may find it difficult, or expensive, to offload the stocks in a timely manner. Consequently, he may lose the benefits of diversification. Therefore, the challenges of realizing the diversification benefits of liquidity comovement (transaction costs) is considered a source of liquidity risk, and hence affects asset prices.

The above discussion suggests that the liquidity of an asset commoves with the aggregate liquidity of the market. When market conditions are tight, as also observed in the Asian Financial Crisis in 2007 and the Russian Financial Crisis (the debacle of LTCM hedge fund) in 1998, liquidity can decrease or dry out. In such situations, Gibson and Mougeot (2004) suggest that investors bid aggressively for the most liquid (safest), and this increases their prices. Moreover, if market liquidity evolves randomly, securities or portfolios which have higher covariation with liquidity should offer a lower liquidity risk premium. They investigate whether market liquidity risk is priced, and whether the lack of significance of the market risk premium as documented in the literature could be explained by omission of stochastic market liquidity shocks. Similarly, in the context of asset pricing, Pástor and Stambaugh (2003) analyse whether market-wide liquidity is considered as a state variable. They find that the stock returns are sensitive to changes in aggregate liquidity, cross-sectionally this sensitivity affects expected stock returns. These studies are further discussed in Section 2.6, where we review the literature on return sensitivity to market liquidity.

The finding that individual stocks exhibit a liquidity comovement with the stock market would lead to the identification of a potential risk factor that should be considered in an asset-pricing framework. Liquidity comovement raises a potential issue of whether a shock in trading costs (as a measure of illiquidity) amounts to a cause or source of systematic priced risk. The asset pricing implication of liquidity comovement implies that if co-variation in trading costs is unexpected and has a varying effect across individual stocks, the expected return of a stock must be greater if it is more sensitive to such shocks. In this case, liquidity comovement ought to be a priced risk factor in security returns.

Acharya and Pedersen (2005) were the first to propose a model that provides a unified theoretical framework that explains how liquidity comovement and other sources of liquidity risk affect asset prices. Their model explains the empirical observation that liquidity commands a premium (Amihud and Mendelson, 1986), that return sensitivity to market liquidity commands a premium (Pastor and Stambaugh, 2003; Amihud, 2002; Chordia et al., 2001), and that liquidity comoves with market returns and this comovement has predictive power on future returns (Amihud, 2002; Chordia et al., 2000). We will discuss the two sources of liquidity risk, sensitivity of returns to market liquidity and sensitivity of liquidity to market returns, and the pricing of liquidity risk in light of Acharya Pedersen (2005) in Sections 2.6 and 2.7. The next section presents a review of the literature on the commonality in liquidity in the options market.

## 2.5 Liquidity Comovement in the Options Market

In option markets, the liquidity of an option is an important determinant of the option price. The relationship between the price and the liquidity of an option was first suggested by Brenner et al. (2001). They find that compared to exchange-traded FX options in Israel over-the-counter (OTC) FX options are discounted by an average of 21%, implying that that this discount is related to the illiquidity of the OTC options because of their non-tradability.

The liquidity of an option comoving with market-wide liquidity, and its impact on option pricing, is a recent topic of discussion. Since an option is a derivative security with payoff dependent on that of the underlying asset, liquidity in both the options market and the underlying asset market becomes relevant for options. Moreover, a common option trading strategy is to hedge exposure in the underlying asset to avoid downside risk. To maintain a completely hedged position, a trader needs to trade some number of its underlying asset (delta) in the underlying asset market. This means that the trader will incur costs for trading in both the options and underlying stock markets. As discussed in Section 2.4, liquidity of a stock comoves with the liquidity of the stock market. When there is hedging interest in the underlying stock by the option traders, and that stock's liquidity comoves with stock market liquidity, it is possible that liquidity of the option on that stock could also comove with the liquidity of the underlying stock market. Therefore, we suggest that the liquidity of an option not only comoves with that of the options market but also with that of the underlying stock market. We investigate this in the first empirical chapter (Chapter 4).

We review the literature on liquidity comovement between options and their market in Section 2.5.1. The most prominent studies on liquidity commonality in the options market are by Cao and Wei (2010) for CBOE equity options market and Deusker et al. (2011) for the Euro interest rate market. These will be reviewed in Section 2.5.1. Although we are not aware of literature on liquidity comovement between options and their underlying asset market, we review some relevant literature in Section 2.5.2 that motivate us to investigate this liquidity comovement.

### 2.5.1 Liquidity Comovement between Options and their Market

In this section, we review the two most important papers on liquidity comovement between options and their market. The first is Cao and Wei (2010) on the CBOE equity options market. The second is Deusker et al. (2011) on the Euro interest rate market. There are three main differences between these markets. The first is that they trade two different asset classes, equities and interest rates. The second is that CBOE is an exchange market, whereas the Euro interest rate is an OTC market. The third is that both studies cover two different markets, US and Euro markets.

Cao and Wei (2010) are the first to study liquidity commonality and its characteristics in the CBOE equity options market. They analyse individual equity options data for the period from 1 January 1996 to 31 December 2004. In order to test for the liquidity commonality between options and their market, they employ market-model time-series regressions. As basic evidence, they regress the daily percentage change in an option's liquidity on the contemporaneous and lagged percentage change in the liquidity of the options market. They also control for the following factors that may affect option's liquidity: the percentage change of the corresponding stock's liquidity, contemporaneous return of the stock, the level and percentage change of the firm return squared, the 30-day implied volatility of S&P 500 index options, a year-dummy representing change in liquidity over time, and corresponding contemporaneous and lagged percentage of the stock's liquidity measure projected on the option's market. Their estimation procedure includes two steps. The first step involves a regression for each stock. For each stock, option liquidity is averaged across all options on that stock. The second step involves calculating the average of the coefficients of contemporaneous and lagged percentage change in the liquidity of the options market across all stock regressions, referred to as contemporaneous and lagged commonality, respectively. They provide evidence of liquidity commonality in the options market when the average coefficient of changes in market liquidity is cross-sectionally significant across stocks.

As proxies for liquidity, they use volume, and price impact. Their results show that options liquidity comoves with the liquidity of the options market for all liquidity variables. For all options (calls and puts) combined, for all liquidity measures, they find that contemporaneous liquidity comovement is significant at the 1% level, and most stocks have positive liquidity commonality coefficients. At least 67.72% of stocks show a positive coefficient for the volume measure of liquidity. The average coefficient for the bid-ask measure is 0,863 with a t-statistic of 61.90. Further, they report that 94.78% of these coefficients are positive. Moreover, the coefficient of lagged liquidity is smaller than that of contemporaneous liquidity, and significant only for the bid-ask spread measure. However, for all measures of liquidity, the total commonality (contemporaneous plus lagged) is positive and significant (1% level). Moreover, they report results supporting the hedging-demand argument as stock's liquidity coefficient is significantly positive, especially when liquidity is measured by volume. This suggests that stocks exhibit strong liquidity commonality.

Chordia et al. (2000) find that when firms are binned into size quintiles, big firms show stronger liquidity commonality, and when firms are binned into volatility quintiles, firms with high volatility show stronger commonality. Since the commonality in options liquidity varies across firms, Cao and Wei (2010) also investigate if the commonality shows any size or volatility effects. They divide the commonality coefficients into five firm size bins and they find that small firms have higher commonality in options liquidity using bid-ask spread and price impact, which is contrary to what Chordia et al. (2000) show that big firms show higher commonality in liquidity. As a comparison with Chordia et al. (2000), Cao and Wei (2010) investigate liquidity commonality in the stock market for their sample stocks. They find that, over the whole sample period, small firms show stronger commonality in liquidity, and this is contrary to Chordia et al.'s (2000) finding. Since Chordia et al. (2000) only use data for the year 1992, which is four years prior to the beginning of Cao and Wei's (2010) sample, the latter authors perform a year-by-year analysis for both options and underlying stocks to investigate liquidity commonality in their respective markets. They report a consistent size-effect for options over all years, wheras the size-effect for stocks is consistent with Chordia et al. (2000) for the first four years of their sample (1996, 1997, 1998, and 1999). In other words, big firms have higher liquidity commonality, but the effect reverses in later years (2000, 2001, 2002, 2003, and 2004). However, for the volume measure, Cao and Wei (2010) find that big firms show higher liquidity commonality, especially contemporaneous commonality. They report that it is not surprising to see that volume commonality is stronger for big firms because of comovement of trading volume for these firms with the market volume as far as size is positively related to volume. To conclude, Cao and Wei (2010) find that options of small firms show stronger liquidity commonality than those of big firms, but the small firms themselves show a weaker liquidity commonality in the first four years of the sample and stronger liquidity commonality in the latter five years of the sample.

Cao and Wei (2010) find that options in the high-volatility quintile exhibit stronger commonality, and a monotonic relationship for the bid-ask spread and price impact measures. However, they do not find any statistically significant differences among quintiles for volume-based measures. They explain that it is either inventory risk or information asymmetry that drives liquidity. Under each theory, high volatility intensifies the impact of either factor, which results in stronger liquidity commonality for high-volatility firms.

Like Chordia et al. (2000), Cao and Wei (2010) also investigate how inventory risk and information asymmetry affect option market liquidity. Chordia et al. (2000) argue that inventory risk is reflected in broad market activity whereas information asymmetry is reflected in individual asset trading activity. Market makers face inventory risk on the likelihood of order imbalance and the level of the optimal inventory increases. Because increased volume levels would decrease the likelihood of order imbalances, market makers are likely to have lower inventory risk. Cao and Wei (2010) use option trading volume and open interest as proxies of inventory risk. They also argue that the degree of information asymmetry in a stock may be reflected in the trading pattern of specific options. Informed traders sometimes hide information with frequent trading of small orders (Barclay and Warner, 1993). Consequently, market makers would increase the bid-ask spread. Chordia et al. (2000) use the number of trades of a stock and the average dollar size of a transaction as proxies for information asymmetry of that stock. However, due to data limitations, Cao and Wei (2010) suggest that the only plausible way to determine information asymmetry is to use 'the number of distinct options traded per day'. In order to capture the hedging costs faced by a market maker, they use the underlying stock volume as a proxy. Since we face similar data limitation issues, we also use trading volume of the underlying stock as a proxy for the hedging costs to investigate the hedging cost argument, trading volume of an option as a proxy for inventory risk, and the number of distinct options as a proxy for information asymmetry.

Cao and Wei (2010) find a positive and significant relationship between trading volume and percentage changes in spread. This indicates that higher trading volume is related to wider bid-ask spreads. This finding contradicts the inventory risk proposition. They suggest that although trading volume is a measure of inventory risk, it could also reveal the information role of the options. For example, Black (1975) and Easley et al. (1998) argue that options may be used by informed traders because of their leverage. There is also evidence that the option trading volumes have predictable power on stock prices (Pan and Poteshman, 2006). Therefore, a positive relationship between percentage spreads and option trading volume would suggest that increased volume may indicate information arrival. Market makers then hedge against potential lossee by widening the spreads. The implication is that information asymmetry is an important characteristic of options.

Yet another interesting result of Cao and Wei (2010) is that they confirm the hedging argument of Cho and Engle (1999). A higher stock volume leads to a smaller percentage spread for options. According to Cho and Engle's model, option spreads should be at their minimum until market makers can hedge their option positions by trading the underlying stocks. They also find that calls are more liquid in bull markets and put options are more liquid in bear markets. Their measure of activity is represented by trading dollar volume, and liquidity by the proportional bid-ask spread (defined as dollar spread divided by bid-ask midpoint). When the stock market is in an up-trend, call (put) option prices (bid-ask midpoint) tend to be higher (lower). Consequently, the option spread as a percentage of the bid-ask midpoint tends to be lower. However, it would be interesting to investigate this result, which we do in this thesis, where we consider cases in which the option bid-ask spread is scaled by the underlying stock price.[6] We refer to this as the 'percentage option bid-ask spread'. In Chapter 4, we investigate the liquidity comovement in the options market and the underlying stock market using both measures: the option bid-ask spread as a percentage of the option bid-ask midpoint (the proportional bid-ask spread), and the option bid-ask spread as a percentage of the underlying stock price (the percentage bid-ask spread).

[6] We differentiate between the proportional option bid-ask spread and the percentage option bid-ask spread. We use the term 'proportional bid-ask spread' to refer to the option bid-ask spread when divided by option bid-ask midpoint. Whereas, we use the term 'percentage bid-ask spread' to refer to the option bid-ask spread when divided by the underlying stock price.

As mentioned at the beginning of this section, the other paper that investigates liquidity commonality in the options market is Deuskar et al. (2011) on euro interest rate options. They use daily bid and ask prices of euro interest rate caps and floors, and report higher prices for less liquid options after controlling for volatility smile curve, and the skewness and excess kurtosis in the underlying interest rate distribution. Conventional wisdom, however, suggests that illiquid securities trade at lower prices relative to the liquid ones, which is found in the stock and bond markets. The exception is reported in a study on the UK equity market. Hwang and Lu (2007) find that illiquid stocks have lower return than liquid stocks (Foran et al., 2015). They relate this anomaly to market structure differences between the UK and US.[7] Deuskar et al. (2011) suggest that the results from the stock and bond markets cannot be generalized without regard to the characteristics of the market under study. They explain that the interest rate cap and floor market is an OTC institutional market with very little presence of retail investors. [8] In this market, the buyers of caps and floors are corporations who seek to hedge exposure to interest-rate risk, and the sellers are market-makers who would primarily be concerned with the liquidity risk inherent in the caps and floors. In these markets, trade size is large, and option portfolios usually have long-maturities upto 10 years. The dealers normally have horizons that are shorter compared to the maturity of the options and incur large amounts of transaction costs especially when they hedge dynamically by trading the spot or interest rate derivatives. Therefore, the market makers like to reverse these trades and minimize inventory. Accordingly, options liquidity is important to them. This suggests that dealers or market makers are net-sellers of interest rate options with short trading horizon, unlike buyers who purchase and hold the long-dated interest rate options. Since the dealers are net-sellers, they raise the price of an illiquid option because they face enormously large costs of dynamic hedging of a long-dated contract. In this way, Deusker et al. (2011) support the arguments of Garleanu et al. (2009) that the lack of liquidity is due to the net-demand pressure affecting the prices of options. This implies a negative relationship between liquidity and prices for these interest rate options. Deuskar et al. (2011) also find a systematic factor, linked to lagged changes in investor perceptions of uncertainty in the equity and fixed income markets, driving changes in liquidity across strikes and maturities.

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[7] There are several studies that have found that illiquid stocks and bonds are cheaper and offer higher expected returns. The examples include Amihud and Mendelsen (1986) and Longstaff (1995a, 2001) in the stock markets, and Amihud and Mendelson (1991), Longstaff (1994), De Jong and Driessen (2007) and Nashikkar et al. (2009) in the bond markets.

[8] The institutional market includes corporations that usually have buy and hold investing style (Deusker et al, 2011)

### 2.5.2 Liquidity Comovement between Options and the Stock Market

As far as we know, no study has specifically analysed liquidity comovement between options and their underlying stock market. Although Cao and Wei (2010) take account of the relationship between options market liquidity and stock market liquidity by employing residuals from the univariate relationship between them, they have not specifically investigated liquidity comovement between options and their underlying stock market. This is carried out in Chapter 4 of this thesis.

The literature suggests that options offer a number of advantages compared to stocks. Liquidity comovement between options and their underlying stock market may be due to their inherent leverage, the conventionally perceived lower transaction costs, the avoidability of restrictions on short-sale on the underlying stocks, and the ability to hedge holdings in stocks. Options will be more liquid the larger their potential value as a hedging instrument. Mayhew et al. (1999) suggest that demand for options is largely determined by the demand for the underlying asset. They suggest that if the interest in a particular underlying security is greater, there will be more interest in its options as well. However, if options are substitutes for stocks, the implication is a negative relationship between option liquidity and the trading activity in the stock. Moreover, Cho and Engle's (1999) hedging argument would already suggest that liquidity of options and the underlying stock market will comove if for some reason option market makers are unable to completely hedge their option positions by trading in the underlying stock market. From this, we can suggest that comovement between options and their underlying stocks is expected to be positive. However, it is interesting to investigate and document how option liquidity comoves with the liquidity of the underlying stock market. It is very similar to a case in which a trader hedges his option portfolio with an underlying stock index. If liquidity comovement between options and the stock market is positive, which is quite intuitive, hedging costs would be lower. A positive liquidity comovement may also indicate that whenever there is a liquidity shock in the stock market, a market maker may widen the spread on the options as he would be bearing higher costs of hedging in the underlying stock market. However, when liquidity comovement between an option and the stock market is negative, this would imply that in times of declining markets (markets become illiquid), options liquidity increases (options become liquid). If such options exist then they would provide a better hedge against liquidity shocks in the stock market. The varying liquidity comovement between options and their underlying stock market has asset pricing implications. The implications for options that have negative liquidity comovement with the underlying stock market is that market participants would accept to pay a premium for such options since they provide insurance against this liquidity comovement. Hence, it would be another source of liquidity risk for options.

We employ market model time-series regressions to investigate liquidity comovements. Following Chordia et al. (2000) and Cao and Wei (2010), we test the hypotheses of the liquidity comovement between options and their market, and between options and their underlying stock market in Chapter 4. Following the argument of Cho and Engle (1999) that liquidity in the options market is related to liquidity in the underlying stock market, we also control for this effect. We hypothesize that there are two sources of liquidity commonality in the equity options market. First, liquidity of an option may comove with the liquidity of the option market. Second, liquidity of an option may comove with the liquidity of the stock market. Apart from Brenner et al. (2001), Deusker et al. (2011), and Bongaerts et al. (2011), most literature on equity options use CBOE data, but we test these hypotheses using the NYSE Euronext LIFFE London Equity Options Market data. Although Cao and Wei (2010) investigate liquidity comovement in the equity options market, they only study liquidity comovement between options and their market and do not study the cross-sectional differences across moneyness and maturity of the options for these liquidity comovements. In Chapter 4, we contribute by investigating these liquidity comovements across moneyness and maturity of options for both calls and puts.

## 2.6 Return Sensitivity to Market Liquidity

There is evidence in the literature that liquidity is persistent. This has two implications for stock returns (Chordia et al., 2001; Jones, 2001; Acharya and Pedersen, 2005). First, liquidity would help predict future returns. Acharya and Pedersen (2005) suggest that high liquidity today predicts high liquidity next period, implying a lower required return. Jones (2001) provides empirical evidence of a positive relationship between bid-ask spread of a previous year and expected annual stock market return, and a negative relationship with a turnover of the previous year. Amihud (2002) finds that liquidity predicts returns for market portfolios as well as stock portfolios sorted by market capitalization (size), and Bakaret et al. (2003) report that liquidity predicts emerging market returns. Second, a negative conditional covariation between contemporaneous returns and liquidity exists (Acharya and Pedersen, 2005). Intuitively, the higher the illiquidity, the higher the return. However, a shock in illiquidity will depress the current price implying a lower return. This should be the case when liquidity is persistent.

Chordia et al. (2001), Jones (2001), and Pastor and Stambaugh (2003) find a negative relation between return and liquidity in the stock market.

Given that options are contingent claims, using the arbitrage pricing theory framework studies by Frey (1998, 2000), Liu and Yong (2005), Cetin et al. (2004, 2006), and Chou et al. (2013) present evidence suggesting that liquidity an underlying asset is an important factor for pricing options on that asset. Option pricing models generally assume that option traders cannot affect the price of the underlying asset when they are replicating the option payoff, irrespective of trade size. Even in a liquid market, trades beyond the quoted depth may occur at worse prices (Liu and Yong, 2005). In imperfectly liquid markets, as in Liu and Yong (2005), when traders buy the underlying as a hedge in option positions, the underlying price will increase, and when traders sell the underlying assets, the stock price will decrease. Liu and Yong (2005) highlight the issues related to the replication of options. First, when attempting to replicate an option with the underlying asset, it may be unclear whether the option is replicable or not. Second, the adverse price impact will increase the replicating costs. Frey (2000) and Liu and Yong (2005) look at the replicating costsof a European option when a price impact exists. Using forward-backward stochastic differential equations, Liu and Yong (2005) derive a generalized non-linear partial differential equation (PDE) for calculating the replicating cost of an European option while considering the underlying stock to be illiquid (they define illiquidity by the price impact). Their model provides explanations for the lower implied volatility of out the money options consistent with the often observed smile curve for calls. The observed pattern in the market is different for puts, however. They rationalize that the prices move against a trader as he trades and consequently he is replicating costs increase. Replicating in the money options imply more trading of the underlying stock and consequently higher trading costs. This means that implied volatility would have to be higher to cover the replicating costs that were generated by the price impact. Replicating out-of-the-money options would imply less trading in the underlying stocks and consequently lower replicating costs and smaller implied volatility. The implication is that in the theoretical models of Heston (1993) and Bates (1996) a negative relationship between the price and volatility of stock is required to generate a volatility smile. In the Liu and Yong (2005) model, if the underlying stock market is illiquid, this relationship needs to be weaker (stronger) for calls (puts).

Cetin et al. (2004, 2006) derive a pricing formula for European call options by modelling liquidity with a stochastic supply curve that is a function of trade size. This generates a different definition of self-finnacing trading strategy. They also argue that their model can be generalized to the case when liquidity risk is measured by transaction costs. Cetin et al. (2006) show that liquidity costs of underlying assets are important determinant of the option price and its impact is related to the moneyness of the options. They find this impact to be more significant for out-of-the-money options and less significant for in-the-money options.

Chou et al. (2013) study the impact on option prices of liquidity of stocks and their options for DJIA index constituents using transaction level data from 1 January 2001 to 31 December 2004. They use implied volatility as a proxy for the option price and measure liquidity of stocks by using proxies based on trades or orders. The trade-based proxies are cumulative trading volume, number of trades, and average trade size. The order-based proxies are absolute order imbalance, average proportional quoted spread, and average proportional effective spread. For options, they measure liquidity by trading volume (number of contracts), option proportional spread, dollar trading volume, and total option open interest. They report that implied volatility increases with the illiquidity of the underlying asset, which is in line with the hedging cost argument of Cetin et al. (2006), and decreases as the illiquidity of the options increase, which is consistent with the illiquidity premium hypothesis of Amihud and Mendelsen (1986). Specifically, when the proportional bid-ask spread is used as a proxy for liquidity, they find that more liquid options and less liquid stocks are associated higher implied volility. The implication is that option prices are higher when the option market is more liquid. This is what was proposed by Amihud and Mendelsen (1986) in their illiquidity premium hypothesis. Another implication is that options have higher prices when underlying stock is less liquid. This is in line with Cetin et al (2006) who document that the dynamic hedging leads to positive costs.

Another approach used in the literature to capture the impact of the underlying stock price on the option price is by using a liquidity discount factor. Feng et al. (2013) develop a liquidity-adjusted option pricing model that demonstrates the impact of liquidity risk on stock prices by using a liquidity discount factor. Their model is based on that of Brunetti and Caldarera (2006), which incorporates a liquidity discount factor into the demand function of a stock to capture the impact of liquidity on stock prices. In the model of Feng et al. (2013), the liquidity discount factor relates to both the mean-reversion of stochastic market liquidity and the sensitivity of stock prices to market liquidity.

Considering the above discussion, liquidity persistence in the stock market (Amihud, 2002; and Acharya and Pedersen, 2005) and in the options market can have implications for option returns. This is investigated in Chapter 5.

## 2.7 Liquidity Risk and Its Pricing

In asset markets, marginal investors typically hold long positions in assets due to positive net supply. A seller of an asset in such markets is not concerned about its expected liquidity after selling, but a buyer does after he buys. If the marginal investor (a buyer) expects the asset to be illiquid, he will require to be compensated for the lack of immediacy that he will face in the future. Therefore, in markets where short-selling is not allowed and the marginal investor is a buyer (as in the case of positive supply markets), a trader will require an illiquidity premium. Hence, ceteris paribus, the illiquidity premium should be higher for more illiquid assets. The required return of the illiquid asset will be higher, consequently the price will be lower. Empirical evidence from the stock and bond markets show that the less liquid stocks and bonds have lower prices and provide higher expected returns. Evidence in the stock market is provided by Amihud and Mendelsen (1986), Longstaff (1995a, 2001), and others; in the Treasury bond market is provided by Amihud and Mendelson (1991), Longstaff (2004), and others; and in the corporate bond market is provided by De Jong and Driessen (2007), Nashikkar et al. (2008), and others.

Derivatives differ from assets such as stocks and bonds. The liquidity of a derivative asset captures the ease by which a dealer offsets the trade. Liqiduity, therefore, is important for the dealer, and will have an effect on the price of a derivative asset. Generally, derivative assets have zero net supply. Accordingly, the marginal investor who is concerned about the liquidity of the derivative can be either long or short in it. Suppose the marginal investor concerned about the liquidity of the asset is long. He will require a 'reduction' in price as a compensation for illiquidity. However, if the marginal investor is short, he will require a compensation in the form of an increase in the price of the derivative asset. Therefore, for assets with zero net-supply, the buyer as well as the seller will worry about illiquidity of the asset, and push prices in the opposite direction. In such markets, if the marginal investor is net long and concerned about liquidity, the buyer effect will dominate and the investor will demand a higher return for less liquid assets. If the investor is net short, however, the seller effect will dominate and that investor will demand a lower return for less liquid assets.

The above discussion implies that in a market with positive supply and where short selling is allowed, the marginal investor concerned about liquidity will be a buyer of the asset and will demand an illiquidity premium. In a market with net-zero supply assets, it is either the seller or the buyer who will demand an illiquidity premium depending on whether the net buyers or the net sellers of zero net supply assets are concerned with the illiquidity of the assets.

For interest rate options (caps and floors), Deuskar et al. (2011) find that the "seller effect" dominates and, therefore, the less liquid the options the lower the returns. For the credit default swaps (CDS) market, Bongaerts et al. (2011) report evidence that the credit protection seller earns an expected liquidity premium and a small liquidity risk premium.

The literature on the illiquidity premia in the stock and bond markets indicates that illiquidity affects returns in both markets. In general, illiquid assets offer a higher expected return.[9] Amihud and Mendelsen (1986), Brennan and Subrahmanyam (1996), Amihud (2002), Pastor and Stambaugh (2003), Acharya and Pedersen (2005), amongst others, study illiquidity and returns in stock markets, while Amihud and Mendelsen (1991), Longstaff (1994), Beber, Brandt and Kavajecz (2009) study the impact of illiquidity on expected returns in bond markets. These papers are reviewed next.

Acharya and Pedersen (2005) derive a uniform Liquidity-adjusted Capital Asset Pricing Model. They consider costs of transacting a stock as a liquidity measure. They show that the asset return net of transaction costs depends on the net-beta of the asset. In their model, an asset could have three channels of risk, other than market risk, due to three covariations. They show that these three channels of covariation in a positive supply market characterize liquidity risk. The first is the covariation of liquidity of a stock with market-wide liquidity (also known as liquidity commonality). The implication of the existence of such covariance is that investors would demand a premium for an illiquid asset when the whole market is illiquid. The second is the covariation of a stock return with market

[9] Amihud and Mendelsen (1986), Brennan and Subrahmanyam (1996), Amihud (2002), Jones (2002), Pastor and Stambaugh (2003) and Acharya and Pedersen (2005).

liquidity. This covariance implies that investors prefer to invest in securities that provide high returns in illiquid markets, therefore are willing to pay a premium. The third is the covariation of liquidity of a stock with market return. Its implication is that investors will be willing to pay a premium to invest in a liquid security that can easily be sold when the return in the market is low.

In Acharya and Pedersen's (2005) model, investors are considered to be long in assets that are in positive net-supply. In this case, illiquidity results in lower prices and high expected returns. However, derivative markets are zero-net-supply markets, and investors can be net-long or net-short. Bongaerts et al. (2011) provide a theoretical asset-pricing framework of liquidity effects in basic and derivative asset markets and test implications for the credit default swap (CDS) market. In their model, heterogeneous investor use assets to hedge exposure to non-traded risk factors. They derive a decomposition of the expected return of these hedge assets into risk-premia on non-hedge assets, hedging demand effects, an expected liquidity component, and several liquidity risk premia. The risk premia are related to: (i) the covariance of hedge asset returns with the non-traded risk factor, (ii) the covariance of hedge asset transaction costs with the return on the non-traded risk factor, and (iii) the covariance of hedge asset transaction costs with market-wide hedge asset returns. Their first main theoretical result is that the sign of the liquidity coefficient is related to the heterogeneity across investors in non-traded risk exposure, and investors' risk aversion, trading horizon, and wealth. This implies that when a long investor is more aggressive due to either an aggregate wealth or a lower risk aversion, or has a shorter trading horizon than the investors who have 'shorted' the assets, expected illiquidity would positively affect the expected returns. This is due to the greater sensitivity of aggressive investors towards transaction costs. Hence, in equilibrium those investors would require compensation for those costs. Their second result is that if net-supply of the hedge assets is zero, some sources of risk have zero risk premia. For example, the covariance of the return of a derivative security with the return of the derivative market has a zero risk premium if net-supply of the assets is zero. Their key empirical finding for the CDS market is that in addition to the compensation for default risk, the sellers of credit protection receive compensation for illiquidity. Moreover, they find that most of the liquidity effects are observed through the expected liquidity component, which implies that due to either higher wealth, less risk aversion, or short trading horizon, credit sellers are more aggressive than protection buyers.

Christoferssen et al. (2015) present evidence that the illiquidity of the option and that of the underlying asset affect expected return of CBOE equity options. They find that the illiquidity of an option positively affects its expected return, which is in line with the illiquidity premium hypothesis. In other words, an illiquid asset will trade at a discount compared to an otherwise similar but liquid asset. Moreover, they relate the finding that, in the cross-section, the illiquidity of the underlying stock negatively affects the option return, to the hedging cost hypothesis. The hedging cost hypothesis suggests that when an underlying asset is traded to hedge an option position, due to the increase in the hedging demand, the price of the underlying asset will increase and, therefore, the price of the option will increase. This increase in the option price contemporaneously decreases the expected return of the option.

However, the literature is silent on the relationship between the channels of liquidity risk and expected returns in the equity options market. This is important since the growing literature on liquidity risk suggests that liquidity varies over time with market-wide variables such as market return and market liquidity. Comovement of liquidity of a stock with that of the stock market was first documented by Chordia et al. (2001) in the NYSE stock market. However, another channel of liquidity risk in which the return of a stock varies over time with market-wide liquidity is documented by Amihud (2002) in the NYSE stock market. Acharya and Pedersen (2005) derive a uniform Liquidity Capital Asset Pricing Model in which not only the level of the liquidity of a stock affects stock returns, but also liquidity variations over time. In their model, liquidity risk has three main channels. The first is the comovement of the liquidity of a stock with that of the stock market (i.e., the liquidity commonality documented in the stock market by Chordia et al. (2001) and in the equity option market by Cao and Wei (2010)). The second is the comovement of the return of a stock with the liquidity of the stock market (Amihud, 2002). The third is the comovement of the liquidity of a stock with the return of the stock market. Acharya and Pedersen (2005) present evidence of liquidity risk premia for all these three channels of risk in the NYSE stock market.

Cao and Wei (2010), for the CBOE equity option market, and Deusker et al. (2011), for the euro interest rate cap and floors market, find that liquidity of an option comoves with option market liquidity. However, they do not investigate whether this liquidity comovement is priced. Moreover, in light of the Liquidity-adjusted Capital Asset Pricing Model of Acharya and Pedersen (2005), the other two channels of liquidity risk are priced in the stock market. The stock market is a positive supply market whereas the option market is a net-zero supply market. In a net-zero supply market, market participants are classified as market makers and end users (Garleanu et al., 2009). Market makers may be net buyers or net sellers. If market makers are net buyers, end users will be net sellers. When market makers are net buyers, they will charge higher prices to discourage building up inventory. Garleanu et al. (2009) find that index options have higher implied volatility than individual equity options because market makers are net short in the index options market and net long in the equity options market. They argue that demand pressure from the end users in the index options market is higher due to the higher cost of index options than individual equity options.

Garleanu et al. (2009) derive a demand based option pricing model. Their paper relates to different aspects of the literature on options. First, the idea of demand pressure dates back to Keynes (1923) and Hicks (1939) who investigated the futures markets. Second, their results could explain the known option puzzles: expensiveness of index options, relatively higher expensiveness of low-moneyness options, and significant differences between index option prices and single-stock option prices. Third, rather than deriving bounds on option prices from the perspective of trading frictions and incomplete markets, they compute option prices based on demand pressure by end users. Fourth, in light of utility-based option pricing, they show how option prices change when demand is high. Departing from the no-arbitrage framework and considering that derivatives are useful and not redundant for all investors, they develop a theoretical model of effects of demand on option prices and empirically test its implications. As derivative securities are in zero net-supply, intermediaries providing liquidity to end-users have the opposite position compared to the end user net demand. If competitive market makers could hedge all their positions, the prices would be determined by the principle of no-arbitrage and prices would not be affected by demand pressure. However, hedging perfectly in real markets is impractical because trading is not continuous, volatility is stochastic, prices and transaction costs have jumps, and capital constraints create sensitivity towards risk.

The authors propose a general theoretical model that computes the equilibrium prices as a function of demand pressure. They consider a discrete-time infinite-horizon economy with a risk-free asset paying a risk-free rate, an underlying risky security with a strictly positive price, dividend and excess return (return minus risk-free rate), and derivative securities. The distribution of future prices and returns of the underlying asset are characterized by a Markov state variable which includes the current price of the underlying asset, and may also incorporate variables such as contemporaneous volatility and jump intensity. The prices of derivatives are determined endogenously, and their payoffs depend on the Markov state variable.

They consider two types of agents in the economy: competitive dealers with constant absolute risk-aversion and end users. The equilibrium prices are computed so that utility maximizing dealers supply the quantities demanded by the end users. Here, their assumption is that end users' demand for derivatives is exogenous without considering the trading motives.

Garleanu et al. (2009) show theoretically that option demand increases the price of that option by an amount which is proportional to the variance of the unhedgeable part of the option, and it changes the prices of the other options written on the same underlying asset by an amount which is proportional to the covariance of their unhedgeable parts. Using excess implied volatility as a measure of expensiveness (risk premia for market makers), their paper empirically shows that index options are relatively expensive on average than equity options and have positive end-user demand. In line with the theoretical predictions of their model, they find that when there is more end-user demand, index options are more expensive, and the expensiveness skew is positively related to the skew in the end user demand when investigated across moneyness. They also report that index options show strong demand effects following losses by market maker than following gains. In case of equity options, they report that option expensiveness and end-user demand are positively related in the cross-section, and the demand effect is weaker with more option activity on a stock.

There is interaction not only between an option and the market where it is traded, but also between an option and the underlying market where it can be hedged or replicated. Similarly, liquidity risk is related to the comovement of the option return or option liquidity not only with the liquidity of the option market but also with the return and liquidity of the underlying asset market. Therefore, one can argue that the nature of an option security is such that the channels of liquidity risk are not confined to the comovement of liquidity or return of an option with market-wide variables of the option market but also with market-wide variables of the underlying stock market. This is investigated in Chapter 6.

## 2.8 Option Returns Strategies

To investigate uncertainty in option returns, the literature uses mainly two approaches to quantify option portfolio returns (Cao and Han, 2011; Carr and Wu, 2009; Bakshi et al., 2003a, b). Researchers argue, and empirically report, that uncertainty in option returns is related to a premium for volatility risk. Since investors pay such a premium, option returns include a negative volatility risk premium or a variance risk premium. Carr and Wu (2009) and Bakshi et al. (2003a, b) use zero-return portfolio strategies in which the net investment pays zero return. However, the literature reports that when these strategies are implemented on market data, they pay significant non-zero returns.[10]

The first approach used to quantify the returns on options employs a delta-hedging strategy. A portfolio is constructed consisting of a long (short) call (put) and short (long) delta units of the underlying stock such that the net investment ought to provide a return equivalent to risk-free rate. The advantage of employing this strategy to calculate gains and use it as a measure of option return is that it hedges all (delta) risk. Any return consistently earned over the risk-free rate will indicate the presence of a priced risk factor (or factors).

Bakshi, Kapadia and Subrahmanyam (2003a, b) compute delta-hedged gains in order to investigate the presence of the volatility risk premium in index and individual equity options. They construct a portfolio of a long call and short delta units of the underlying stock such that the net investment provides a return equivalent to the risk-free rate. They argue that when hedging dynamically, the net gain on the delta-hedged portfolio should precisely be zero as all risks are dynamically hedged. A finding of significant non-zero delta-hedged gains would imply that there is some other risk that is priced. They argue that this risk is volatility risk, and options are expensive because buyers are willing to pay a premium for increased market volatility.

However, a significant non-zero delta-hedged gain may also indicate that traders in the option or the underlying stock market are concerned about illiquidity, more specifically the transaction costs of the option or its underlying stock, or perhaps because illiquidity

[10] Bakshi et al. (2003a, b) use delta-hedged option portfolio returns and find that net-investment pay returns that are significantly less than the risk-free rate. Carr and Wu (2009) synthesize the variance swap rate using option prices and find that the difference between the variance swap rate and the synthesized rate is significantly negative.

itself is risky. As discussed earlier, illiquidity risk may emanate from channels related to covariance of liquidity of the asset with market return and market liquidity and investors may be pricing some of these in determining the price of the option.

The second approach used is the variance swap. Carr and Wu (2009) employ variance swaps to investigate the variance risk premium in options. They quantify the variance risk premium using a variance swap. Carr and Wu (2009) define variance swap as an over-the-counter (OTC) contract paying the difference between a standard estimate of the realized variance and the fixed variance swap rate. The variance swap has no costs to enter into and, therefore, represents the risk-neutral expected value of the realized variance. They propose that the variance risk premium can be quantified as the difference between the ex-post realized variance and the synthetic variance, which is synthesized from a linear combination of option prices. They find that the variance risk premia are strongly negative.

This portfolio construction is very specific to quantifying the variance risk premium. It cannot be employed to investigate whether the liquidity or liquidity risk is priced in options. However, this approach can be used to further investigate the relationship between variance risk premium and option liquidity, underlying stock liquidity, or liquidity in the options and stock markets. Since the focus of this thesis is to study the effects of liquidity and its comovements on equity options, we cannot use this methodology because it measures the variance risk premia. However, it would be interesting to investigate the interaction between liquidity or liquidity risk and the variance risk premia by constructing portfolios based on double sorts on liquidity or liquidity risk and variance risk premia of options. We leave it as a recommendation for future research.

## 2.9 Summary Table of the Literature Review Papers

In Table 2.1, we present the summary of the main articles reviewed in this thesis.

**Table 2.1 Summary Table of the Main Literature Review Papers**

| Title | Data / Sample Period | Research Question(s) / Hypotheses | Major Findings |
|---|---|---|---|
| **Commonality in Liquidity**<br><br>Chordia, Roll & Subrahmanyam (2001) | NYSE Stocks<br><br>Sample Period: 1992 | Empirically examining the commonality in liquidity | The existence of commonality is a key to suggest that inventory risks and asymmetric information both affect intertemporal changes in liquidity. |
| **Common Market Makers and Commonality in Liquidity**<br><br>Coughenoura & Saad (2004) | NYSE Stocks<br><br>Sample Period: 1999-2000 | How common liquidity movements are induced by common market makers? | Individual stock liquidity co-varies with specialist portfolio liquidity apart from information reflected by market liquidity variation. |
| **Aggregate Liquidity and Commonality in Liquidity on the LSE**<br><br>Hillier, Hillier and Kyaw (2007) | London Stock Exchange (LSE)<br>Sample Period: 1993-2003 | Existence of liquidity commonality and the effect of aggregate liquidity on a stock's liquidity. | She finds that liquidity commonality is a phenomenon of large stocks. She finds positive liquidity commonality in the LSE stocks. Moreover, liquidity of large stocks is important market determinant as it affects the liquidity of other large stocks and affects the small stocks significantly. She also finds that the introduction of order book in the LSE does not change the liquidity commonality effects. |
| **Liqudity Commonality and Intervalling Effect**<br><br>Hillier, Hillier and Kyaw (2007) | London Stock Exchange (LSE)<br>Sample Period: 1993-2003 | Does liquidity commonality depend on the intervalling effect (the interval of measuring aggregate liquidity)? | They find that the bigger the interval for aggregation of liquidity, the stronger the commonality in liquidity. They suggest that the intervals are caused by delays in information being incorporated into bid-ask spreads. |

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| **Commonality in Liquidity of UK Equity Markets: Evidence from the Recent Financial Crisis**<br><br>Gregoriou, Ioannidis and Zhu (2008) | London Stock Exchange<br><br>Sample Period: 2005-2009 | What is the empirical association between correlated movements in liquidity for the UK equity market? | The movements in liquidity is related to trading activity between individual firms and the London Stock Exchange. |
| **Illiquidity and Stock Returns: Cross-section and Time-series Effects**<br><br>Yakov Amihud (2002) | Stocks listed on New York Stock Exchange (NYSE)<br><br>Sample Period: 1964 to 1997 | Does expected stock excess return command a premium for stock illiquidity?<br><br>The effect of unexpected stock market illiquidity on expected stock returns?<br><br>How illiquidity differs across the size of the firm? | They report that implication of persistence is that both expected and unexpected liquidity affect the expected stock returns.<br><br>Expected stock return reflects compensation for expected market illiquidity. Moreover, unexpected market illiquidity lowers contemporaneous stock prices. |
| **Asset Pricing with Liquidity Risk**<br><br>Acharya and Pedersen (2005) | Theoretical Paper | Providing a simple equilibrium model with liquidity risk | In liquidity adjusted CAPM, a security's required return depends on its expected liquidity and covariance of its own return and liquidity with the market return and liquidity. |
| **Trading activity and bid-ask spreads of individual equity options**<br><br>Wei and Zheng (2010) | Ivy Database OptionsMetrics Equity options on Chicago Board of Options Exchange (CBOE)<br><br>Sample Period: 1996 – 2007 | What are the determinants of option liquidity?<br><br>How do trading activities affect option liquidity? | When medium term options are unavailable, traders substitute short term options whose higher volume leads to smaller bid-ask spread.<br><br>When stock return volatility goes up, trading shifts from ITM options to OTM options causing later's spread to narrow. |

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|---|---|---|---|
| **Options Market Liquidity: Commonality and Other Characteristics**<br><br>Cao and Wei (2010) | Ivy Database OptionsMetrics Equity options on Chicago Board of Options Exchange (CBOE)<br><br>Sample Period: 1996 - 2004 | Examining commonality and other liquidity characteristics for options market | The commonality remains stronger even after controlling for underlying stock market liquidity and other liquidity determinants.<br><br>Smaller firms and firms with higher volatility exhibits stronger commonalities in option liquidity.<br><br>Information asymmetry is stronger driving force of liquidity than inventory risk.<br><br>Market-wide option liquidity is closely related to underlying stock market's movement. |
| **Liquidity effect in OTC options markets: Premium or Discount**<br><br>Deuskar, Gupta and Subrahmanyam (2010) | OTC Interest rate options data from WestLB<br><br>Sample Period: 1999-2001 | Can the liquidity premium in asset prices, as stated in exchange-traded liquidity and bond markets, be generalized to the OTC derivative markets? | Illiquid options are traded at higher prices relative to liquid options. Hence, effect of liquidity on asset prices cannot be generalized without regard to the characteristics of the market. |
| **Bid-Ask Spreads and Trading Activity in the S&P 100 Index Options Market**<br><br>George and Longstaff (1993) | CBOE and NYSE<br><br>Sample Period: 1989 | Examining the cross-sectional distribution of bid-ask spreads and trading activity in S&P 100 index options market | Cross-sectional differences in the bid-ask spread are directly related to differences in the market making costs and trading activity across options.<br><br>Traders view call and put options as substitute. |

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|---|---|---|---|
| **Liquidity of CBOE Equity Options**<br><br>Vijh (1990) | CBOE<br><br>Sample Period: 1985 | Examining the CBOE option market depth and bid-ask spreads | Bid-ask spread for CBOE and NYSE stocks are nearly equal although average option is less than half the stock price + borrowing, and this trade-off between market depth and bid-ask spreads on CBOE andNYSC is explained by difference in market mechanism.<br><br>Adverse selection component of the options spread is very small. |
| **Cross-section of Option Returns and Volatility**<br><br>Goyal and Saretto (2009) | IvyDB OptionsMetrics<br><br>Sample Period: 1996-2006 | Studying the cross-section of stock options returns by sorting stocks on the difference between historical realized volatility and ATM implied volatility | An economically and statistically significant average monthly return is yielded when a zero-trading strategy is impied that is long (short) in the portfolio with a large positive (negative) differences. |
| **Demand-Based Options Pricing**<br><br>Garleanu, Pedersen and Poteshman (2009) | IvyDB OptionsMetrics and CRSP<br><br>Sample Period: 1996-2001 | Modeling the demand-pressure effects on option prices | Demand helps explain the overall expensiveness and skew patterns of index options.<br><br>Demand also impacts the expensiveness of single-stock options. |
| **Option Prices with an Illiquid Underlying Asset Market**<br><br>Liu and Yong (2005) | Theoretical Paper | How the price impact in the underlying asset market affects the replication of a European contingent claim? | Replication with price impact is always cheaper than superreplication.<br><br>Price impact implies endogenous implied volatility.<br><br>Out-of-money option has lower implied volatility than ITM options. |

| | | | |
|---|---|---|---|
| **The Impact of Liquidity on Options Prices**<br><br>Chou, Chung, Hsiao, & Wang (2013) | Dow Jones Industrial Area (DJIA)<br><br>Sample Period: 2001-2004 | Examining the impact of both spot and option liquidity levels on option prices. | With a reduction (increase) in spot (option) liquidity, there is a corresponding increase in the level of the implied volatility curve. |
| **Illiquidity Premia in the Equity Options Market**<br><br>Christoffersen, Goyanco, Jacobs and Karoui (2015) | CBOE Equity Options<br><br>1996-2007 | Investigating the cross-sectional relationship between option illiquidity and expected option returns. | An increase in option illiquidity decreases the current option price and predicts higher expected option returns. |

# CHAPTER 3
# DATA AND VARIABLES

## 3.1 Introduction

In this Chapter, we describe data sources, a screening criteria in the selection of a sample, creation of variables required for each empirical chapter. Our data sample consists of daily data on UK equity options and stocks from 22 February 2008 to 31 December 2010.

This chapter is structured as follows: Section 3.2 describes the sources of data. Section 3.3 discusses the screening criteria for sample selection. Section 3.4 defines and provides formula of the variables that will be used in the empirical analyses in Chapter 4, 5 and 6. Section 3.5 describes the classification of options into moneyness and maturity portfolios. Lastly, Seciton 3.6 presents and discusses the descriptive statistics of data.

## 3.2 Data Sources

The main sources of our data on options are the NYSE Euronext LIFFE end-of-day data files purchased from NYSE Euronext LIFFE. The data on underlying stocks and zero-coupon yields of the UK zero-coupon government bonds (also known as gilts) are obtained from Datastream.

### 3.2.1 NYSE Euronext LIFFE Data

The London International Financial Futures and Options Exchange (LIFFE) is a futures and options exchange based in London. Following a merger with the London Traded Options Market (LTOM) in 1993, LIFFE added equity options to its product range. Following the takeover by Euronext in January 2002 and Euronext's merger with NYSE in April 2007, LIFFE is currently part of NYSE Euronext. NYSE LIFFE is the derivatives part of the European derivative market comprising the Amsterdam, Brussels, Lisbon, London and Paris markets. Equity options are traded on Amsterdam, Brussels, London and Paris exchanges only. The LIFFE CONNECT is the main trading platform of NYSE LIFFE. It is an anonymous electronic order-driven system that operates an open system architecture allowing users direct access via an Application Platform Interface (API). The NYSE LIFFE trading structure also includes the Euronext Liquidity Provider System

(ELPS), through which a market maker can submit two-sided quotes of bid and ask prices. Market makers vetted to participate in the ELPS are required to provide liquidity by quoting simultaneously bid and ask prices at a maximum spread with a minimum quantity regulated by the exchange. In this market, the complete depth is visible to all participants including market makers.

LIFFE London covers options on FTSE 100 stocks. The data is provided as end-of-day files for LIFFE equity options. They provide the following variables: contract name on which an option is written, strike price, expiry date, end-of-day bid and ask quotes, option close price, volume traded, and open interest. The files provided by NYSE Euronext LIFFE contain bid-ask quotes for options on each FTSE 100 stock from 22 February 2008 to 31 December 2010. We, therefore, use this as the sample period of analyses in this thesis.

### 3.2.2 Thomson Reuters Datastream

Thomson Reuters Datastream (Datastream) is used to extract data on the underlying stocks and UK government bond (gilts) zero curve rates (provided by Inter Capital through Datastream), which are considered as risk-free rates.[11]

For underlying stocks, we extract the following variables: unadjusted closing bid, unadjusted closing ask, unadjusted close price, daily stock volume, market capitalization, and annualized dividend yield. The unadjusted price is the price of a stock as historically recorded by the stock exchange. This is the relevant price for equity options since option prices depend on the spot price of the underlying at the time.

The options database is used to identify the equities for which options data are available. However, the stock symbol in NYSE Euronext LIFFE Data is different from the symbol used in Datastream, and the Euronext LIFFE end-of-day data files do not provide company names. We, therefore, resort to the NYSE Euronext website to extract the company names and ISIN number to match the option data with the underlying stock data.

[11]The Datastream symbols used to download UK zero curve rates are: UK00Y01, UK00Y02, UK00Y03, UK00Y04, UK00Y05, UK00Y06, UK01Y00, UK02Y00, and UK03Y00 for maturities of 1 month, 2 months, 3 months, 4 months, 5 months, 6 months, 1 year, 2 years, and 3 years, respectively.

Moreover, FTSE 100 Index constituent stocks are important for our empirical work for two main reasons. First, we need to determine which FTSE index is suitable as a proxy for the underlying stock market, for example the FTSE 100 index or the FTSE All Share index. Second, we need to construct a liquidity proxy for the underlying stock market. Since indices are not spot traded on the stock market, we use liquidity data on the constituents of a market index to calculate a liquidity measure for the index. For example, the bid-ask spread of an index is calculated as the un-weighted cross-sectional average of the bid-ask spreads of the constituent stocks.

On comparing the list of stocks on which options exist (option stocks) with the FTSE 100 constituents, we find that 68 out of 71 in 2008, 70 out of 73 in 2009, and 73 out of 77 in 2010 option stocks are part of FTSE 100 index (see Table 3.1). Moreover, the market capitalization of the stocks in our sample is £1,310 million in 2008, £1,228 in million 2009 and £1,541 million in 2010. The market capitalization of the FTSE 100 index stocks in 2014 is £1,682 million. Accordingly, the FTSE 100 is chosen as the proxy of the underlying market and we use its constituents to construct the underlying stock market liquidity measure.

**Table 3.1 Stocks with Options Data from NYSE Euronext LIFFE Files**

This table shows the total number of stocks on which options data is available from the NYSE Euronext LIFFE database.

| | **2008** | **2009** | **2010** |
|---|---|---|---|
| Total Option Stocks | 71 | 73 | 77 |
| Total Option Stocks in FTSE 100 | 68 | 70 | 73 |
| Percentage of Option Stocks Not in FTSE100 (%) | 4.23% | 4.11% | 5.19% |

**FTSE 100 Constituent Stock Data**

The data on the FTSE 100 index and its constituents is collected from Thomson Reuters Datastream. Datastream has a functionality to extract a list of the stocks constituting the FTSE 100 in a particular month/quarter of past years. The list of constituents of the FTSE 100 are downloaded for every quarter of 2008, 2009, and 2010. FTSE 100 is an index of the 100 largest companies listed on the London Stock Exchange and these companies are screened for FTSE's size and liquidity criteria before becoming part of the FTSE 100 Index. Every quarter, some companies are deleted and some are added based on their performance. Therefore, to construct a daily measure of market liquidity, special attention is paid to the companies that are added or deleted from the FTSE 100 Index. The number of these companies is reported in Table 3.2 for the years 2008, 2009 and 2010.

The column entitled 'Companies Added' presents the number of companies that have been added to the index during the year. The column entitled 'Companies Deleted' presents the number that were excluded from the index during the year. The column entitled 'Total Companies' presents the number of total companies that have been part of the index through the year. This includes those that have been part of index for a period less than a year. A company could have been part of the index in the first quarter of a year, excluded for another two quarters and then added again in the last quarter. In these cases, the company is counted twice in that year in the table.

**Table 3.2 Companies Joining and Leaving the FTSE 100 Index**

This table presents the total number of companies in the index, those that were added and those that were deleted during the three years of the sample.

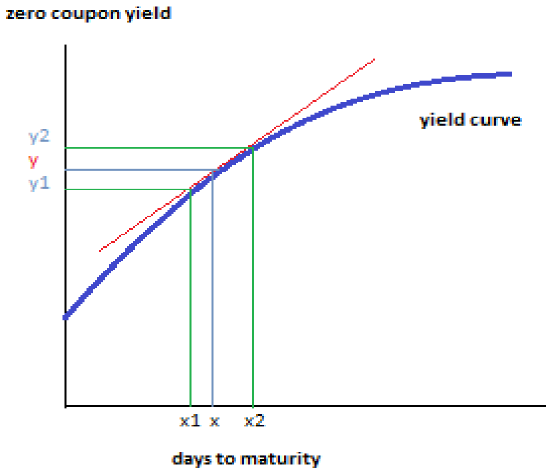
| Year | Companies Added | Companies Deleted | Total Companies |
|---|---|---|---|
| 2008 | 17 | 18 | 117 |
| 2009 | 12 | 12 | 111 |
| 2010 | 7 | 7 | 107 |

For risk-free rate, we download daily time-series data of annualized zero-coupon rates for maturities of 1, 2, 3, 4, 5 and 6 months, and 1, 2 and 3 years. At each date, for each option's remaining days to maturity, we linearly interpolate these rates to calculate the appropriate risk-free rate that matches option maturity. The rates are interpolated using the following formula.

$$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)} \cdot (x - x_1) \,, \tag{3.1}$$

where y is the yield to maturity required for x days to maturity, $y_2$ is the yield for $x_2$ days to maturity and $y_1$ is the yield to maturity for $x_1$ days to maturity. This approximation is depicted in Figure 3.1.

**Figure 3.1 Linear Interpolation**




## 3.3 Data Screening Criteria

Data screening is necessary to have data which is not erroneous and is sound for empirical analysis. Following Bakshi, Kapadia and Subrahmanyam (2003), Goyal and Saretto (2009) and Cao and Wei (2010), we define a criteria to clean the options data. We exclude observations of an option for which one or more of the following criteria are true:

1. The option bid price is greater its ask price.
2. The option bid or ask price is missing.
3. The option bid or ask price is zero.
4. The option bid is equal to the ask price, to avoid stale quotes.
5. Options with fourteen days or less to maturity, to avoid noise in the results. Usually options that are close to maturity exhibit high volatility.
6. Observations that breach the lower and upper no-arbitrage bounds for options. The lower and upper bounds for call options are $Se^{-qT} - Xe^{-rT}$ and $S_o$, respectively, and for put options are $Xe^{-rT} - Se^{-qT}$ and $Xe^{-rT}$, respectively, where $S$ is the stock price, $q$ is the annualized dividend yield, $X$ is the strike price, $r$ is the risk-free rate and $T$ is the time-to-maturity in years.

After applying the first five filters, the dataset contains 38.7%, 52.6%, and 58.4% of the original number of observations in years 2008, 2009, and 2010, respectively. After excluding observations that breach the no-arbitrage bounds, the final dataset contains 22.7%, 34.1%, and 38.9% of the initial data set observations reported in Table 3.3. Although this represents a large reduction, the final sample consists of a reasonable number of observations for performing the empirical analyses. The final sample includes option data on 71, 73 and 77 stocks in 2008, 2009 and 2010, respectively.

**Table 3.3 Data Sample Observations Before and After Applying Filters**

This table shows the total number of option observations before and after applying the screening criteria. Raw Files consist of option observations obtained from NYSE Euronext.

| | **2008** | **2009** | **2010** | **Total** |
|---|---|---|---|---|
| **Raw Files** | 2,591,333 | 3,282,230 | 2,071,802 | 7,945,365 |
| **After Above First Five Filters** | 1,002,566 (38.7%) | 1,728,092 (52.6%) | 1,209,501 (58.4%) | 3,940,159 (49.6%) |
| **After Above Six Filters** | 588,599 (22.7%) | 1,120,874 (34.1%) | 805,069 (38.9%) | 2,514,542 (31.7%) |

## 3.4 Variables

In this section, we discuss how we construct different variables necessary to perform empirical analysis in Chapter 4, 5 and 6. These variables are related to liquidity of an option, its underlying stock, the options market and its underlying stock market, and related to calculation of option return, stock return, stock volatility, implied volatility, option Greeks, and delta-hedged option return.

### 3.4.1 Variables related to Stocks

We calculate liquidity of a stock by bid-ask spread and the percentage bid-ask spread as follows:

***Stock Bid-Ask Spread (SS ):***

Stock bid-ask spread is difference between ask and bid price of a stock.

$$SS = Ask\ Price - Bid\ Price \quad (3.2)$$

***Stock Percentage Bid-Ask Spread ($SS_{prop}$):***

Stock percentage bid-ask spread is defined as 100 times the stock bid-ask spread ($SS$) expressed as a percentage of the stock price($P_s$).

$$SS_{prop} = \frac{SS}{P_s} * 100 \tag{3.3}$$

Equity options on NYSE Euronext LIFFE London are options written on constituent stocks of the FTSE 100 index. Therefore, the best approximation for the underlying stock market would be to consider the FTSE 100 index as the underlying stock market. The liquidity of the stock market, therefore, is the average liquidity of the constituent stocks of the FTSE 100.

We construct two measures of stock market liquidity: the bid-ask spread and the percentage bid-ask spread.

***Stock Market Bid-Ask Spread ($SMS$):***

$$SMS = \frac{\sum_{j=1}^{m} SS_j}{m} \tag{3.4}$$

where $SS_j$ is the bid-ask spread of stock $j$.

***Stock Market Proportional Bid-Ask Spread ($SS_{prop_m}$):***

$$SS_{prop_m} = \frac{\sum_{j=1}^{m} SS_{prop_j}}{m} \tag{3.5}$$

where $SS_{prop_j}$ is the percentage bid-ask spread of stock $j$.

***Stock Market Return*** ($R_{mt}$)

The stock market return is then calculated as 100 times the natural logarithm of the ratio of the closing index level ( $P_{m,t}$ ) on day $t$ and the closing index level ($P_{m,t-1}$) on day $t-1$.

$$R_{mt} = ln \frac{P_{m,t}}{P_{m,t-1}} \cdot 100 \tag{3.6}$$

### 3.4.2 Variables related to Options

We calculate the liquidity of an option by option bid-ask spread, the proportional bid-ask spread and the percentage bid-ask spread.

***Option Bid-Ask Spread*** $(\boldsymbol{OS})$:

Option bid-ask spread is the difference between ask and bid price of a stock.

$$OS = Ask\ Price - Bid\ Price \tag{3.7}$$

***Option Proportional Bid-Ask Spread*** $(\boldsymbol{OS_{prop}})$:

Proportional bid-ask spread is defined as 100 times the option bid-ask spread $(OS)$ expressed as a percentage of the option's bid-ask midpoint $(OBAM)$.

$$OS\_prop = \frac{OS}{OBAM} * 100 \tag{3.8}$$

***Percentage Bid-Ask Spread*** $(\boldsymbol{OS\_perc})$:

Percentage bid-ask spread is defined as 100 times the option bid-ask spread $(OS)$ expressed as a percentage of the underlying stock price $(P_s)$.

$$OS\_perc = \frac{OS}{P_s} * 100 \tag{3.9}$$

By dividing an option's bid-ask spread by its underlying stock price, the percentage bid-ask spread will not be affected by the price of the stock for the same moneyness options.

***Option Return*** $(\boldsymbol{OR_t})$

Option return is defined as 100 times the natural log of the ratio of the option's bid-ask midpoint $(OBAM)$ at day $t$ and the option's bid-ask midpoint at day $t-1$.

$$OR_t = \ ln\frac{OBAM_t}{OBAM_{t-1}} \cdot 100 \tag{3.10}$$

***Implied Volatility***

The implied volatility of an option is calculated by inverting the standard Black-Scholes formula, i.e., it is the value of volatility at which the reported market price of an option equals that of the Black-Scholes'. The Black-Scholes option pricing formulae used are given by:

*Call Option Price*

$$C = Se^{-qT}N(d_1) - Xe^{-rT}N(d_2) \tag{3.11}$$

*Put Option Price*

$$P = Xe^{-rT}N(-d_2) - Se^{-qT}N(-d_1) \tag{3.12}$$

where, $d_1 = \frac{\ln\left(\frac{S}{X}\right)+\left(r-q+\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$, $d_2 = d_1 - \sigma\sqrt{T}$ , $C$ is the call option premium/price, $P$ is the put option premium, $S$ is the stock price, $X$ is the strike price of the option, $q$ is the annualised dividend yield, $r$ is the annualised risk-free rate, $T$ is the time left to maturity of an option in years, $\sigma$ is the annualised volatility (standard deviation) of the underlying asset price, and $N(.)$ is the cumulative standard normal distribution function.

**Option Greeks**

We calculate delta, gamma and vega of an option using the Black-Scholes formula.

***Delta***

The delta of a call and put is given by the following equations:

$$Delta_{Call} = N(d_1) \tag{3.13}$$

$$Delta_{Put} = N(d_1) - 1 = N(-d_1) \tag{3.14}$$

The delta of a call option is between 0 and 1. In-the-money call options have a delta close to 1, out-the-money call options have a delta close to zero, and at-the-money call options have a delta of 0.5. The delta of a put option is between -1 and zero. As moneyness increases the put delta decreases from 0 to -1.

***Gamma***

The gamma of an option is defined as the rate of change of the delta of that option with respect to the price of the underlying asset. Gamma is calculated in the same way for call and put options.

$$Gamma_{put} = Gamma_{call} = \Gamma = \frac{e^{-qT}N'(d_1)}{S_t\sigma\sqrt{T}} \quad (3.15)$$

where, $N'(d_1) = e^{[-\frac{d1^2}{2}]}\ \cdot)$ is the first derivative of $N(d_1)$. The delta of an option is more sensitive to the underlying price when the option is at-the-money. Therefore, gamma is higher for at-the-money options than for both in-the-money and out-the-money options. Gamma is always 0 or positive.

***Vega***

The vega of an option is defined as the rate of change of the option price with respect to the volatility of the underlying asset, keeping all other parameters constant. The vega of both call and put options is calculated as follows:

$$\nu = S_t e^{-qT}\sqrt{T}N'(d_1) \quad (3.16)$$

Volatility is the main input in the valuation of the option price. At-the-money options are more sensitive to volatility fluctuations relative to out-the-money and in-the-money options. Vega is higher for at-the-money options and is always 0 or positive.

## 3.5 Portfolio Construction

Options are securities characterized by maturity and strike price. Those issued with different strikes can be classified into the various moneyness categories. Those issued with different maturities would be classified in different maturity categories. Moreover, as the stock price changes over time, the moneyness of an option also changes over time. For examply, an option with a maturity of six months was issued as 'at-the-money'option may not be 'at-the-money' after one month. To control for moneyness and maturity characteristics, we group options in several moneyness and maturity categories.

The Black-Scholes option pricing model requires that option volatility is constant. However, the literature finds a volatility smile across options' moneyness. At-the-money options have a lower implied volatility as compared to out-the-money or in-the-money options. Therefore, we classify options in categories of moneyness and maturity. Moneyness, $m$, is defined as:

$$\text{Call Options:} \qquad m = \frac{S_t e^{(r_f - q)T}}{X} \tag{3.17}$$

$$\text{Put Options:} \qquad m = \frac{X e^{(q - r_f)T}}{S_t} \tag{3.18}$$

where, $S_t$ is the stock price at time $t$, $X$ is the strike price, $q$ is the annualized dividend yield, $r_t$ is the risk-free rate at time $t$, and $T$ is the time-to-maturity. Moneyness close to 1 indicates that an option is at-the-money, moneyness greater than 1 indicates that an option is in-the-money, and moneyness less than 1 indicates that an option is out-the-money.

We classify options into 30 portfolios based on six maturity and five moneyness categories. First, we assign each option into a maturity bin and then each bin is further subdivided into five moneyenss bins. The maturity and moneyness groups created are based on criteria listed in Table 3.4.

**Table 3.4 Maturity and Moneyness Criteria for Option Portfolios**

This table reports the criteria for classifying options into portfolios of maturity and moneyness based on the remaining days-to-maturity (dtm) and moneyness (m) of options.

| Maturity Group | Criteria | Moneyness Group | Description | Code | Criteria |
|---|---|---|---|---|---|
| 1 | $14 < dtm \leq 30$ | 1 | Deep In The Money | DITM | $m > 1.10$ |
| 2 | $30 < dtm \leq 60$ | 2 | In The Money | ITM | $1.05 < m \leq 1.10$ |
| 3 | $60 < dtm \leq 91$ | 3 | At The Money | ATM | $0.95 < m \leq 1.05$ |
| 4 | $91 < dtm \leq 182$ | 4 | Out The Money | OTM | $0.90 \leq m < 0.95$ |
| 5 | $182 < dtm \leq 273$ | 5 | Deep Out The Money | DOTM | $m < 0.90$ |
| 6 | $dtm > 273$ | | | | |

Following Wei and Zheng (2010) we classify options in different moneyness and maturity buckests. These are grouped as follows: Options that have moneyness greater than 1.05 are binned into Groups 1 and 2. Options in Group 1 are referred to as deep-in-the-money (DITM) and those in Group 2 as in-the-money (ITM). Options that have moneyness close to 1 fall into Group 3 and are referred as at-the-money (ATM). Options that have moneyness below 0.95 are binned into Groups 4 and 5. Those that fall in Group 4 are referred to as out-the-money (OTM) and those that fall in Group 5 are referred to as deep-out-the-money (DOTM). Other papers like Goyal and Saretto (2009) have used equivalent approach by using delta of an option to classify options into moneyness buceks.

## 3.6 Descriptive Statistics

In this section, we report and compare summary statistics of liquidity, implied volatility and the Greeks, and compare these with the literature.

### 3.6.1 Summary Statistics for Options Data

Table 3.5 reports the mean, median, standard deviation, skewness and kurtosis of the three liquidity measures as well as the implied volatility of the options. For each variable, the following calculation is carried out. First, the time-series average for each stock in each year is calculated. Then, the average across the stocks in that year is calculated. The average bid-ask spread for call and put options for the sample period is 7.82 and 7.78 pence, respectively. The proportional bid-ask spread for call and put options is 25.55% and 23.72%, respectively. This is higher than reported by Verousis et al. (2015) for London options (14.43% for calls and 10.53% for puts) for the same sample period. They study liquidity and trading activity of equity options. There could be two main reasons for the differences between their and our numbers. First, their sample size is smaller comprising of 30 stocks. Second, their selection criteria is different from ours; they eliminate options with missing volume data and we do not, since the end-of-day file contains many observations which do not have any volume reported. Cao and Wei (2010) report an average bid-ask spread of 13.44% for CBOE equity options.

Call options have a smaller mean bid-ask spread of 8.83 pence in 2008 as compared to 9.03 pence for put options. For both call and put options, bid-ask spreads decrease from 2008 to 2010. However, the mean bid-ask spread is smaller for put options than call options in 2009 and 2010. The proportional spread is higher in 2010 as compared to 2008 and 2009.

The three spread measures are positively skewed for both call and put options over the three years. The kurtosis for these liquidity measures is positive for both call and put options. Option spread and option percentage spread have a kurtosis of less than 1.00 in

2008 and 2010. The positive kurtosis and positive skewness indicate that the tails are heavier and most of the outliers lie on the right side of the distribution.

**Table 3.5 Summary of Options Liquidity Measures and Option Implied Volatility**

This table shows the mean (μ), median(P50), standard deviation (SD), skewness (Sk), and kurtosis (K) for option liquidity proxied by the option bid-ask spread, option proportional spread (Prop Spread) and option percentage spread (Perc Spread), and implied volatility (IV). The option proportional spread is option bid-ask spread as a percentage of option bid-ask midpoint. The option percentage spread is option bid-ask spread as a percentage of the option's underlying stock price.

| | year | Calls | | | | | Puts | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **μ** | **P50** | **SD** | **Sk** | **K** | **μ** | **P50** | **SD** | **Sk** | **K** |
| Bid-ask spread | **2008** | 8.83 | 8.14 | 2.42 | 0.99 | 0.20 | 9.03 | 8.00 | 3.01 | 1.32 | 1.42 |
| | **2009** | 7.52 | 6.70 | 2.63 | 1.35 | 1.60 | 7.28 | 6.53 | 2.22 | 1.32 | 1.35 |
| | **2010** | 7.12 | 6.29 | 2.94 | 1.08 | 0.53 | 7.03 | 6.14 | 2.73 | 1.14 | 0.63 |
| Prop bid-ask spread (%) | **2008** | 25.00 | 16.67 | 19.99 | 1.61 | 2.40 | 22.51 | 16.15 | 16.25 | 1.47 | 1.79 |
| | **2009** | 22.90 | 15.00 | 18.04 | 1.56 | 2.10 | 21.88 | 14.68 | 17.46 | 1.60 | 2.36 |
| | **2010** | 28.80 | 18.60 | 24.24 | 1.19 | 0.45 | 26.77 | 18.29 | 22.46 | 1.26 | 0.89 |
| Perc bid-ask spread (%) | **2008** | 1.43 | 1.29 | 0.30 | 1.39 | 1.41 | 1.46 | 1.28 | 0.46 | 1.59 | 2.35 |
| | **2009** | 1.43 | 1.28 | 0.39 | 1.61 | 2.38 | 1.40 | 1.24 | 0.39 | 1.66 | 2.59 |
| | **2010** | 1.03 | 0.93 | 0.34 | 1.18 | 0.81 | 1.02 | 0.91 | 0.32 | 1.33 | 1.27 |
| IV (%) | **2008** | 45.60 | 45.38 | 3.61 | 1.00 | 0.87 | 45.79 | 44.32 | 3.05 | 0.65 | -1.79 |
| | **2009** | 47.70 | 45.18 | 4.83 | 1.51 | 1.84 | 47.22 | 46.55 | 2.99 | 0.90 | -0.16 |
| | **2010** | 32.10 | 29.99 | 4.69 | 1.55 | 2.15 | 32.71 | 31.38 | 3.33 | 0.38 | -2.48 |

Implied volatility is similar for call and put options, being 45.55% and 45.79% in 2008, respectively. It increased slightly in 2009 but declined by almost 13% in 2010 compared to 2008 for both call and put options. The markets seemed to have relatively calmed down after the crisis of 2008. Put option implied volatility shows negative kurtosis, and that of call options shows positive kurtosis. Skewness of implied volatility is positive for both call and put options with put options having lower skewness than call options.

## 3.6.2 Summary Statistics of Option Moneyness Portfolios

In this section, we describe the summary statistics of the options classified into moneyness and maturity portfolios as presented in Tables 3.6a and 3.6b. Table 3.6a shows that the absolute option bid-ask spread (in pence) is increasing in the option price (option bid-ask midpoint) and decreasing in the moneyness. Out-the-money options have a wider absolute bid-ask spread, when controlled for price levels. Options with higher prices show wider bid-ask spreads. For example, call options in decile 1 have an average bid-ask spread of 2.85 pence compared to 13.45 pence for decile 10. When we control for the price level of the option within a decile, the bid-ask spread of an option decreases in the moneyness. However, when we do not control for the option price level, the bid-ask spread on average increases in the moneyness (see Table 3.6b). Thus, opposite patterns in the bid-ask spread are observed across moneyness depending on whether or not we control for price level. However, the increase in the absolute bid-ask spread with respect to the price of the option, or its decrease with respect to moneyness within a decile, may not necessarily indicate that the option is illiquid.

**Table 3.6a  Option Bid-Ask Spread by Option Bid-Ask midpoint.**

This table reports the the option bid-ask spread (OS) in the first of a numbered row, and the number of option observations in the second row for the full sample (Sample) and five moneyness categories. Data is sorted into deciles of the option bid-ask midpoint (obam).

| Decile | OBAM Range | | Sample | DITM | ITM | ATM | OTM | DOTM |
|---|---|---|---|---|---|---|---|---|
| ***Panel A: Call Options*** | | | | | | | | |
| 1 | | < 5.25 | 2.15 | 1.31 | 1.24 | 1.43 | 1.74 | 2.35 |
| | | | 142,626 | 104 | 678 | 14,656 | 23,269 | 103,919 |
| 2 | 5.38 | 9.75 | 2.85 | 1.61 | 1.64 | 1.75 | 2.30 | 3.52 |
| | | | 133,318 | 2,794 | 3,679 | 28,141 | 22,553 | 76,151 |
| 3 | 9.88 | 15.88 | 3.08 | 2.03 | 1.86 | 2.14 | 2.75 | 4.11 |
| | | | 137,874 | 8,998 | 8,060 | 37,978 | 22,503 | 60,335 |
| 4 | 16.00 | 24.00 | 4.03 | 2.88 | 2.66 | 3.10 | 3.84 | 5.52 |
| | | | 138,083 | 14,477 | 10,157 | 42,578 | 20,971 | 49,900 |
| 5 | 24.13 | 35.25 | 4.82 | 3.67 | 3.45 | 3.95 | 4.91 | 6.83 |
| | | | 138,275 | 18,528 | 14,235 | 46,159 | 19,751 | 39,602 |
| 6 | 35.38 | 51.25 | 5.97 | 4.85 | 4.50 | 5.15 | 6.38 | 8.71 |
| | | | 137,179 | 23,342 | 19,519 | 46,388 | 16,498 | 31,432 |
| 7 | 51.38 | 76.50 | 7.07 | 5.81 | 5.59 | 6.66 | 7.74 | 10.55 |
| | | | 138,095 | 36,448 | 22,554 | 40,207 | 14,178 | 24,708 |
| 8 | 76.63 | 121.00 | 8.93 | 7.61 | 7.95 | 8.46 | 10.07 | 13.73 |
| | | | 137,657 | 52,020 | 18,263 | 36,642 | 12,066 | 18,666 |
| 9 | 121.13 | 225.25 | 13.45 | 12.36 | 12.19 | 13.09 | 15.86 | 19.92 |
| | | | 137,624 | 59,511 | 22,431 | 33,987 | 8,734 | 12,961 |
| 10 | | > 225.25 | 26.26 | 26.22 | 23.25 | 26.48 | 30.11 | 33.47 |
| | | | 137,698 | 95,558 | 16,040 | 17,468 | 4,089 | 4,543 |
| ***Panel B: Put Options*** | | | | | | | | |
| 1 | | < 5.5 | 2.23 | 1.35 | 1.33 | 1.49 | 1.79 | 2.49 |
| | | | 139,466 | 205 | 793 | 16,240 | 27,186 | 95,042 |
| 2 | 5.63 | 10.50 | 2.86 | 1.74 | 1.78 | 1.83 | 2.41 | 3.66 |
| | | | 132,187 | 4,671 | 4,630 | 31,066 | 24,746 | 67,074 |
| 3 | 10.63 | 17.25 | 3.15 | 2.19 | 1.99 | 2.29 | 2.93 | 4.43 |
| | | | 135,915 | 13,218 | 9,367 | 40,286 | 23,589 | 49,455 |
| 4 | 17.38 | 26.50 | 4.25 | 3.17 | 3.01 | 3.42 | 4.25 | 6.21 |
| | | | 136,952 | 20,316 | 11,385 | 45,671 | 21,714 | 37,866 |
| 5 | 26.63 | 39.13 | 5.10 | 3.98 | 3.92 | 4.36 | 5.44 | 7.80 |
| | | | 133,579 | 23,517 | 16,267 | 47,624 | 18,354 | 27,817 |
| 6 | 39.25 | 57.50 | 6.19 | 5.11 | 4.95 | 5.57 | 7.02 | 9.82 |
| | | | 135,900 | 31,903 | 22,327 | 44,808 | 15,493 | 21,369 |
| 7 | 57.63 | 86.50 | 7.63 | 6.55 | 6.30 | 7.34 | 8.73 | 12.48 |
| | | | 135,704 | 49,413 | 20,675 | 37,316 | 12,255 | 16,045 |
| 8 | 86.63 | 137.00 | 9.33 | 8.17 | 8.21 | 9.19 | 11.29 | 15.89 |
| | | | 135,424 | 61,560 | 18,258 | 33,759 | 10,034 | 11,813 |
| 9 | 137.13 | 250.00 | 15.47 | 14.51 | 14.02 | 15.29 | 18.67 | 24.99 |
| | | | 135,701 | 70,089 | 21,902 | 28,459 | 6,538 | 8,713 |
| 10 | | > 250 | 28.20 | 28.08 | 24.36 | 29.25 | 32.87 | 38.73 |
| | | | 135,311 | 103,629 | 12,418 | 13,135 | 3,225 | 2,904 |

Clearly, the increase of the pence bid-ask spread in the option price is due to the level of option price itself. Because, when we divide options into five moneyness categories, the option pence bid-ask spread increases in moneyness. A high pence bid-ask spread would not necessarily suggest that the option is illiquid. Therefore, we look at the proportional (percentage) bid-ask spread. The relationship between the proportional (percentage) bid-ask spread and the moneyness is negative (positive) in general and even when we sort the options by proportional (percentage) bid-ask spread in deciles. The relationship between the proportional bid-ask spread and moneyness is not affected by the level of the option price, therefore, we consider proportional bid-ask spread and percentage bid-ask spread for our analysis, the other two measures of illiquidity.

Table 3.6b reports the average bid-ask spread, the proportional bid-ask spread, the percentage spread, implied volatility, delta, gamma, and vega of option moneyness portfolios. DITM options have average moneyness close to 1.20 whereas DOTM options have average moneyness close to 0.84. On average, all call moneyness portfolios show higher (lower) proportional bid-ask spread (bid-ask spread) than put portfolios in all years. The bid-ask spread generally increases in moneyness as more expensive options have higher minimum spreads, whereas the proportional bid-ask spread generally decreases and is convex in moneyness. The latter is consistent with George and Longstaff (1998), Cho and Engle (1999) and Engle and Neri (2010). This is quite intuitive as the option price is a positive function of moneyness, i.e., the higher the moneyness, the higher the option price; therefore, the cost of trading an option would also be higher. In other words, the deeper out-the-money the option, the larger the proportional spread, since these options provide the most leverage (Cho and Engle, 1999; Wei and Zheng, 2010). The percentage spread generally increases in moneyness, which is also intuitive. The round-trip cost for trading options ranges from 2.23% to 0.76% of the stock price for put options and from 2.06% to 0.73% of the stock price for call options during the sample period. However, the percentage spread declined from 2% in 2008 to 1.5% in 2010 for DITM options.

Put options have lower delta compared to call options, which indicates that there are probably more in-the-money call options than put options and less out-the-money call options than put options. The data indicates that traders trade more in-the-money call options to take advantage of the leverage, and trade more out-the-money put options to protect themselves from declining markets. The implication is that when the stock market has been in an uptrend, one would expect that more call options will be bought, whereas when the stock market has been in a downtrend, more put options will be bought.

**Table 3.6b Liquidity Measures, Implied Volatility and Greeks of Option Moneyness Portfolios**

This table shows the mean of the variables when the options are assigned to moneyness portfolios ($m$). $mon$ is the average moneyness, defined as $Se^{-qT}/Ke^{-rT}$ for call and $Ke^{-rT}/Se^{-qT}$ for put options, $OS$ is the option bid-ask spread, $OS_{prop}$ is the proportional spread, $OS_{perc}$ is the percentage spread. Moneyness greater than 1.10 indicates deep-in-the-money options; between 0.95 and 1.05 indicates at-the-money options, and less than 0.90 indicates deep-out-the-money options. P stands for puts and C stands for calls.

| Year | CP | $m$ | $mon$ | $OS$ | $OS_{prop}$ | $OS_{perc}$ | $IV$ | $delta$ | $gamma$ | $vega$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | **P** | 1 | 1.20 | 13.88 | 9.91 | 2.23 | 49.95 | -0.70 | 0.0042 | 165.27 |
| | **P** | 2 | 1.07 | 9.86 | 10.95 | 1.54 | 44.32 | -0.59 | 0.0053 | 191.37 |
| | **P** | 3 | 1.00 | 8.00 | 16.15 | 1.28 | 42.71 | -0.43 | 0.0065 | 195.87 |
| | **P** | 4 | 0.93 | 7.05 | 26.43 | 1.14 | 43.97 | -0.29 | 0.0047 | 176.37 |
| | **P** | 5 | 0.84 | 6.36 | 49.13 | 1.12 | 48.00 | -0.18 | 0.0032 | 127.59 |
| | **C** | 1 | 1.18 | 12.51 | 10.27 | 1.92 | 51.17 | 0.77 | 0.0035 | 144.13 |
| | **C** | 2 | 1.07 | 9.84 | 11.31 | 1.52 | 46.37 | 0.68 | 0.0046 | 182.92 |
| | **C** | 3 | 1.00 | 8.14 | 16.67 | 1.29 | 42.83 | 0.52 | 0.0065 | 197.28 |
| | **C** | 4 | 0.93 | 7.16 | 28.33 | 1.18 | 42.02 | 0.36 | 0.0053 | 185.30 |
| | **C** | 5 | 0.82 | 6.49 | 58.37 | 1.25 | 45.38 | 0.22 | 0.0040 | 135.29 |
| 2009 | **P** | 1 | 1.20 | 10.84 | 8.84 | 2.06 | 48.56 | -0.71 | 0.0053 | 142.42 |
| | **P** | 2 | 1.07 | 7.91 | 10.02 | 1.46 | 44.84 | -0.59 | 0.0065 | 164.56 |
| | **P** | 3 | 1.00 | 6.53 | 14.68 | 1.24 | 44.43 | -0.44 | 0.0074 | 169.44 |
| | **P** | 4 | 0.93 | 5.77 | 24.86 | 1.13 | 46.55 | -0.29 | 0.0057 | 153.65 |
| | **P** | 5 | 0.81 | 5.35 | 50.99 | 1.14 | 51.71 | -0.16 | 0.0036 | 107.06 |
| | **C** | 1 | 1.22 | 11.78 | 9.70 | 2.08 | 55.59 | 0.79 | 0.0038 | 123.89 |
| | **C** | 2 | 1.07 | 8.15 | 10.39 | 1.50 | 48.87 | 0.68 | 0.0056 | 158.64 |
| | **C** | 3 | 1.00 | 6.70 | 15.00 | 1.28 | 45.18 | 0.53 | 0.0073 | 169.89 |
| | **C** | 4 | 0.93 | 5.73 | 26.73 | 1.15 | 43.88 | 0.37 | 0.0064 | 159.98 |
| | **C** | 5 | 0.83 | 5.22 | 52.80 | 1.17 | 44.75 | 0.23 | 0.0049 | 124.53 |
| 2010 | **P** | 1 | 1.17 | 11.30 | 8.32 | 1.54 | 36.77 | -0.76 | 0.0055 | 167.97 |
| | **P** | 2 | 1.07 | 8.05 | 10.20 | 1.12 | 30.67 | -0.65 | 0.0076 | 201.93 |
| | **P** | 3 | 1.00 | 6.14 | 18.29 | 0.91 | 29.06 | -0.45 | 0.0095 | 212.82 |
| | **P** | 4 | 0.93 | 5.12 | 34.65 | 0.80 | 31.38 | -0.26 | 0.0066 | 183.15 |
| | **P** | 5 | 0.83 | 4.54 | 62.38 | 0.76 | 35.67 | -0.14 | 0.0040 | 121.06 |
| | **C** | 1 | 1.20 | 11.67 | 9.09 | 1.56 | 39.83 | 0.81 | 0.0043 | 144.99 |
| | **C** | 2 | 1.07 | 8.21 | 10.68 | 1.15 | 33.01 | 0.71 | 0.0067 | 191.56 |
| | **C** | 3 | 1.00 | 6.29 | 18.60 | 0.93 | 29.16 | 0.51 | 0.0094 | 213.20 |
| | **C** | 4 | 0.93 | 5.03 | 38.76 | 0.79 | 28.31 | 0.30 | 0.0075 | 191.05 |
| | **C** | 5 | 0.85 | 4.36 | 66.61 | 0.73 | 29.99 | 0.17 | 0.0052 | 136.70 |

Moreover, Table 3.6b shows that gamma and vega of options across moneyness categories are higher for ATM than ITM or OTM options. Implied volatility for both call and put options in all three years exhibits smiles. The implied volatility is higher for ITM and OTM than ATM options.

### 3.6.3 Summary Statistics of Option Maturity Portfolios

Table 3.7 reports the bid-ask spread, the percentage bid-ask spread, the option percentage spread, implied volatility, delta, gamma, and vega of option maturity portfolios.

**Table 3.7 Liquidity Measures, Implied Volatility and Greeks of Option Maturity Portfolios**

This table shows the mean of the variables when options are assigned to maturity portfolios. $OS$ is the option bid-ask spread, $OS_{prop}$ is the $OS$ reported as a percentage of option bid-ask midpoint, $OS_{perc}$ is the $OS$ reported as a percentage of stock price, $IV$ reports the implied volatility of options, delta, gamma and vega are option greeks.

| Year | $CP$ | $Maturity$ | $mon$ | $OS$ | $OS_{prop}$ | $OS_{perc}$ | $IV$ | $delta$ | $gamma$ | $vega$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | P | 1 | 1.00 | 6.86 | 38.10 | 1.30 | 57.12 | -0.46 | 0.0076 | 58.09 |
| | P | 2 | 1.01 | 7.63 | 27.89 | 1.32 | 49.13 | -0.46 | 0.0059 | 95.74 |
| | P | 3 | 1.00 | 7.41 | 22.54 | 1.22 | 42.49 | -0.45 | 0.0055 | 127.64 |
| | P | 4 | 1.01 | 8.78 | 17.66 | 1.41 | 43.96 | -0.44 | 0.0041 | 178.08 |
| | P | 5 | 1.01 | 10.91 | 16.21 | 1.79 | 40.34 | -0.42 | 0.0034 | 243.91 |
| | P | 6 | 1.02 | 12.59 | 12.68 | 1.75 | 41.71 | -0.40 | 0.0023 | 324.31 |
| | C | 1 | 1.00 | 6.64 | 39.43 | 1.27 | 55.85 | 0.50 | 0.0076 | 57.53 |
| | C | 2 | 1.00 | 7.54 | 30.95 | 1.30 | 48.06 | 0.51 | 0.0059 | 94.96 |
| | C | 3 | 1.00 | 7.29 | 26.15 | 1.20 | 41.23 | 0.49 | 0.0056 | 125.30 |
| | C | 4 | 1.00 | 8.69 | 20.72 | 1.39 | 43.48 | 0.51 | 0.0040 | 175.94 |
| | C | 5 | 1.00 | 10.60 | 17.75 | 1.75 | 40.75 | 0.52 | 0.0033 | 243.21 |
| | C | 6 | 0.99 | 12.21 | 14.94 | 1.69 | 43.97 | 0.52 | 0.0023 | 316.96 |
| 2009 | P | 1 | 1.00 | 5.69 | 38.32 | 1.17 | 53.45 | -0.46 | 0.0093 | 53.57 |
| | P | 2 | 1.00 | 6.16 | 27.69 | 1.18 | 48.81 | -0.46 | 0.0072 | 83.11 |
| | P | 3 | 1.00 | 6.03 | 21.84 | 1.16 | 45.17 | -0.45 | 0.0063 | 108.23 |
| | P | 4 | 1.00 | 7.01 | 17.08 | 1.31 | 45.62 | -0.44 | 0.0047 | 151.76 |
| | P | 5 | 1.00 | 8.63 | 13.76 | 1.63 | 44.24 | -0.42 | 0.0038 | 208.70 |
| | P | 6 | 1.00 | 10.16 | 12.59 | 1.98 | 46.02 | -0.40 | 0.0030 | 279.17 |
| | C | 1 | 1.00 | 5.61 | 40.39 | 1.15 | 51.65 | 0.50 | 0.0092 | 51.88 |
| | C | 2 | 1.01 | 6.21 | 29.00 | 1.20 | 48.39 | 0.51 | 0.0070 | 81.87 |
| | C | 3 | 1.01 | 6.34 | 23.30 | 1.21 | 45.62 | 0.50 | 0.0062 | 107.81 |
| | C | 4 | 1.02 | 7.46 | 17.59 | 1.38 | 46.57 | 0.52 | 0.0046 | 152.06 |
| | C | 5 | 1.01 | 8.96 | 14.31 | 1.67 | 46.27 | 0.53 | 0.0037 | 208.90 |
| | C | 6 | 1.01 | 10.51 | 12.93 | 1.98 | 47.44 | 0.54 | 0.0029 | 281.81 |
| 2010 | P | 1 | 1.00 | 6.18 | 47.12 | 0.93 | 39.52 | -0.46 | 0.0098 | 63.76 |
| | P | 2 | 1.00 | 6.58 | 35.87 | 0.95 | 33.05 | -0.47 | 0.0084 | 98.16 |
| | P | 3 | 1.00 | 6.58 | 29.22 | 0.95 | 30.03 | -0.46 | 0.0074 | 128.96 |
| | P | 4 | 1.00 | 7.35 | 21.12 | 1.02 | 30.35 | -0.46 | 0.0057 | 183.96 |
| | P | 5 | 1.00 | 7.97 | 14.74 | 1.09 | 30.54 | -0.45 | 0.0046 | 256.68 |
| | P | 6 | 1.00 | 7.53 | 12.53 | 1.21 | 32.76 | -0.42 | 0.0039 | 332.77 |
| | C | 1 | 1.00 | 5.90 | 48.35 | 0.85 | 36.07 | 0.49 | 0.0098 | 60.84 |
| | C | 2 | 1.01 | 6.50 | 39.05 | 0.93 | 31.78 | 0.49 | 0.0084 | 95.32 |
| | C | 3 | 1.01 | 6.63 | 31.93 | 0.95 | 29.61 | 0.49 | 0.0074 | 127.00 |
| | C | 4 | 1.01 | 7.58 | 23.17 | 1.05 | 30.69 | 0.50 | 0.0056 | 182.55 |
| | C | 5 | 1.01 | 8.06 | 16.74 | 1.14 | 31.35 | 0.51 | 0.0045 | 253.89 |
| | C | 6 | 1.02 | 8.02 | 13.23 | 1.26 | 32.88 | 0.52 | 0.0040 | 333.39 |

Values reported in the monyeness column ($m$) indicate that on average the moneyness of all maturity portfolios is close to 1. Apart from a dip for middle maturity portfolios in 2008 and 2009, the bid-ask spread and the percentage spread increase with maturity. This suggests that the average transaction cost for trading short maturity options is smaller. However, the proportional spread, which is the spread expressed as a percentage of the option price, decreases in maturity. This finding is in line with that of Cho and Engle (1999) and Engle and Neri (2010), but contrary to that of George and Longstaff (1998). Cho and Engle (1999) report that in a static model, proportional bid-ask spreads are explained by the main characteristics of option contracts such as moneyness, maturity, option price, and stock market activity such as hedge ratios and volatility. They find that the coefficient of time-to-maturity is negative and argue that this is because an option close to maturity is more likely to be exercised and, as a result, it may be difficult for an options market maker to maintain a hedged position or make a market, suggestging that this is due to inventory risk. Therefore, option proportional spreads are higher for short maturities. However, George and Longstaff (1993) find that proportional option spreads decrease with moneyness but increase with time-to-maturity.

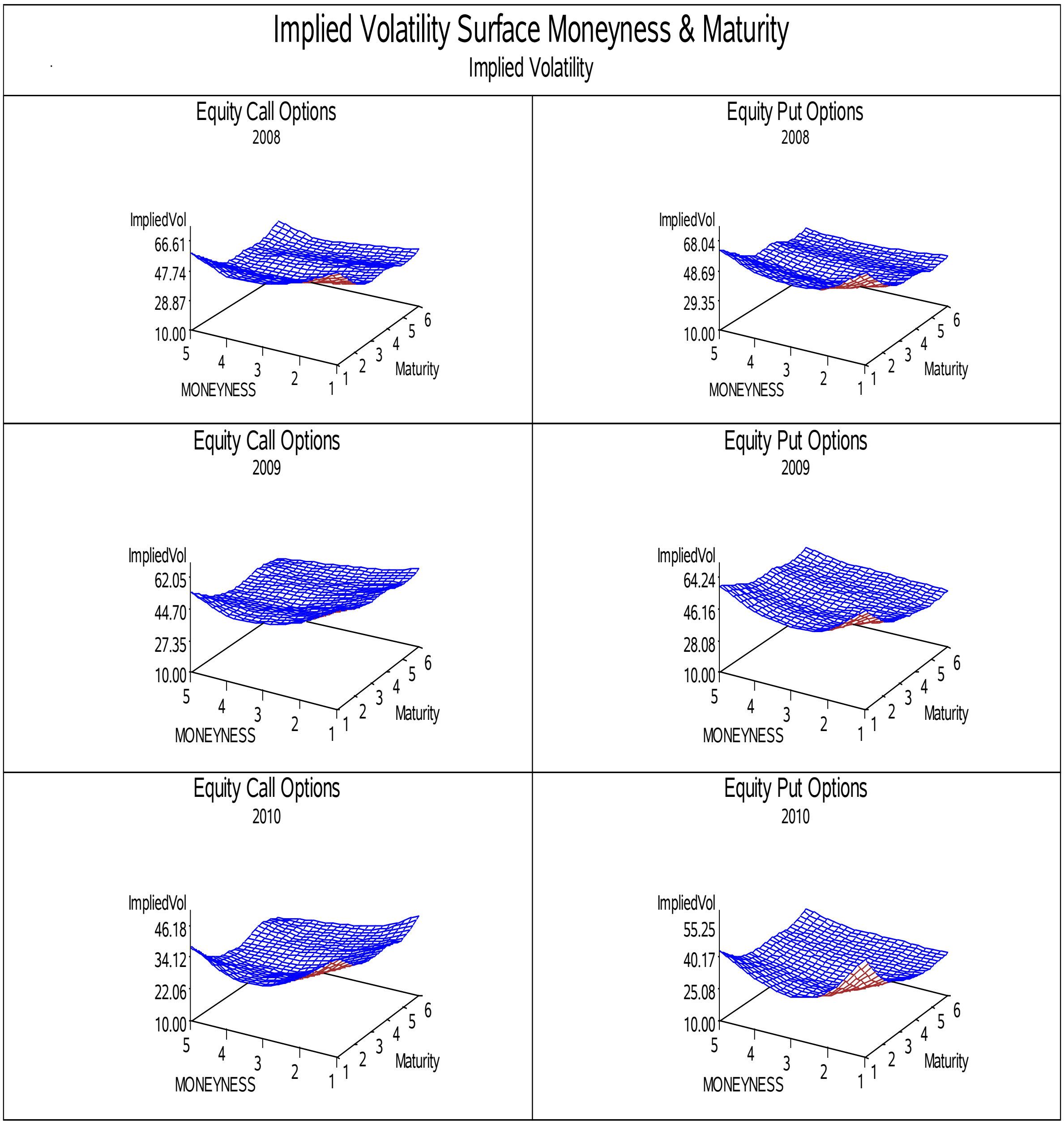
In Table 3.7, we observe that implied volatility generally decreases with longer maturity for both call and put options. The analysis period is a financial crisis period, especially the year 2008, and in that year we observe short maturity put options (category 1) have implied volatility of 57.12% compared to 41.71% for long maturity put options (category 6), suggesting a difference of 15.41% in that year. This difference for put options is 7.43% in 2009 and 6.76% in 2010. Some of the observations made for the implied volatility of options is summarized as follows. First, put options have generally slightly higher implied volatilities than call options. Second, the implied volatilities are higher for short-maturity options and lower for long-maturity options. Third, implied volatilities have declined in 2010 as compared to 2008. Fourth, the difference in implied volatility between long-maturity and short-maturity portfolios has declined over the three years. The higher value for the implied volatility in 2008 can be related to the crisis period. Moreover, volatility tends to be a decreasing function of maturity when short-dated volatility is historically high, because there is an expectation that volatility will decrease.

### 3.6.4 Summary Statistics – Implied Volatility

Figure 3.2 plots the smile surfaces, which are graphs of implied volatility of call and put portfolios against their moneyness and maturity. In general, implied volatility is higher for ITM and OTM than ATM options, and for shorter maturity than longer maturity options.

**Figure 3.2 Implied Volatility**

Figure 3.2 plots the implied volatilities of call and put options separately across moneyness and maturity buckets. Short-term maturity options show a pronounced smile whereas long-term options show a pronounced smirk. Moreover, deep-out-the-money options are more expensive than deep-in-the-money options, with at-the-money options being the cheaper options.




It is observed that the implied volatility shows a smile for short-maturity options in all years for both call and put options. However, the pattern is not the same across all maturities. On the main, the curvature of the implied volatility looks flatter for long-maturity options. In 2010, ITM and DITM call options show higher implied volatility.

Generally, the smile pattern is more visible for short-maturity options than for long-maturity options. Since the 1987 US stock market crash, volatility surfaces for global indices have been characterized by the volatility skew. There are several explanations for the volatility skew.

1. The leverage effect, where negative price movements are associated with higher volatility.
2. Large jumps in spot prices tend to be downwards rather than upwards. Higher volatility is associated with downward market movements.
3. Supply and demand: investors are net buyers of stock and, therefore, tend to be net buyers of puts (which provide downside insurance) and sellers of calls (which provide leverage).

### 3.6.5 Summary Statistics – Liquidity Surface

Figure 3.3 plots the option liquidity surface using the percentage spread as the liquidity measure. The percentage spread shows a pattern similar to a smile, but varies across moneyness and maturity. In 2008, the call and put options have higher spreads for longer maturity options and moreover, spread declines from maturity category 2 to category 3 and rises for maturity category 4 and thereafter. In 2009 and 2010, put options do not show a 'U' shape pattern. DOTM options show a flatter relation between the percentage spread and maturity relative to ITM options. ATM options have lower spreads compared to ITM and OTM options. This suggests that option spreads do not increase linearly with moneyness.

### 3.6.6 Summary Statistics – Option Market Liquidity

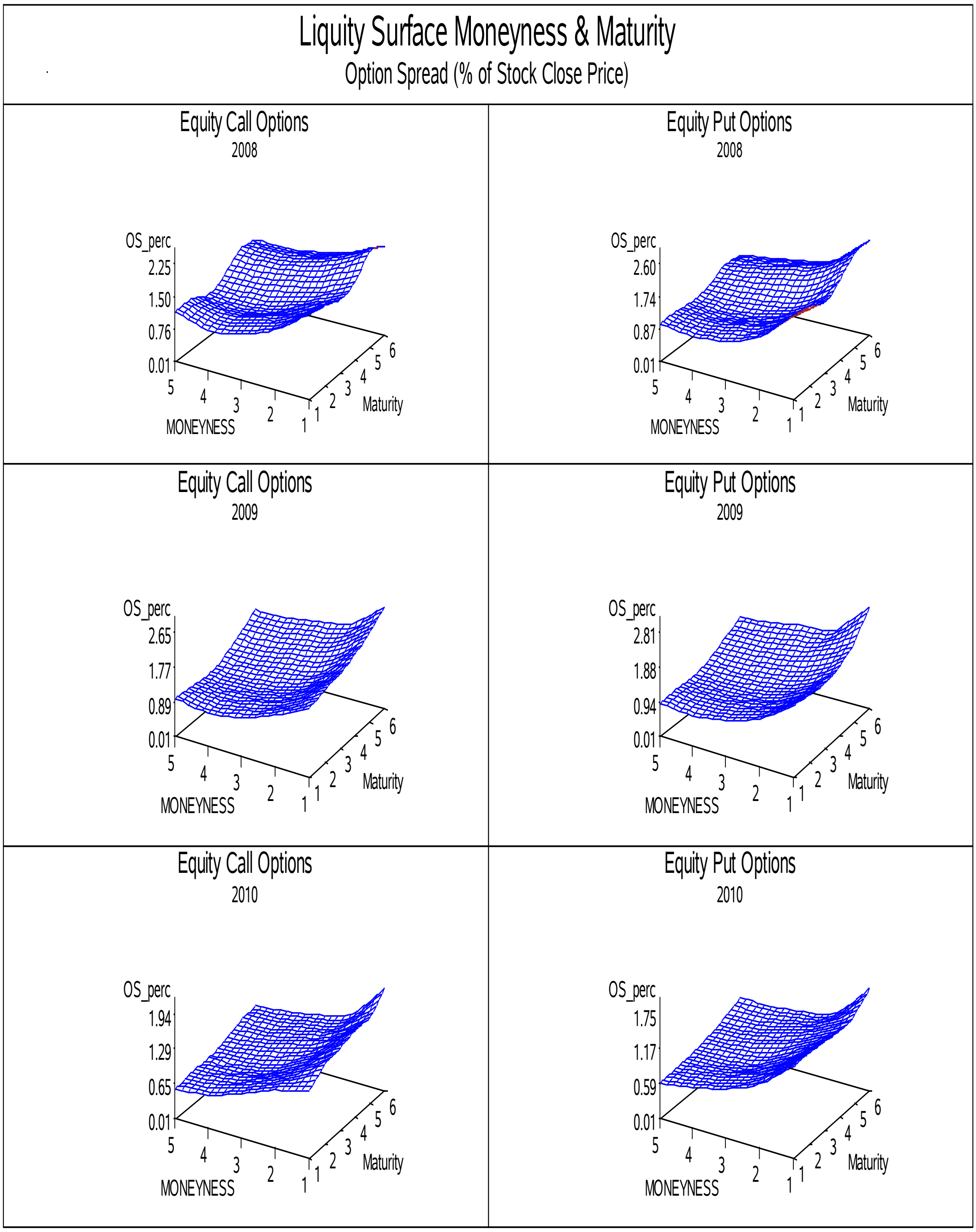
As shown in Figure A1 and Table A2 in Appendix A of this chapter, liquidity in call and put options markets move together.[12] However, we can see a dramatic decrease in liquidity in September-October-November 2008 for the London LIFFE market. It then took some time to return to its previous level. This is the same period in which the short-selling ban was imposed in the financial markets (Verousis and Gwilym, 2012). Verousis and Gwilym (2012) also report a dramatic drop in depth during the same period. We observe a similar pattern for the all equity options market (both calls and puts combined).

[12] The table and figure are put in the Appendix due to their large size.

In Figure A3, the stock market also shows a decline in liquidity during the same period, but the effect is not as pronounced as in the options market.

**Figure 3.3 Liquidity Surface (Option Spread as Percentage of Stock Price)**

This graph shows the liquidity surface across moneyness and maturity of equity options. For each sample year, the percentage bid-ask spread of options are plotted against the option maturity and moneyness for calls and puts separately.



# CHAPTER 4
# LIQUIDITY COMOVEMENT

## 4.1 Introduction

Chordia et al. (2000) are the first to report evidence of liquidity comovement (liquidity commonality) in the NYSE stock market by demonstrating that changes in the liquidity of a stock can be partially explained by changes in the liquidity of the stock market. They also report that liquidity comovement varies across stocks, which implies that it is a potential source of liquidity risk. It is shown theoretically and empirically by Acharya and Pedersen (2005) that liquidity commonality is indeed a source of liquidity risk, and is priced in NYSE stock returns. They document a premium of 0.08% for this liquidity comovement. This implies that, on average, a marginal investor receives a premium of 0.08% for buying (or holding) a stock whose liquidity comoves perfectly with the liquidity of the stock market.

Accordingly, liquidity comovement of an asset is important for the construction of diversified portfolios of basic as well as derivative assets. In general, an asset is added to a portfolio to increase the returns and decrease the overall risk of the portfolio. The diversification benefits could be affected if an added asset becomes illiquid when the overall market is illiquid or when the overall market provides small returns. Moreover, derivative assets are added to a portfolio to either minimize market risk or earn profits by speculating. Derivatives also have their own liquidity, which varies with the market as shown by Cao and Wei (2010). Cao and Wei (2010) investigate liquidity commonality in CBOE equity options from January 1996 to December 2004 and present evidence that changes in the liquidity of equity options varies with changes in the liquidity of the options market.

Options are derivative securities having a payoff dependent on the payoff of the underlying asset, and are considered redundant securities only in complete and competitive markets with no transaction costs, no asymmetric information and no short-sale restrictions. However, since none of these assumptions actually hold, options are not spanned by stock prices. In other words, option prices are no longer functions of only underlying stock prices and risk-free securities, but are affected by transaction costs, information asymmetry costs and costs related to the difficulty of hedging in the underlying asset market. Cho and Engle (1999) propose a derivative hedge theory that in the options market, liquidity and spreads are determined by liquidity and spreads in the underlying stock market when market makers are able to completely hedge their option positions by deriving liquidity in the underlying stock market. Differences in bid-ask spreads between derivatives and underlying asset markets could emerge because of difficulties in hedging in underlying markets. It is, therefore, reasonable to conjecture that liquidity of a derivative and that of its underlying asset matter, as well as time variation in these measures.

In the equity options market, the price of an option may, therefore, be affected by the liquidity of the option and that of its underlying asset. Similarly, if the spreads in the option market are determined by the spreads in the underlying stock market, we propose that changes in option spreads may vary with changes in spreads of the options market as well as with changes in the spreads of the underlying stock market. When the spread of an asset changes with that of the market it is commonly referred to as liquidity commonality in the literature. When the spread of an option covaries with spreads in the options market and with spreads in the underlying market, we shall use the terms 'liquidity comovement between options and their market' and 'liquidity comovement between options and their underlying stock market,' respectively. In this study, we fill a gap in literature on the nature and the extent of liquidity commonality in the UK equity options market.

The main aim of this chapter is to investigate two potential sources of liquidity risk. First, we check whether the liquidity comovement between equity options and their market, documented by Cao and Wei (2010) for CBOE equity options, is present in the UK options market. Second, we fill a gap in the equity options literature by investigating liquidity comovement between options and their underlying stock market. Most studies on equity options have been conducted on US options markets. Recently, however, there has emerged a study on the NYSE Euronext LIFFE equity options market. Verousis et al. (2015) investigate the intraday behaviour of equity option liquidity and its determinants, and the influence of macroeconomic events and commonality on intraday liquidity of NYSE LIFFE (Amsterdam, London, and Paris) options. They find that the inventory management models cannot explain the intraday variation in option spreads and depths.

However, they find that option liquidity is strongly correlated with option volatility. Increases in option volatility are associated with decreases in option liquidity, which is in line with information asymmetry models and the derivative hedge theory. Although, they investigate the intraday behaviour of liquidity of equity options, our focus is different. This study uses the daily NYSE Euronext LIFFE data to document liquidity comovement in the UK equity options market. We also examine the size and volatility effects in this liquidity comovement and investigate the factors affecting changes in bid-ask spreads. Further, we compare our findings to those documented in the literature on CBOE equity options.

This study employs two measures of liquidity for an option: the proportional bid-ask spread and the percentage bid-ask spread. The option proportional bid-ask spread is the option bid-ask spread divided by the option bid-ask midpoint. The option percentage bid-ask spread is the option bid-ask spread divided by the closing price of its underlying stock. The difference between the proportional and the percentage bid-ask spreads is due to the division factor only. We use ‘proportional’ and ‘percentage’ to differentiate between them. To our knowledge, no study has yet used the bid-ask spread scaled by the underlying stock price. We propose to use it since proportional bid-ask spreads are found to be a function of stock price for the same moneyness options, as reported by Wei and Zheng (2010).

Cao and Wei (2010) present strong evidence of liquidity commonality between CBOE equity options and their market. However, they only study these effects for ATM options with maturity of upto one year. The analysis in this chapter differs in two aspects. First, this study investigates liquidity comovement not only between options and their market but also between options and the stock market. By investigating the latter, the analysis documents evidence of yet another source of liquidity risk. Second, this study investigates these comovements in both the moneyness and maturity dimensions of an option. This is important because it is well known that options on a particular stock have an implied volatility smile, with OTM and ITM options have higher implied volatilities than ATM options. Moreover, implied volatility is usually a decreasing function of maturity when short-term volatility is historically high, because there is an expectation that volatility will subsequently decrease.

More specifically, the analysis in this chapter aims to answer the following questions and the related hypotheses:

**Hypothesis H1:**

Liquidity comovement in the options market is positive.

Is there evidence of liquidity comovement between options and their market? A positive liquidity comovement would imply that whenever there is a positive liquidity shock in the options market, the liquidity of an option increases.

**Hypothesis H2:**

Liquidity comovement between options and their underlying stock market is positive.

Is there evidence of liquidity comovement between options and the market of their underlying stocks? This is motivated by derivative hedge theory (Cho and Engle, 1999), which implies that when hedging is a primary reason for trading in the derivatives market, the liquidity of the derivative is a function of the liquidity of the underlying market. Therefore, if the spreads in the options market are determined by the spreads in the underlying stock market, liquidity comovement between options and the stock market is expected to be positive.

For both the above questions, we further investigate the following:

**Hypothesis H1a & H2a:**

Liquidity comovement between options and the option market has same sign for both calls and puts.

Is liquidity comovement different for call than for put options? Does liquidity comovement exhibit any systematic patterns across different maturity and moneyness? What are the implications of these differences, if any?

**Hypotheses H1b & H2b:**

The options on small firms show higher liquidity comovement.

**Hyptheses H1c & H2c:**

The options on low volatility stocks show higher liquidity comovement.

Size and volatility effects in liquidity comovement have been observed in stock markets (Chordia et al., 2000). The size effect implies that small firms show high liquidity comovement and the volatility effect implies that firms with high return volatility exhibit high liquidity comovement. It is plausible to expect that options of small firms have a higher liquidity comovement since stocks of small firms are more affected by inventory risk and information asymmetry than those of large firms (Cao and Wei, 2010).

**Hyptheses H3:**

Does inventory risk, information asymmetry or derivative hedge theory, or a combination of these help explain the liquidity comovement in options?

The remainder of this chapter is structured as follows: Section 4.2 discusses the literature on liquidity comovement, Section 4.3 describes the hypotheses and research methodology employed to investigate the hypotheses, Section 4.4 describes the data and correlations Section 4.5 discusses the results, Section 4.6 discusses the robustness checks and Section 4.7 concludes.

## 4.2 Literature Review

In Chapter 2, the literature on liquidity comovement in the stock and the derivative markets was reviewed. This section summarizes the main literature on liquidity comovement in the stock and equity options markets.

Comovement refers to the concept that liquidity of a security covaries with market-wide factors such as returns, liquidity and volatility. When liquidity of an asset comoves with that of the whole market, it is referred to as liquidity comovement or liquidity commonality. Several explanations or reasons have been forwarded for this commonality. For example, when a common component across stocks related to the costs of providing liquidity is present, or when securities act as substitutes for other securities, there would be correlation in liquidity across stocks.[13] Further, when liquidity is measured by

[13] For example, Hasbrouck and Seppi (2001) find that the first common principal component explains the variation in liquidity as measured by bid-ask spreads. Huberman and Halka (2001) on the other hand suggest that to cause correlations in liquidity across stocks, securities must act as substitutes.

transaction costs, such as the bid-ask spread, increased trading activity is the most likely explanation for the existence of a common factor affecting liquidity. If the increased trading activity indicates an information disadvantage to market makers, they will adjust their inventory, and this could cause comovement in the bid-ask spread. In this case, the common component that induces the comovement in liquidity would be related to information asymmetry or inventory risk.

Investigating liquidity comovement may have important implications for market participants. For example, Acharya and Pedersen (2005) note that not only stocks with higher average liquidity costs have higher returns but also stocks with higher liquidity comovement have higher returns. They report that investors who buy stocks that have higher sensitivity to shocks in market liquidity (i.e., have higher liquidity comovement) require an extra compensation in the form of a liquidity risk premium. Intuitively, if a stock becomes highly illiquid because of some exogenous shock in market liquidity such that the market becomes unexpectedly illiquid, investors would demand a higher return for that stock. This implies a required risk premium for liquidity comovement between that stock and the market.

The first main studies investigating liquidity comovement in the US stock markets include Chordia et al. (2000), Hasbrouck and Seppi (2001), and Huberman and Halka (2001). Chordia et al. (2000) are the first to investigate liquidity commonality in the stock market. They analyse a sample of 1,169 stocks traded on NYSE in 1992. Their approach focuses on how the daily changes in liquidity of each stock covary with the daily changes in the liquidity of the stock market. They measure market liquidity by average liquidity of all stocks in the sample. Their results of market model regressions provide evidence of comovement in liquidity. They report that the percentage quoted spread has a significant comovement coefficient of 0.791, with an average adjusted-$R^2$ of less than two percent for all individual stock regressions. They conclude that inventory risk and information asymmetry theories explain liquidity comovement when they estimate the relation between the percentage bid-ask spread and market-wide dollar volume (proxy for inventory risk), average dollar size of a transaction (proxy for asymmetric information/informed trading), and the total number of trades for a stock. On the other hand, Hasbrouck and Seppi (2001) document a systematic time-varying component of liquidity. They argue that both inventory and asymmetric information-based theories can not explain this component. Huberman and Halka (2001) study Dow Jones Industrial

Average (DJIA) index stocks during 1994. They document the presence of a systematic component of liquidity by employing principal component analysis (PCA) on data with 15-minute granularity. They report weak evidence of liquidity comovement since the first common factor explains 13% of the total variation in the log quote slope[14], 11.83% of the total variation in the log spread, and 10.75% of the total variation in the quote slope.

Another explanation of liquidity comovement in a dealer market is forwarded by Coughenour and Saad (2004). In a dealer market like NYSE, the exchange requires a stock specialist firm to provide liquidity for more than one stock. Since the firms that provide liquidity for the same stock share the same capital pool, information regarding inventory levels, and profits, the liquidity of such stock comoves with the other stocks managed by the same firm. They report empirical evidence that liquidity of individual stocks co-varies with that of specialist's portfolio after controlling for the variation in market liquidity. They report a mean adjusted-$R^2$ of approximately 22%, which is higher than the 1.4% reported by Chordia et al. (2000). Coughenour and Saad (2004) argue that the difference in the R-square is due to the aggregation period. When they aggregate data at daily intervals instead of aggregating liquidity for a part of the day, the mean adjusted R-square decreases to between 2.9% and 3.9%, which is comparable to the 1.4% reported by Chordia et al. (2000).

Liquidity comovement has also been investigated in order-driven markets (e.g., Domowitz and Wang, 2002, on the Australian Stock Exchange; Bauer, 2004 on the Swiss Stock Exchange; and Corwin and Lipson, 2011 on electronic order-flow of a sample of NYSE stocks).

In an order driven market, a trader submits either a market order or a limit order. When a trader submits a market order, he is regarded as a liquidity taker. When he submits a limit order, he is regarded as a liquidity provider. When the choice of order type is correlated across stocks, this may result in comovement in liquidity. Domowitz and Wang (2002) support this conjecture through order book simulations for two hypothetical stocks and the use of actual order book data from the Australian Stock Exchange. Their results show that there is a link between comovement in liquidity and comovement in returns as they

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[14] Log quote slope is $=\frac{\log\left(\frac{A_k}{B_k}\right)}{\log\,(N_k^A)+\log(N_k^B)}$, where, $A_k$and $B_k$ are ask and bid quote prices of record k, and $N_k^A$ and $N_k^B$ are the number of shares posted at ask and bid quotes, respectively.

find that liquidity comovement is due to supply and demand comovements (comovement in order type across stocks) and return comovement is caused by the comovement in order-flow (the size and direction of trades). They also suggest that when stock returns are negatively correlated, liquidity comovement for these stocks can be positive. In such a scenario, this may pose a problem in diversification strategies for portfolio managers. Corwin and Lipson (2011) confirm the results of Domowitz and Wang (2002) using electronic order book data for a sample of NYSE stocks. They find that both the common order flow and the common order type for specific traders matter for liquidity. They classify traders as program, institutional, retail, and exchange traders. They do not separately include the common factor of order type in the regressions, so it is not possible to determine what the incremental explanatory power is for disaggregating trader type, or whether the comovement of order type is mainly due to a specific group of traders. For order flow, they show that comovement is mainly due to program traders, so the common factor of order type might very well be due to program traders. In addition, because the order flow factor explains some fraction of liquidity (albeit small), program traders play a role. This evidence suggests that algorithm traders might have a significant influence on liquidity commonality, as they usually operate across many different stocks and have correlated strategies, or their strategies involve buying and selling many different stocks at the same time (e.g., statistical arbitrage), therefore taking or providing liquidity across many different stocks at once.

Bauer (2004) uses principal component analysis to investigate liquidity commonality in an order-driven market. He uses order book data of 19 stocks listed on the Swiss Stock Exchange (SWX) for the period from 03 May 2002 to 31 July 2002. Bauer's (2004) results suggest that about 45% of the variation in liquidity is explained by three principal components. This is higher than the 30% reported for NYSE (quote-driven market) by Huberman and Halka (2001).[15] He further reports that liquidity is affected by these common factors across orders and quoted quantities of all sizes. The proportion of liquidity variation that these common factors explain varies over the trading day. Further, he report that cross-sectional liquidity is significantly affected by market-wide liquidity

[15] Huberman and Halka (2001) only find one principal component to be significant and explaining the variation in liquidity across stocks. They look at the residuals of autoregressive processes of the liquidity measures, and define the presence of positive correlation in these residuals as evidence of a common factor affecting liquidity in different stocks. Whereas, Bauer (2004) follow Hasbrouk and Seppi (2001) and perform a principal component analysis of the liquidity proxies.

and volatility, and these two variables are accountable for a fifth of the variation in the cost of liquidity whereas they are responsible for only 6% of depth.

Two working papers that empirically investigate liquidity comovement in the UK equity market using LSE-listed stocks are Gregoriou et al. (2010) and Foran et al. (2015). Gregoriou et al. (2010) analyse a sample of LSE stocks covering the period from 10 October 2005 to 10 June 2009. They apply the methodology of Chordia et al. (2000) and present evidence supporting the argument of Fernando et al. (2008) that liquidity shocks that result in a financial crisis are permanent and systematic. Fernando et al. (2008) explain that due to negative shocks, liquidity in an order-driven market decreases because large number of market makers withdraw from the exchange following large order imbalances. Gregoriou et al. (2010) observe that liquidity comovement is more apparent after the credit crunch. They proxy trading activity by the number of trades and pound trading volume. They provide evidence that in the UK equity market, the liquidity comovement between the market portfolio and financial companies is mainly due to trading activity around the 2007 crisis. They report that the mean change in concurrent market liquidty ranges from 0.1030 to 0.9052, and 80% of the stocks in the sample have a positive and significant coefficient. Moreover, their results indicate that liquidity commonality is higher in the LSE market compared to the NYSE market as the average $R^2$ is above 5%, which is higher than the 1.4% reported by Chordia et al. (2000) for NYSE stocks. For the credit crisis subsample, they report that the concurrent liquidity coefficient is significant for all stock regressions and the average $R^2$ has also increased to more than 10%. The plausible reason for FTSE100 stocks showing stronger liquidity comovement than NYSE stocks is that FTSE 100 stocks are the largest and most heavily traded in the UK whereas Chordia et al.'s (2000) 1169 US-firm sample was more mixed. Also, Galariotis and Giouvris (2007) report that normal market size in LSE is higher than NYSE or NASDAQ. Therefore, one could observe a stronger liquidity comovement in LSE stocks. The finding of stronger liquidity comovement in the post crisis period is consistent with the proposition by Brockman and Chung (2002) that investor behaviour can create stronger commonality for big firms. Gregoriou et al. (2010) suggest that when a market is under stress, investors holding shares of big firms seek to offload inventory of their stocks at the lowest possible cost, whereas the share price of small firms with higher level of information asymmetry will decrease drastically in bear markets causing an increase in the component of their costs that is associated with liquidity, which explains the higher liquidity comovement in big firms.

The second recent study on liquidity comovement in the UK equity market is Foran et al. (2015). Their sample includes daily data from January 1991 to December 2013 starting with 1274 stocks and ending with 2240 stocks in 2006. They investigate both the liquidity comovement in the stock market and its effect on stock returns. They find that liquidity shocks to individual stocks are related to those of the market, which is evidence for liquidity commonality. Using principal component analysis, they extract systematic, or market, liquidity factors and provide evidence that these command a positive risk premium. This result is quite counter-intuitive because it suggests that a less liquid stock provides a lower return compared to an otherwise liquid stock. However, in a positive supply market, such as the stock market where shares are always in a positive supply, a marginal investor would purchase an illiquid stock only when he is compensated for its illiquidity. Amihud and Mendelson (1986) and Acharya and Pedersen (2005) maintain that US stocks with higher proportional bid-ask spreads (illiquid stocks) have higher returns. Foran et al. (2015) suggest that their anomalous result may be due to differences in the market structure between US and UK exchanges. For example, NASDAQ in the US moved from a quote driven to a hybrid mechanism that includes an order book, and NYSE is a hybrid structure with specialists who are obliged to provide some stability to stocks assigned to them. However, in the UK, the London Stock Exchange (LSE) operates two main mechanisms: the Stock Exchange Electronic Trading Service (SETS) and the Stock Exchange Automated Quotation System (SEAQ). SETS is a pure order book for liquid stocks and SEAQ is a quote-driven system for less liquid stocks that are supported by market makers.

The findings of the above two studies on liquidity comovement in the UK equity market are summarized as follows. First, both studies show that stocks trading on LSE exhibit comovement in liquidity. Second, common liquidity shocks during the financial crisis are permanent and non-diversifiable. These non-diversifiable effects have obvious implications for asset pricing. Third, liquidity comovement between a stock and its market is higher for stocks that trade on LSE compared to those that trade on NYSE. This is concluded based on the magnitude of the coefficient on a contemporaneous variable of changes in market liquidity and the overall average $R^2$ of the stock regressions. Fourth, in the post-crisis period, liquidity commonality is stronger, which is consistent with the argument that investor behaviour can create higher liquidity comovement for big firms. Finally, since liquidity comovement is non-diversifiable, it has an impact on stock returns. Although counter-intuitive, a stock that becomes illiquid when the market faces an illiquidity shock provides a lower return compared to a stock that is liquid when the market faces an illiquidity shock.

Brockman et al. (2007) study liquidity commonality across 47 stock markets. Using intraday spread and depth data, they report that liquidity changes at firm-level are significantly affected by those at the exchange level. They find exceptionally strong commonality in liquidity for emerging Asian exchanges and very low commonality in liquidity for Latin American exchanges. Through a cross-exchange analysis, they also report a “distinct global component in bid-ask spreads and depths”. They further show that local and global sources of liquidity commonality explain approximately 39% and 19% of a firm’s total liquidity commonality, respectively. They find that both domestic and U.S. macroeconomic announcements drive commonality in liquidity at both exchange and global levels.

Liquidity comovement is not only a stock market phenomenon. Liquidity is found to comove in derivatives as well. Derivatives are often used to optimize portfolio returns and hedge market risks. Since the focus of this thesis is equity options, we review the developing literature on liquidity comovement in derivative markets. As observed in the stock markets, liquidity comovement is non-diversifiable, and if this is the case in derivative markets, the obvious next step would be to investigate its effect on returns of derivative assets, which in our case are equity options.

Liquidity comovement between an option and the market, and its impact on the pricing of an option, is a recent topic of discussion in the literature. Since the payoff of an option depends on the payoff of the underlying asset, one would expect the liquidity of an option to be affected by changes in the liquidity of the options market as well as that of the underlying stock market. Moreover, a common option trading strategy is to hedge exposure in the underlying asset to avoid downside risk. To maintain a completely hedged position, a trader trades a number of its underlying asset equal to the delta of the option. This would mean that the trader will incur costs for trading in both the options and the underlying stock markets. As discussed in Section 2.4, it is documented that liquidity of a stock comoves with liquidity of the stock market. Therefore, when there is a hedging interest in the underlying stock and that stock’s liquidity comoves with the stock market liquidity, the liquidity of the option on that stock could also comove with the liquidity of the underlying stock market. Thus, we suggest that the liquidity of an option does not only comove with the liquidity of the options market but also with the liquidity of the underlying stock market.

There are several studies which investigate liquidity comovement in the options market. The seminal studies are by Cao and Wei (2010) on the CBOE equity options market and by Deusker et al. (2010) on the Euro interest rate market. Recently, Verrousis et al. (2015) investigates the intraday behaviour of liquidity of the equity options in NYSE LIFFE market.

The study by Cao and Wei (2010) is the main study that we follow and to which we compare our results. Cao and Wei (2010) are the first to study liquidity commonality and its characteristics in the CBOE equity options market using individual equity options data during the period from 1 January 1996 to 31 December 2004. To test for liquidity commonality between options and their market, they employ market-model time-series regressions. As basic evidence, they regress the daily percentage change in an option's liquidity on the contemporaneous and lagged percentage change in the liquidity of the options market. To ensure liquidity comovement is not due to other factors that might affect changes in the liquidity of the underlying stock, they consider a more robust regression setup in which they consider the following control variables: the percentage change of the stock's corresponding liquidity, the stock's contemporaneous return, the level and percentage change of the firm return squared, the 30-day implied volatility of S&P 500 index options, a year-dummy capturing potential time variation in liquidity, and the corresponding contemporaneous and lagged percentage of the stock's liquidity measure projected on the option's market. Their estimation procedure includes two steps. The first step involves estimating a regression for each stock. For each stock, option liquidity is averaged across all options on that stock. They then calculate the average across stocks of the coefficients of contemporaneous and lagged percentage change of the option market's liquidity (referred as contemporaneous and lagged commonality, respectively). Evidence of liquidity commonality in the options market is then detected by the significance of this average.

As proxies for liquidity, Cao and Wei (2010) use volume, bid-ask spread and price impact. Their results reveal that options liquidity comoves with that of the option market for all liquidity measures. For all options (calls and puts) combined, for all liquidity measures, they find that contemporaneous liquidity commonality is significant at the 1% level, and the liquidity commonality coefficient is positive across most stocks. At least 67.72% of stocks show a positive coefficient for the volume measure of liquidity. The average coefficient for the bid-ask measure is 0,863 with a t-statistic of 61.90. Further, they report that 94.78% of these coefficients are positive. Further, the coefficient of lagged liquidity is smaller than that of contemporaneous liquidity, and is significant for the bid-ask spread measure only. However, for all measures of liquidity, the total commonality (contemporaneous plus lagged) is positive and significant (1% level). Moreover, they report results supporting the hedging-demand argument as stock's liquidity coefficient is significantly positive, especially when liquidity is measured by volume. This suggests that stocks exhibit strong liquidity commonality.

Cao and Wei (2010) also investigate whether liquidity comovement is related to the size or the volatility of the firm. In the stock market, Chordia et al. (2000) find that large firms and firms with high return volatility have higher liquidity commonality. Cao and Wei (2010) find that liquidity of options on small firms exhibit higher commonality when the bid-ask spread and price impact measures are used, which is contrary to what Chordia et al. (2000) find for NYSE stocks. Cao and Wei (2010) investigate whether this difference is due to size effects. They find that this size effect in liquidity commonality for options is consistent across all years, whereas for stocks Chordia et al. (2010) find it consistent for the first four years of their sample (1996, 1997, 1998, and 1999) but is reversed for later years (2000, 2001, 2002, 2003, and 2004). However, for the volume measure, Cao and Wei (2010) find that large firms show higher liquidity commonality, especially for contemporaneous market liquidity. Their forwarded rationale for this is that trading volume of large firms should covary with the volume traded in the market when commonality is present to the extent that volume and firm size are positively related. They conclude that the size effect in liquidity commonality shows a structural break.

Cao and Wei (2010) find that options in the high-volatility group exhibit stronger commonality and a monotonic relationship for the bid-ask spread and price impact measures. However, they do not find any statistically significant differences between quintiles for volume-based measures. They explain that it is either inventory risk or information asymmetry drives liquidity (under both theories high volatility intensifies the impact of either factor).

Cao and Wei (2010) also investigate whether inventory risk, information asymmetry, or derivative hedge theory explain option market liquidity. Chordia et al. (2000) argue that inventory risk can be reflected in broad market activity whereas information asymmetry can be reflected in individual trading activity. They argue that market makers face inventory risk when the likelihood of an order imbalance and level of the optimal inventory increase. As high trading volume reduces the risk of order imbalance, market makers face low inventory risk. As proxies for inventory risk, they use open interest and option trading volume. Moreover, they suggest that the extent of information asymmetry in a stock may be reflected in the trading patterns of specific options. The informed traders sometimes hide information by submitting small orders (Barclay and Warner, 1993), and market makers respond by increasing the bid-ask spread. Chordia et al. (2000) use the number of trades of a stock and the average dollar size of a transaction as proxies of information asymmetry in that stock. However, due to data limitations, since they use daily rather than trade and quote data, Cao and Wei (2010) suggest that the only plausible way to determine information asymmetry is to use ‘the number of distinct options traded per day’. In order to capture the hedging costs faced by a market maker, Cao and Wei (2010) use the underlying stock volume as a proxy.

They find a positive and significant relationship between trading volume and the percentage change in the spread, indicating that higher trading volume leads to a widening of bid-ask spreads. This finding is contrary to inventory risk theory proposition. They suggest that trading volume could reveal the information role of the options, although it is widely used as a proxy for inventory risk. For example, Black (1975) and Easley et al. (1998) argue that options may be used by informed traders because of their leverage. There is also evidence that the option trading volumes have predictable power on stock prices (Pan and Poteshman, 2006). Therefore, a positive relationship between the percentage spread and the option trading volume would suggest that increased volume may indicate information arrival. Market makers then hedge against potential losses by widening the spreads. Based on their findings, they conclude that information asymmetry is an important characteristic of options that explains changes in the bid-ask spread. They also support the hedging argument proposed by Cho and Engle (1999). A higher stock volume leads to a smaller percentage spread for options. According to Cho and Engle's model, option spreads should be at their minimum until market makers can hedge their option positions by trading the underlying stocks. They also find that calls are more liquid in bull markets and put options are more liquid in bear markets.

The other study is by Deusker et al. (2011) on the Euro interest rate market. Although a totally different market, it still provides insights due to the different market structure. We are not aware of any study that investigates liquidity comovement between options and their underlying asset market, but we provide some insights that motivate us to investigate this as a separate source of liquidity risk. Deuskar et al. (2011) examine liquidity effects on Euro interest rate option prices. They use daily bid and ask prices of euro interest rate caps and floors, and report higher prices for less liquid options after controlling for volatility smile and the skewness and excess kurtosis in the underlying interest rate distribution. Conventional wisdom, however, suggests that relatively illiquid securities trade at lower prices, evidence to which is found in the stock and bond markets.[16] They suggest that the results from the stock and bond markets cannot be generalized without considering the characteristics of the market under study. They explain that the interest rate cap and floor market is an OTC institutional market with very little retail investor presence. [17] In this market, the buyers of caps and floors are corporations who seek to hedge exposure to interest-rate risk, and the sellers are market-makers who would primarily be concerned with the liquidity risk inherent in the caps and floors. In these markets, trade size is large and option portfolios have long-maturities of up to 10 years. The dealers normally have shorter trading horizons compared to the maturity of the options, and as suggested by Deuskar et al. (2011) they incur large amount of transaction costs especially when they hedge dynamically by trading the interest rate spot or derivatives. Therefore, the market makers like to reverse the trades and minimize the inventory. Accordingly, options liquidity is important to them. Moreover, Deuskar et al. (2011) suggest that in such a market, the marginal investor is likely to have net-short positions. He would raise the price of an illiquid option because the cost of dynamic hedging of a long-dated contract would be enormously large. In this way, they support the arguments of Garleanu et al. (2009) that the lack of liquidity is due to the net-demand pressure affecting the prices of options. This implies a negative relationship between liquidity and prices for these interest rate options. Deuskar et al. (2011) also find a systematic factor, linked with lagged changes in investor perceptions of uncertainty in the

[16] There are several studies that find that illiquid stocks and bonds are cheaper and offer higher expected returns. The examples include Amihud and Mendelsen (1986) and Longstaff (1995a, 2001) in the stock markets, and Amihud and Mendelson (1991), Longstaff (1994), De Jong and Driessen (2007) and Nashikkar et al. (2009).

[17] The institutional market includes corporations that usually have buy and hold investing style (Deusker et al, 2011)

equity and fixed income markets, driving changes in liquidity across strikes and maturities.

To our knowledge, no study has looked specifically at liquidity comovement between options and their underlying stock market. Options offer a number of advantages compared to stocks. As Manaster and Rendleman (1982) report, these advantages come from their inherent leverage, lower transaction costs in absolute terms compared to the transaction costs for stocks, and the avoidability of restrictions on short-sale on the underlying stocks. Moreover, options allow investors to hedge their holdings in stocks. Mayhew et al. (1999) suggest that demand for options is largely determined by the demand for the underlying asset. They suggest that if the interest in a particular underlying security is greater, there will be more interest in its options as well. However, if options are substitutes for stocks, the implication is a negative relationship between option liquidity and the trading activity in the stock.

From Cho and Engle's (1999) hedging argument, liquidity comovement between options and their underlying stocks is expected to be positive. However, the comovement in liquidity between options and the whole stock market could be either positive or negative. Liquidity comovement with the underlying stock market is similar to a case in which a trader hedges his option portfolio with an underlying stock index. If this comovement is positive, it would imply hedging costs are lower. It may also indicate that whenever there is a liquidity shock in the stock market, a market maker may widen spreads on the options as he would be bearing higher costs of hedging in the underlying stock market. However, a negative liquidity comovement would imply that in times of declining markets (markets become illiquid), options liquidity is higher (options become liquid). If such options exist then they would provide a better hedge against liquidity shocks in the stock market. If this comovement varies across stocks or even across moneyness and maturity of options, it would have asset pricing implications. The consequence is that market participants would accept to pay a premium for buying such options as these options provide them with an insurance against liquidity risk.

In this chapter, we employ market model time-series regressions to investigate liquidity comovement. Following Chordia et al. (2000) and Cao and Wei (2010), we test the liquidity comovement between options and their market, and between options and their underlying stock market. Apart from Brenner et al. (2001), who investigate liquidity discounts for FX options; Deusker et al. (2011), who investigate liquidity discounts for Euro interest rate options; and Bongaerts et al. (2011), who investigate liquidity and pricing of liquidity risk for credit default swaps, most of the literature uses CBOE data. We test these hypotheses in the NYSE Euronext LIFFE London Equity Options Market. Cao and Wei (2010) investigate liquidity comovement in equity options, but do not study whether moneyness and maturity of the options affect these liquidity comovements. We fill this gap in literature by investigating these liquidity comovements across moneyness and maturity of options for both calls and puts.

## 4.3 Research Methodology and Hypotheses

In Section 4.3.1, we present the hypotheses that will be investigated in this chapter and in Sections 4.3.2 and upto 4.3.6 we define the regression methodology and construction of the regression models to investigate the hypotheses reported in Section 4.3.1.

### 4.3.1 Hypotheses

Following is the list of the hypotheses that we test in this chapter.

**Hypothesis H1:**

Liquidity comovement in the options market is positive.

**Hypothesis H2:**

Liquidity comovement between options and their underlying stock market is positive.

Is there evidence of liquidity comovement between options and the market of their underlying stocks? This is motivated by derivative hedge theory (Cho and Engle, 1999), which implies that when hedging is a primary reason for trading in the derivatives market, the liquidity of the derivative is a function of the liquidity of the underlying market. Therefore, if the spreads in the options market are determined by the spreads in the underlying stock market, liquidity comovement between options and the stock market is expected to be positive. For both the above questions, we further investigate the following:

**Hypothesis H1a & H2a:**

Liquidity comovement between options and the option market has same sign for both calls and puts.

Is liquidity comovement different for call than for put options? Does liquidity comovement exhibit any systematic patterns across different maturity and moneyness? What are the implications of these differences, if any?

**Hypotheses H1b & H2b:**
The options on small firms show higher liquidity comovement.

**Hyptheses H1c & H2c:**
The options on low volatility stocks show higher liquidity comovement.

Size and volatility effects in liquidity comovement have been observed in stock markets (Chordia et al., 2000). The size effect implies that small firms show high liquidity comovement and the volatility effect implies that firms with high return volatility exhibit high liquidity comovement. It is plausible to expect that options of small firms have a higher liquidity comovement since stocks of small firms are more affected by inventory risk and information asymmetry than those of large firms (Cao and Wei, 2010).

**Hyptheses H3:**
Does inventory risk, information asymmetry or derivative hedge theory, or a combination of these help explain the liquidity comovement in options?

### 4.3.2 Research Methodology

We use market model time-series regressions to investigate liquidity comovement. Following Chordia et al. (2000) and Cao and Wei (2010), we test the hypotheses of liquidity comovement between an option and its market and between an option and its underlying stock market. Following the argument of Cho and Engle (1999) that the liquidity in the options market is related to the liquidity in the underlying stock market, we control for this effect. The other factors that can potentially affect option liquidity can be options moneyness, maturity, delta, gamma, vega, and stock return and return volatility (stock return squared).

We hypothesize that there are two main sources of liquidity commonality in the equity options market. First, liquidity of an option may comove with liquidity of the options market. Second, liquidity of an option may comove with liquidity of the stock market.

Most of the literature on the equity options uses CBOE data but we test these hypotheses using NYSE Euronext LIFFE London Equity Options Market data.

As discussed earlier, there are two main articles that investigate liquidity comovement in options; these articles only focus on the ATM options with the maturity of one year (Cao and Wei, 2010). However, the literature does not report any results on how liquidity comovement between an option and its market varies across maturity and moneyness. Moreover, only one source of liquidity risk has been studied, which is liquidity comovement between an option and its market. In this chapter, two sources of liquidity risk are investigated across different categories of moneyness and maturity.

### 4.3.3 Liquidity Comovement between Options and their Market

To detect the comovement in liquidity, we follow Chordia et al. (2000) and Cao and Wei (2010). We estimate a market model time-series regression for each stock in an option moneyness and maturity portfolio.

At time $t$, each stock in each maturity and moneyness portfolio has a number of options. For each stock in that moneyness and maturity portfolio, we take the cross-sectional average of option liquidity across all its options. We construct time-series data of average option liquidity for each stock in each moneyness and maturity portfolio. We estimate the following time-series market model for each stock in that moneyness and maturity portfolio.

$$DOL_{i,t} = \beta_{0,i} + \beta_{1,i} DSL_{i,t} + \beta_{2,i} DOL_{m,t} + \beta_{2lag,i} DOL_{m,t-1} + \beta_{3,i} DSOL^{res}_{m,t} + \beta_{3lag,i} DSOL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6\, D_{1,t} + \beta_7\, D_{2,t} + \varepsilon_{i,t} \qquad (4.1)$$

where $DOL_{i,t}$ is the percentage change of option $i$ 's liquidity from day $t-1$ to day $t$ (option percentage spread, option proportional spread), $DSL_{i,t}$is the percentage change of the underlying stock's liquidity measure, $DOL_{m,t}$ is the percentage change in the options market liquidity measure from day $t-1$ to day $t$, and $DSOL^{res}_{sm,t}$ is a control variable that stands for the residual ($\epsilon_t$) from regressing the percentage change of the stock market liquidity on the percentage change of the options market liquidity. We also include the following control variables: the underlying stock return, $r_{i,t}$ , and its instantaneous volatility proxied by the square of return, ${r^2}_{i,t}$, and $D_{1,t}$ and $D_{2,t}$ are year dummy variables for 2009 and 2010, respectively. Since we have three years' data, we incorporate two year dummies to capture the variation in liquidity over time. $D_{1,t}$ is 1 if an observation belongs to 2009 and zero otherwise, and $D_{2,t}$ is 1 if an observation belongs to 2010 and zero otherwise. To calculate $DSOL_{m,t}^{res}$ we run three regressions to get residuals for call, put and all options markets.

$$DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t \qquad (4.2)$$

In Equation (4.2), we regress the percentage change in the stock market liquidity on the percentage change in the options market liquidity, and store the residuals. These residuals are included as a control variable in the 'market model' of Equation (4.1). As discussed earlier in the literature review, Cho and Engle (1999) propose the derivative hedge theory, arguing that if market makers in a derivative market can hedge their positions by trading the underlying asset, the liquidity and the spread in the derivative market will be determined by the liquidity and the spread in the underlying market instread of the trading activity in the derivative market. Cho and Engle (1999) find that the options market spread is positively related to the spread in the underlying market. We, therefore, consider three variables related to stock and stock market liquidity: $DSL_{i,t}$, which is the percentage change in underlying stock $i$'s liquidity at time $t$, and the residuals and lagged residuals $DSOL_{m,t}^{res}$ and $DSOL_{m,t-1}^{res}$ from Equation (3.19), which control for the correlation between stock market and options market liquidities. The definition and formulae of all the variables in the regression are reported in Table 4.1.

The main variables whose coefficients will be interpreted for liquidity comovement between options and their markets in the regression model of Equation (4.1) are $DOL_{m,t}$ and $DOL_{m,t-1}$ (percentage change in options market liquidity, and its lag).

**Table 4.1 Definition of Variables used in Regressions**

This table provides the formulae and definitions of the variables used in the regressions.

| Variable | Formula | Definition |
|---|---|---|
| $DOL_{i,t}$ | $\frac{OL_{i,t}-OL_{i,t-1}}{OL_{i,t-1}} * 100$ | $DOL_{i,t}$ is percentage change in option liquidity $OL_{i,t}$ . Option Liquidity is measured by proportional option bid-ask spread or percentage option bid-ask spread (see Section 3.4.2). |
| $DOL_{m,t}$ | $\frac{OL_{m,t}-OL_{m,t-1}}{OL_{m,t-1}} * 100$ | $DOL_{m,t}$ is percentage change in options market liquidity $OL_{m,t}$. Options market liquidity is measured as an average of liquidity of all options in trading in the market (see Section 3.4.2). |
| $DSL_{i,t}$ | $\frac{SL_{i,t}-SL_{i,t-1}}{SL_{i,t-1}} * 100$ | $DSL_{i,t}$ is percentage change in underlying stock liquidity $SL_{i,t}$. Stock liquidity is measured by percentage bid-ask spread (see Section 3.4.2). |
| $DSL_{m,t}$ | $\frac{SL_{m,t}-SL_{m,t-1}}{SL_{m,t-1}} * 100$ | $DSL_{m,t}$ is percentage change in stock market liquidity $SL_{m,t}$ . Stock market liquidity is calculated as an average of liquidity of stocks in FTSE 100 (see Section 3.4.2). |
| $DSOL^{res}_{m,t}$ | $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$ | Residuals from this equation are termed as$DSOL^{res}_{m,t}$. Residual from projection of percentage change in options market liquidity $DOL_{m,t}$ on stock market liquidity $DSL_{m,t}$. |
| $r_{i,t}$ | $\ln(\frac{S_t}{S_{t-1}}) * 100$ | Log stock return in percentage. |
| ${r^2}_{i,t}$ | $(r_{i,t})^2$ | Squared return of a stock |
| $D_{1,t}$ | $D_{1,t}$ = 1 if year = 2009<br>$D_{1,t}$ = 0 if year is not 2009 | Dummy variable for year 2009. |
| $D_{2,t}$ | $D_{2,t}$ = 1 if year = 2010<br>$D_{2,t}$ = 0 if year is not 2010 | Dummy variable for year 2010. |

**Cross-sectional Mean and Significance of Coefficients across Stocks**

After saving coefficients from time-series regressions for each stock in each maturity and moneyness portfolio, we calculate the cross-sectional average and *t*-statistics for each coefficient across the stocks that belong to a particular maturity and moneyness portfolio.

To check the reliability of the *t*-statistics for the cross-sectional mean, we need to check that the error terms from time-series regressions for each stock are cross-sectionally independent across stocks. If the errors are cross-sectionally dependent, this would suggest that common variables may have been omitted from the model, thus making the model misspecified. Chordia et al. (2000) and Cao and Wei (2010) check this cross-sectional dependence by performing pair-wise, time series regressions using the error terms. The error terms from Equation (4.1) for stock one are regressed on regression errors of every stock within the same maturity and moneyness portfolio. Specifically,

$$\varepsilon_{j,t} = a_{i,0} + a_{i,1}\,\varepsilon_{k,t} + e_{i,t} \qquad \text{for } j \neq k; j,k \in 1,2,3,\ldots,m \tag{4.3}$$

where *j* is for stocks and there are *N*-1 stocks that belong to a portfolio of a particular combination of maturity and moneyness. This implies *N*-1 pair-wise regressions. The null hypothesis is $a_{i,1} = 0$, i.e. there is no cross-dependence between errors of two stocks from the time-series regressions.

### 4.3.4 Liquidity Comovement between Options and the Stock Market

The methodology adopted for analysing liquidity comovement between options and the stock market is similar to that used for investigating liquidity comovement between options and their market. We re-write the time-series market model as follows:

$$\begin{aligned} DOL_{i,t} = {} & \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} \\ & + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6\, D_{1,t} + \beta_7\, D_{2,t} + \varepsilon_{i,t} \end{aligned} \tag{4.4}$$

where $DSL_{m,t}$ is the percentage change in the stock market liquidity from day $t-1$ to $t$. $DOSL^{res}_{m,t}$ is the residual ($e_t$) from regressing the percentage change of options market liquidity on the percentage change of stock market liquidity. We run three of the following regression to get residuals for the call option market, the put option market, and the all options market:

$$DOL_{m,t} = \delta_0 + \delta_1 DSL_{m,t} + \xi_t \tag{4.5}$$

### 4.3.5 Size and Volatility Effects in Liquidity Comovement

In this section, we describe the effect of firm size and volatility in liquidity comovement in options markets.

**Size Effect in Liquidity Comovement**

Another objective is to explore the size effect in liquidity comovement. A strong liquidity comovement between small firm options and their market would support the argument that small firms exhibit higher liquidity comovement since such firms are more prone to risks of inventory and information asymmetry.

Inventory management theory suggests that dealers adjust their spreads in order to rebalance their inventory positions when faced with large order imbalances. Big firms are traded more frequently and therefore, traders face reduced risk of not finding a counterparty when they trade in big firms (Stoll, 2000 and Lesmond, 2005). The hedging argument of Cho and Engle (1999) suggests that liquidity in derivative markets is determined by liquidity in the underlying market since hedging is the primary motive for investors in derivative markets. When investors find it difficult to hedge their net positions by deriving liquidity in the underlying market, the variability in liquidity in derivative markets would be high and this would suggest that the liquidity comovement between options and their market would also be high. Based on this hypothesis, it is expected that small firms will have high liquidity comovement between their options and the stock market as compared to big firms. We test this hypothesis.

In order to test the size effect in liquidity commonality, we construct size quartile portfolios of stocks for each maturity and moneyness group. Market capitalization of a stock is used as a measure of the size of a stock. Here, the size rank assigned to a stock is based on the average market capitalization of the stock over the entire sample period. We then bin these stocks into four size quartiles.

We perform an equality of means test on the coefficients of big and small firms to test the difference in liquidity comovement between these two groups. This is carried out separately for call equity options, put equity options, and call and put equity options combined. The test is given by:

$$t = \frac{\bar{X}_H - \bar{X}_L}{S_{X_H X_L} \cdot (\frac{1}{n_H} + \frac{1}{n_L})} \qquad (4.6)$$

$$S_{X_H X_L} = \frac{\sqrt{(n_H - 1)s_{X_H}^2 + (n_L - 1)s_{X_L}^2}}{n_H + n_L - 2} \qquad (4.7)$$

where $\bar{X}_H$ is the average coefficient of the highest quartile, $\bar{X}_L$ is the average coefficient of the lowest quartile, $s^2_{X_H}$ is the variance of coefficients in the highest quartile, $s^2_{X_L}$ is the variance of coefficients in the lowest quartile, $n_H$ is the sample size of the highest quartile, and $n_L$ is the sample size of the lowest quartile.

**Volatility Effect in Liquidity Comovement**

Following the same procedure described above for the size effect, we bin stocks into four quartiles based on the average implied volatility of options assigned to stocks. We compute the implied volatility of an option by inverting the Black-Scholes option pricing formula. The implied volatility of a stock on a day is the average implied volatility across all options on that stock on that day. The overall average implied volatility of options on a stock during the sample period is the time-series average of implied volatility of options on that stock. The stocks are then binned into quartiles based on their average implied volatilities.

### 4.3.6 Inventory Risk, Information Asymmetry and Options Market Liquidity

When trading volume in a market is high, market makers face a lower risk of order imbalance. Low order imbalance implies a low inventory risk for a market maker. When there are more market participants (broader market activity), inventory risk is also low. From an inventory risk argument, higher volume in options would suggest higher liquidity, which, in turn, implies lower bid-ask spreads (or transaction costs).

With high trading volume, it is not necessary for informed traders to submit large-size trade orders. They would rather execute more trades with lower order size (Barclay and Warner, 1993) since this helps informed traders to hide their information. The number of transactions, however, can potentially detect informed trading. Market makers would widen the bid-ask spread when they observe a high number of transactions with small order sizes. Thus, a negative relation between changes in liquidity (bid-ask spread) and number of trades within a day would be expected.

When intra-day data is available, dollar size of transactions and number of trades can be used as proxies for information asymmetry (Chordia et al., 2000). With daily end-of-day data, the average dollar size of transactions and the number of trades are not available. To proxy for information asymmetry, Cao and Wei (2010) suggest the use of the total number of distinct options across maturity and moneyness being traded per day as a proxy for trading frequency. The main motivation behind using this proxy is that when informed traders trade in the options market, they break their orders by spreading them over options with different strike prices and maturities. However, for inventory risk, Cao and Wei (2010) use trading volume and open interest as proxies since both variables are also available for daily end-of-day data.

We test for the influence of information asymmetry and inventory risk in explaining the spread in the options market using the following multivariate regression:

$$DOL_{i,t} = \gamma_{0,i} + \gamma_{1,i}\, DSL_{i,t} + \gamma_{2,i}\, DT_{i,t} + \gamma_{3,i}\, DOI_{i,t} + \gamma_{4,i}\, DV_{i,t} + \gamma_{4lag,i}\, DV_{i,t-1} + \gamma_{5,i}\, DSV_{i,t}^{res} + \gamma_{5lag,i} DSV_{i,t-1}^{res} + \gamma_6\, r_{i,t} + \gamma_7\, {r^2}_{i,t} + \gamma_8\, D_{1,t} + \gamma_9\, D_{2,t} + \varepsilon_{i,t} \tag{4.8}$$

where, $DOL_{i,t}$ is the percentage change of the option's liquidity measure from day $t-1$ to day $t$ (option percentage spread or proportional spread), $DSL_{i,t}$ is the percentage change of the underlying stock's corresponding liquidity measure, $DT_{i,t}$ is the percentage change in the number of options written on stock $i$ traded on day $t$, $DOI_{i,t}$ is the percentage change in total open interest for all options trading across all maturity and moneyness groups for stock $i$ on day $t$, $DV_{i,t}$ is the percentage change in the volume of all options trading across all maturities and moneyness groups for stock $i$ on day $t$, $X$ is a vector of control variables that includes the stock's return and volatility (squared return), and $D_{j,t}$ is a year dummy.

$DSV_{i,t}^{res}$ are residuals $\vartheta_{i,t}$ from regressing the percentage change in trading volume of a stock $DSV_{i,t}$ on the percentage change in trading volume of all options written on that stock $DV_{i,t}$:

$$DSV_{i,t} = c_0 + c_1 DV_{i,t} + \vartheta_{i,t} \tag{4.9}$$

Chalodera and Schlag (2004) suggest that the trading volume of a stock has a significant and positive impact on option transactions. This suggests that more active trading in stocks generates active trading in options, implying hedging activity in the options market.

Therefore, we control for trading activity in the stock market due to trading activity in the options market.

First, we estimate the time-series regressions for each stock and then calculate the cross-sectional average of the coefficient estimates across all stocks in each maturity and moneyness portfolio.

From the above regressions, we expect $\gamma_1$ in Equation 4.8 to be positive based on the derivative hedge theory that the primary concern of traders is hedging when trading in the derivative markets. Therefore, spreads in the options market are dictated by spreads in the stock market. Since the number of distinct options is used to proxy for information asymmetry, higher information asymmetry would lead to higher bid-ask spreads in options markets, so the coefficient $\gamma_2$ is expected to be positive. The open interest variable is used as a proxy for inventory risk, since a larger value for open interest suggests a rise in market maker inventory. In response, liquidity in the options market may decrease and this would be indicated by a widening of option spreads. Accordingly, we expect $\gamma_3$ to be positive. Another proxy for inventory risk is option volume, and a higher volume suggests a lower risk of order imbalance, which leads to lower inventory risk. Accordingly, we expect $\gamma_4$ to be negative.

## 4.4 Data and Correlations

The sample period is from 22 February 2008 to 31 December 2010, and the sample consists of daily options on 71 constituent stocks of the FTSE 100. The analysis is repeated for thirty portfolios of each call and put options. For each firm, we construct five portfolios of calls and puts based on moneyness and for each moneyness portfolio, the options are grouped into six portfolios. The classification of options into moneyness and maturity portfolios is discussed in Section 3.5.

For the descriptive statistics on bid-ask spread and proportional bid-ask spreads, we refer the reader to Section 3.6. However, we report here the correlations among DT, DOI and DV regressors introduced in Section 4.3.4. $DT_{i,t}$ is the percentage change in the number of options written on stock $i$ traded on day $t$, $DOI_{i,t}$ is the percentage change in total open interest for all options trading across all maturity and moneyness groups for stock $i$ on day $t$, $DV_{i,t}$ is the percentage change in the volume of all options trading across all maturities and moneyness groups for stock $i$ on day $t$

**Table 4.2 Correlations**

This table reports the cross-sectional average of the correlation among the percentage change in the distinct number of options written on a stock (DT), the percentage change in total open interest for all options on a stock (DOI), and the percentage change in the volume of all options on a stock (DV).

| **Correlations** | **Call Options** | | **Put Options** | |
|---|---|---|---|---|
| | **DOI** | **DT** | **DOI** | **DT** |
| **DV** | 0.0375 | 0.043 | 0.003 | 0.025 |
| | ( 4.2 ) | ( 4.7 ) | ( 0.41 ) | ( 4.52 ) |
| **DOI** | | 0.094 | | 0.107 |
| | | ( 15.82 ) | | ( 11.47 ) |

The correlations for both call and put options are very small for all variables and do not show any concern about the multi-collinearity. In the next section, we estimate the regression models and discuss their results.

## 4.5 Results

In this section, we report the results of the empirical analysis. In Section 4.5.1, we report and discuss the results on the liquidity comovement between options and their market. Section 4.5.2 and Section 4.5.3 discuss the results of the size effects and volatility effects in the liquidity comovement between options and their markets, respectively. Section 4.5.4 reports and discusses the results of liquidity comovement between options and the underlying stock market. Section 4.5.5 and Section 4.5.6 discuss the results of size effects and volatility effects in liquidity comovement between options and their underlying stock market. Finally, Section 4.5.7 discusses whether inventory, information asymmetry and/or derivative hedge theories explain the changes in option illiquidity.

### 4.5.1 Liquidity Comovement between Options and their Market

We perform a liquidity comovement analysis for each option category separately and we report the results for two spread measures: the proportional spread and the percentage spread, across moneyness and maturity portfolios.

As in Table 3.4 of Section 3.5, we use the terminology of deep-in-the-money (DITM), in-the-money (ITM), at-the-money (ATM), out-the-money (OTM) and deep-out-the-money (DOTM) to refer to moneyness categories 1, 2, 3, 4 and 5, respectively.

#### 4.5.1.1 Preliminary Evidence

We report the estimation results of Equation 4.1 of the liquidity comovement between options and their market. In our sample, option data is not available for all stocks in each moneyness and maturity category during the entire sample period of 2008-2010. Therefore, we select stocks in each moneyness and maturity portfolio for which the time-series data is available for at least 50 days during the 2008 to 2010 sample period. First, we estimate the time-series market model of Equation 4.1 for options on each stock. We then calculate the cross-sectional average of the coefficients across all stocks in a portfolio.

We report the average coefficients, their significance, represented by superscripts 1, 2, and 3 for significance levels of 1%, 5%, and 10%, respectively, and the associated t-statistics. We also report the sum of the coefficients of current and lagged variables of options market liquidity and current and lagged residuals of stock market and options market regressions (see Equation 4.1).

#### 4.5.1.2 Results of the Proportional Bid-Ask Spread

We first report the results using the proportional spread measure. These are in Tables A1, A2 and A3 in the Appendix to this chapter for call, put, and all options, respectively. As discussed in Section 3.4.3, option market liquidity is calculated as an average of options across stocks at time $t$. We discuss next the results for call, put, and all options separately.

***Call Options***

Results for liquidity comovement between call options and their market are reported in Table A1. Since there are 30 portfolios, we report the results in a table on three pages, each page presenting the results of 10 portfolios (2 maturity * 5 moneyness portfolios). The total number of stocks in portfolio 6 (maturity above 273 days) is 19, which is way less than 60 (the minimum number of stocks in other portfolios), therefore, we need to treat the results of long-maturity options with care as the reported coefficients are the average of the coeffficients estimated in Equation 4.1 for each stock.

The regression analysis shows that liquidity comovement between options and their market is strong in the equity call options market. The average coefficient on the underlying stock liquidity is mainly insignificant and has mixed sign for different portfolios. It is significant (at 10%) only for options that are out-the-money and with maturities between 91 and 182 days. This suggests that the derivative hedge theory cannot explain the percentage spread in options.. The average coefficient on options market liquidity, $\beta_2$, is positive and significant for almost all portfolios except those with maturity greater than 273 days. We find that the average liquidity comovement coefficient ranges from -0.0003 (insignificant) for ITM with 30 days maturity to 0.6496 (significant) for ITM with 30-60 days maturity. Moreover, the percentage of stocks in a portfolio with a positive options market liquidity coefficient is above 50 for all portfolios. ATM option portfolios of all maturities, except maturity category 5 (dtm between 182 and 273) and category 6 (273 days and above), have stocks with higher current liquidity comovement between options and their market than ITM and OTM options. Trading in ATM options is higher than in OTM or ITM options.

For comparison, Cao and Wei (2010) report a value of 0.863 for a similar coefficient for liquidity commonality in the CBOE equity options market (ATM up to one year maturity options), and Chordia (2000) report a value of 0.791 for the stock market.

The coefficient $\beta_{2lag}$ on lagged options market liquidity has different signs for different option portfolios. Those that are negative are insignificant, but some positive values are significant. In general, this suggests that liquidity comovement is mainly due to contemporaneous and not lagged market liquidity.

We also report the total liquidity comovement between options and their markets by adding the current and lagged coefficients. We find that stocks with ITM and short-maturity (30 days or less) options show no significant liquidity comovement. However, stocks of other option portfolios show that the liquidity comovement between options and their market is positive and significant at the 1% level. We plot the liquidity comovement betas in Figure 4.1

**Figure 4.1 Liquidity Comovement Betas for Call Options (Proportional Spread)**

This figure plots estimates of total (current and lagged) liquidity comovement between options and their market in Equation 4.1. For each portfolio, we add the coefficients of current and lagged market liquidity (proportional bid-ask spread) from the time-series market model for each stock in a moneyness and maturity portfolio. The average of this combined liquidity comovement coefficient across all stocks in that portfolio is then calculated and plotted.

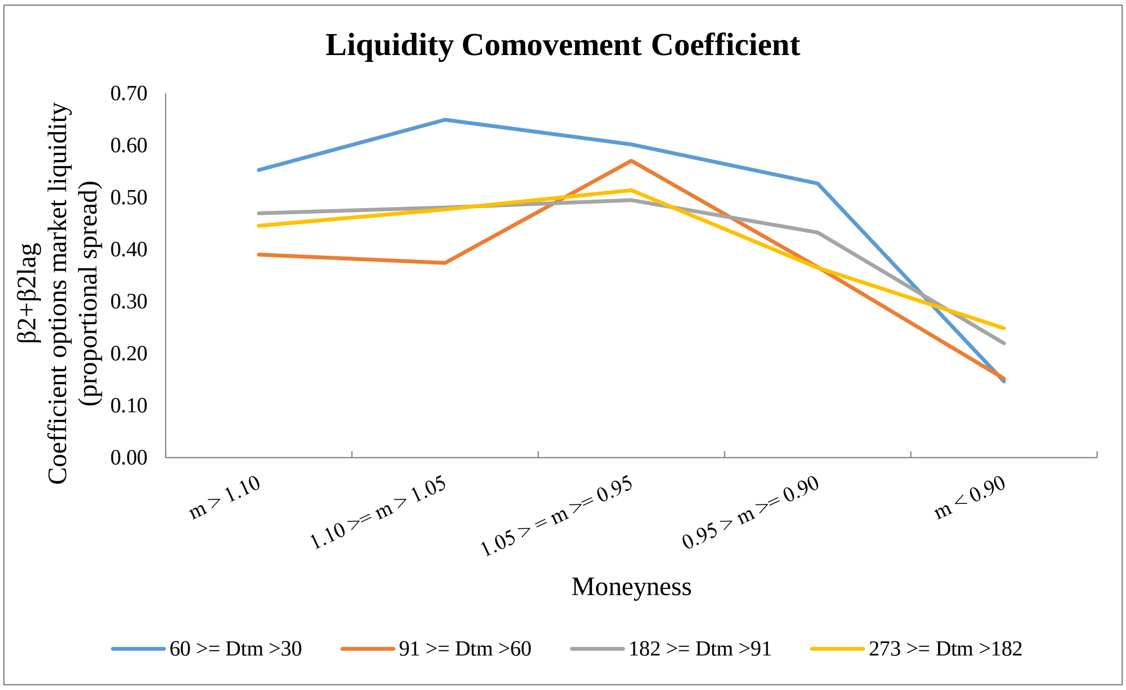



Figure 4.1 shows that the liquidity comovement in the options market is higher for at-the-money options as compared to OTM and ITM options. However, OTM options exhibit lower liquidity comovement than ITM options.

The coefficient of the current stock market residual $\beta_3$ is generally positive, and for some portfolios it is significant. There is no particular relation with moneyness or maturity. This shows that shocks in stock market liquidity that are not explained by options market liquidity may affect option liquidity. The coefficient of lagged stock market residual $\beta_{3lag}$ has mixed signs; however, it is generally significant for short-maturity option portfolios. The combined coefficient ($\beta_3 + \beta_{3lag}$) has mixed signs but it is positive and significant for most portfolios.

The coefficient on stock return is negative and significant across all moneyness and maturity portfolios. We also observe that the absolute value of the coefficient is increasing as call options decrease in moneyness. This is intuitive since declining markets are less liquid, hence, the percentage change in option liquidity decreases as the underlying stock prices fall (or stock return is negative). Moreover, the impact of the decline in the stock price on option liquidity is lower for OTM options. The lower the moneyness, the lower the impact of negative stock returns on the percentage change in option liquidity. The stock's instantaneous volatility has a mostly significant and positive coefficient $\beta_5$ across, which suggests higher uncertainty in the increase of proportional spreads.

The coefficients on year dummies are mostly negative for 2009 and positive for 2010. This suggests that the percentage change in the option proportional spread is lower for 2009 and higher for 2010 relative to 2008. The proportional spread decreased in 2009 and rose again in 2010.

The reported $adj\ R^2$ is higher for option portfolios that are decreasing in moneyness, and ranges from less than 10% to above 40%. For example, for options portfolios with maturity of 30 days, DITM options have $adj - R^2$ of 6.91% and DOTM options have $adj - R^2$ of approximately 45.62%.

***Put Options***

Table A2 reports the results on the liquidity comovement between put options and their market. These show that liquidity comovement between put options and their market is strong. The average coefficient on the underlying stock liquidity is insignificant, and shows mixed signs for different portfolios. Only two option portfolios, ATM options with maturity between 61 and 91 days and OTM options with maturity between 92 and 182 days, have negative underlying stock liquidity coefficients, which are significant at the 5% and the 10% levels, respectively. Derivative hedge theory suggests that if options are used as hedge instruments, option spreads should be determined by stock spreads. This suggests that an increase in the option proportional spread is due to an increase in the stock spread.

All portfolios have a positive and significant coefficient $\beta_2$ on options market liquidity, except some of those with maturity of 273 days or more. We find that this average liquidity comovement coefficient ranges from 0.0174 (insignificant) for ITM options with 273 days maturity to 0.7106 (significant) for ATM options with 62-92 days maturity. Moreover, the proportion of stocks in a portfolio with a positive options market liquidity coefficient is above 50% for all portfolios. ATM options generally have more stocks with a positive options market liquidity coefficient compared to ITM and OTM options.

Similar to call options, ATM put options generally have a higher options market liquidity coefficient than OTM and ITM options. Moreover, the lagged options market liquidity coefficient $\beta_{2lag}$ has mixed signs. Most of those that are negative are insignificant, but some of the positive coefficients are significant. In general, this suggests that liquidity comovement is mainly due to contemporaneous market liquidity.

Unlike call options, the total liquidity comovement between put options and their market (the sum of the coefficients on current and lagged variables) is positive and significant for all portfolios except those with maturity of 273 days and more. Figure 4.2 plots the liquidity comovement betas.

**Figure 4.2 Liquidity Comovement Betas for Put Options (Proportional Spread)**

This figure shows total (current and lagged) liquidity comovement between put options and their market in Equation 4.1. For each portfolio, we first add the coefficients of current and lagged market liquidity (proportional bid-ask spread) from the time-series market model for each stock in the moneyness and maturity portfolio. The average of this combined liquidity comovement coefficient is then calculated across all stocks in that portfolio.

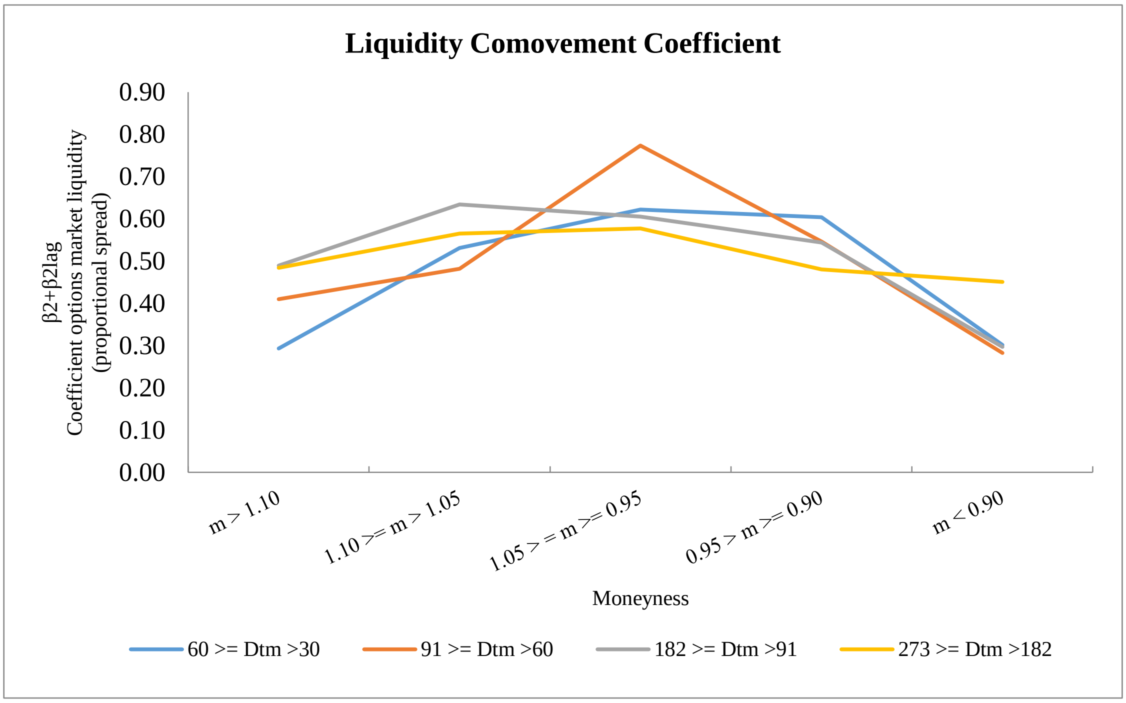



Figure 4.2 shows that ATM options market liquidity comovement increases with maturity, and OTM options show lower liquidity comovement than ITM options.

The coefficient $\beta_3$ on the contemporaneous stock market liquidity residual, is generally positive except for options with maturity less than 30 days. However, it is positive and significant across other maturities. This shows that shocks in stock market liquidity unexplained by options market liquidity may affect option liquidity. The coefficient on the lagged stock market liquidity residual $\beta_{3lag}$ has a mixed sign, and is significant for some portfolios but with no particular pattern. The combined coefficient ($\beta_3 + \beta_{3lag}$) has a mixed sign as well, but is mostly significant when the coefficient is positive. This suggests that the options market liquidity is not completely explained by stock market liquidity as the derivative hedge theory would suggest. The stock market liquidity residual has positive impact on option liquidity.

The coefficient on stock return, $\beta_3$, is positive and significant across all moneyness and maturity portfolios. It increases as moneyness decreases. The impact of stock return on put option percentage change in the proportional spread is opposite to that on call options. In puts, an increase in stock return leads to an increase in the percentage change in the proportional spread. This is likely due to the fact that an increase in the stock price would lead to a decrease in the price (premium) of a put option, such that the proportional spread (bid-ask spread divided by the bid-ask midpoint) would increase as the price of the option is the denominator, with the proportional bid-ask spread being more sensitive than the bid-ask spread. Moreover, the impact of an increase in the stock price on option liquidity is lower for OTM options. The lower the moneyness, the lower the impact of positive stock returns on the percentage change in option liquidity. The stock's instantaneous volatility has mostly significant and positive coefficient $\beta_5$ for all the portfolios, except those of longest maturity, which suggests that higher uncertainty in the underlying leads to an increase in put options proportional spreads.

The coefficient $\beta_6$ on the 2009 year dummy has mixed signs and is significant for many of the positive coefficients. This is contrary to the finding for call options. Put options are considered as insurance securities against market declines. Since the financial crisis started in 2008, the average percentage change in put option proportional spread has been higher in subsequent years. The coefficient $\beta_7$ on the 2010 year dummy is mostly positive and significant. Its value is higher than the 2009 year dummy in most cases.

***All Options***

Results for liquidity comovement between all options (call and put options combined) and their market are reported in Table A3. Generally, the liquidity comovement between options and their market, $\beta_{2+}\beta_{2lag}$, is strong. The average coefficient on underlying stock liquidity has mixed sign and is insignificant in all portfolios.

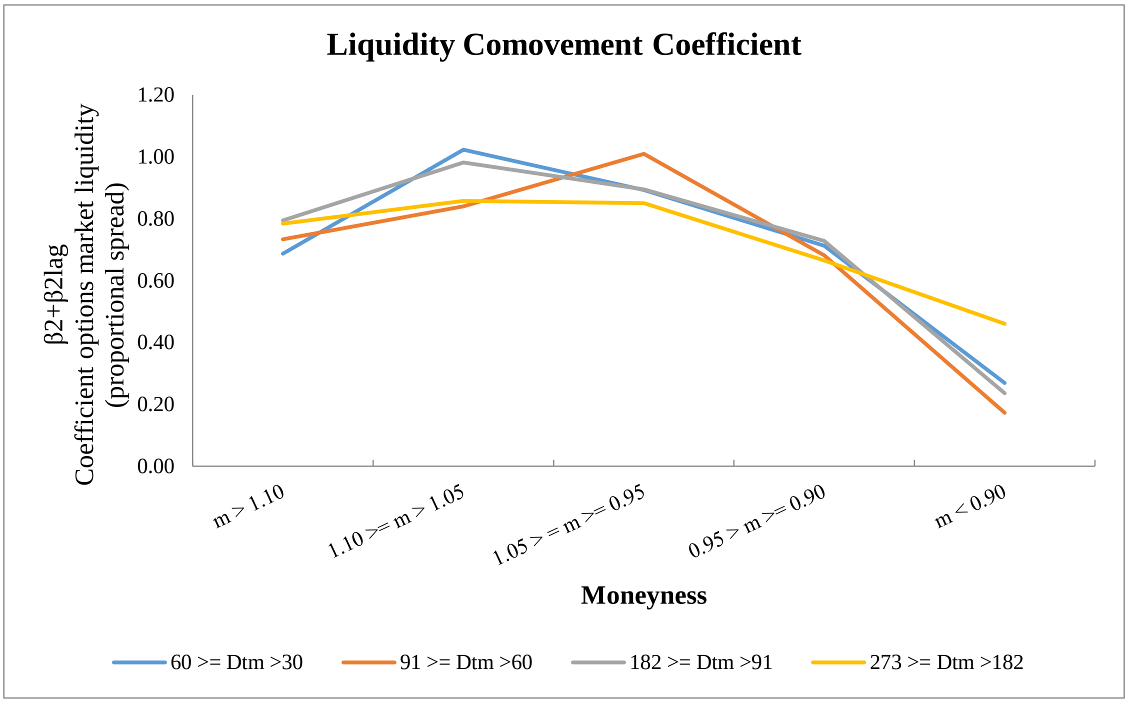
All portfolios have positive and mostly significant coefficient $\beta_2$ on options market liquidity. The exceptions are the coefficients on two portoflios: the one with moneyness greater than 1.10 and maturity of less than 30 days and that with moneyness less than 0.90 and maturity greater than 273 days, where the coefficients are positive but insignificant. This average liquidity comovement coefficient ranges from 0.0284 (insignificant) for DOTM with 273 days maturity options portfolio to 0.9918 (significant) for ATM options with 62-92 days maturity. Moreover, the percentage of stocks with positive liquidity comovement between options and their markets is higher for ATM options and less for DOTM and DITM option portfolios. Usually, most trading occurs in ATM options, and liquidity comovement between options and their market is positive for stocks with such options. These results are similar to those of call and put option portfolios as discussed earlier.

The lagged options market liquidity coefficient $\beta_{2lag}$ has mixed signs for option portfolios, and most are insignificant except for three portfolios. These portfolios are: OTM with maturity of 31-61 days (0.0424), ITM with maturity of 62-92 days (0.0386), and OTM with maturity of 183-273 days (-0.0562). Being mostly insignificant this suggests that liquidity comovement is mainly due to conemporaneous rather than lagged market liquidity.

Not all option portfolios have significant total liquidity comovement with their market ($\beta_{2+}\beta_{2lag}$). It is positive and significant for all ATM, ITM, and OTM options for all maturity categories. However, the pattern is strikingly similar for call options and put options. The liquidity comovement is higher for ATM as compared to OTM and ITM options. We plot the liquidity comovement betas in Figure 4.3.

**Figure 4.3 Liquidity Comovement Betas for All Options (Proportional Spread)**

This figure plots liquidity comovement between options and their market estimated in Equation 4.1. For each portfolio, we first add the coefficients of current and lagged market liquidity (proportional bid-ask spread) from the time-series market model for each stock in the moneyness and maturity portfolio. We then take an average of this combined liquidity comovement coefficient across all stocks in that portfolio.




In Figure 4.3, DITM and DOTM options show a lower liquidity comovement coefficient than ATM options. The coefficient on the contemporaneous stock market liquidity residual $\beta_3$ is generally positive and significant for most portfolios. This finding is similar to the call and put options analysed separately. This confirms that spreads in the options markets are not completely dictated by the stock market liquidity, and do not behave according to the derivative hedge theory. The coefficient on the lagged stock market liquidity residual $\beta_{3lag}$ has mixed sign and is significant for some portfolios with no particular pattern. The combined coefficient ($\beta_3 + \beta_{3lag}$) has mixed signs as well but is mostly significant when the coefficient is positive. This suggests that option market liquidity is not completely explained by stock market liquidity, as the perfect-derivative hedge theory would suggest. The stock market liquidity residual has a positive impact on option liquidity.

The impact of stock return on the percentage change in option proportional spread is negative in the case of call options and positive in the case of put options. However, when the option portfolios are combined, the impact is mixed in sign. Most of the portfolios have insignificant coefficients. The stock's instantaneous volatility has mostly significant and positive coefficient $\beta_5$. This impact increases with decreases in moneyness.

The coefficient $\beta_6$ on the 2009 year dummy has mixed signs. Most of the portfolios have negative and significant coefficients. The coefficient $\beta_7$ on 2010 year dummy is mostly positive and significant. Its value is higher than the 2009 year dummy in most cases.

#### 4.5.1.3 Results for Percentage Bid-Ask Spread

The results of the liquidity comovement between options and their market using the percentage bid-ask spread as the liquidity measure are reported in Tables A4, A5, and A6 for call, put and all options, respectively. As discussed in the methodology, Section 3.4.3, option market liquidity at time $t$ is calculated as the average of option liquidity across stocks at time $t$. We discuss the results for call, put, and all options separately.

***Call Options***

Table A4 reports the estimation results of the market model regressions of Equation 4.1 for liquidity comovement between call options and their market. We use the option percentage spread as the measure of option liquidity and options market liquidity.

The results are similar to those obtained using the proportional bid-ask spread as the measure of liquidity. The regression results reported in Table A4 show that the underlying stock liquidity does not have a significant effect on option liquidity after controlling for current and lagged option market liquidity, current and lagged stock market residual liquidity, stock return, stock instantaneous volatility, and yearly dummies. The underlying stock liquidity coefficient $\beta_1$ has mixed signs and is insignificant.

The average coefficient on options market liquidity $\beta_2$ is positive and significant for almost all portfolios except those of ATM options and DOTM options with maturity of more than 272 days. The average liquidity comovement coefficient using the percentage spread ranges from 0.0677 (insignificant) for DOTM options with maturity greater than 272 days to 0.8619 (significant) for ITM options with 92-182 days maturity. In contrast, the range using the proportional spread was -0.0003 to 0.6496. Moreover, most of the stocks in all portfolios have a positive coefficient for liquidity comovement, which suggests that the liquidity comovement between options and their market is positive across different spread measures of liquidity.

Similarly, the lagged options market liquidity coefficient $\beta_{2lag}$ has mixed signs for different option portfolios. Total liquidity comovement between options and their markets is reported as the sum of the coefficients on contermporaneous and lagged options market liquidity. It is positive and significant generally for all portfolios. The percentage proportion of stocks having positive liquidity comovement is around 50%. We plot the liquidity comovement betas in Figure 4.4.

**Figure 4.4 Liquidity Comovement Beta for Call Options (Percentage Spread)**

This figure plots liquidity comovement between options and their marke estimated in Equation 4.1. For each portfolio, we first add the coefficients of current and lagged market liquidity (percentage bid-ask spread) from the time-series market model for each stock in the moneyness and maturity portfolio. We then take an average of this combined liquidity comovement coefficient across all stocks in that portfolio.

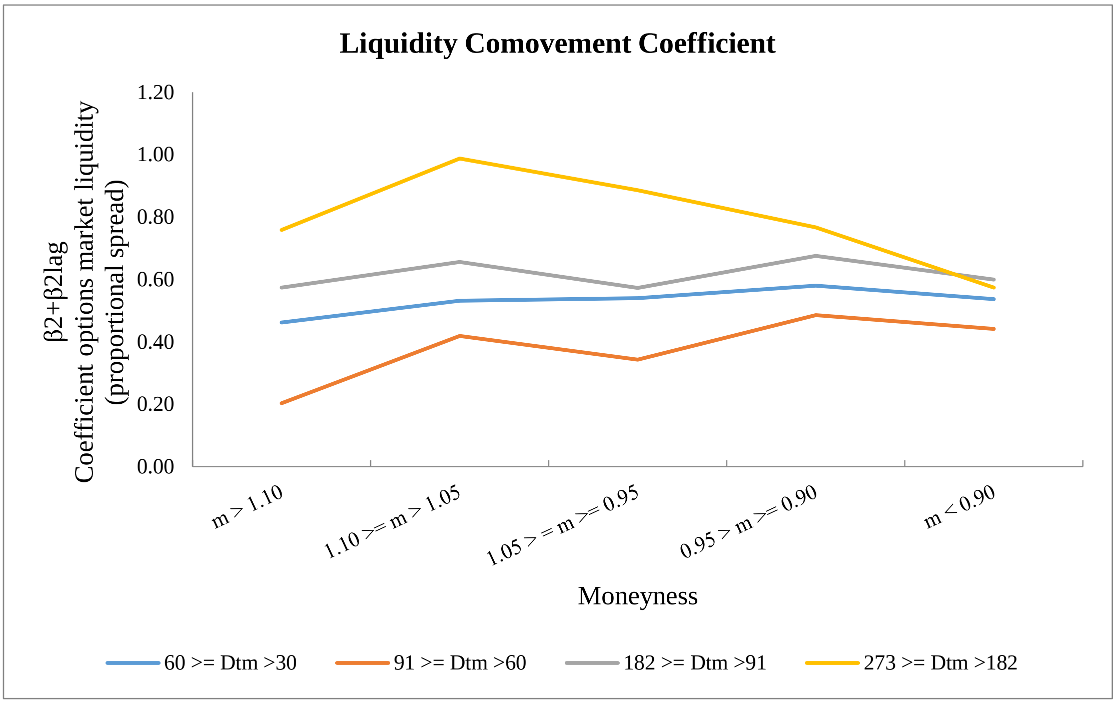



Figure 4.4 shows that DOTM and DITM options have lower liquidity comovement than ITM, ATM, and OTM options. Except for those with maturity between 182 and 273 days, OTM options have a higher liquidity comovement coefficient than all other maturity portfolios.

The qualitative results summarised from the coefficients of the current stock market liquidity residual ($\beta_3$), lagged stock market liquidity residual ($\beta_{3lag}$), and their combination ($\beta_3 + \beta_{3lag}$) are similar to those obtained earlier when the proportional bid-ask spread is used as the measure of liquidity.

The coefficient on the stock return $\beta_4$ has mixed signs but is mostly positive and significant. This is in contrast to the results for call options using the proportional bid-ask spread. The coefficient on stock volatility $\beta_5$ has a positive impact on the percentage change in option percentage spreads. The coefficient on the 2009 year dummy $\beta_6$ has mixed sign and mostly insignificant. The 2010 year dummy coefficient $\beta_7$ is mostly positive and significant.

***Put Options***

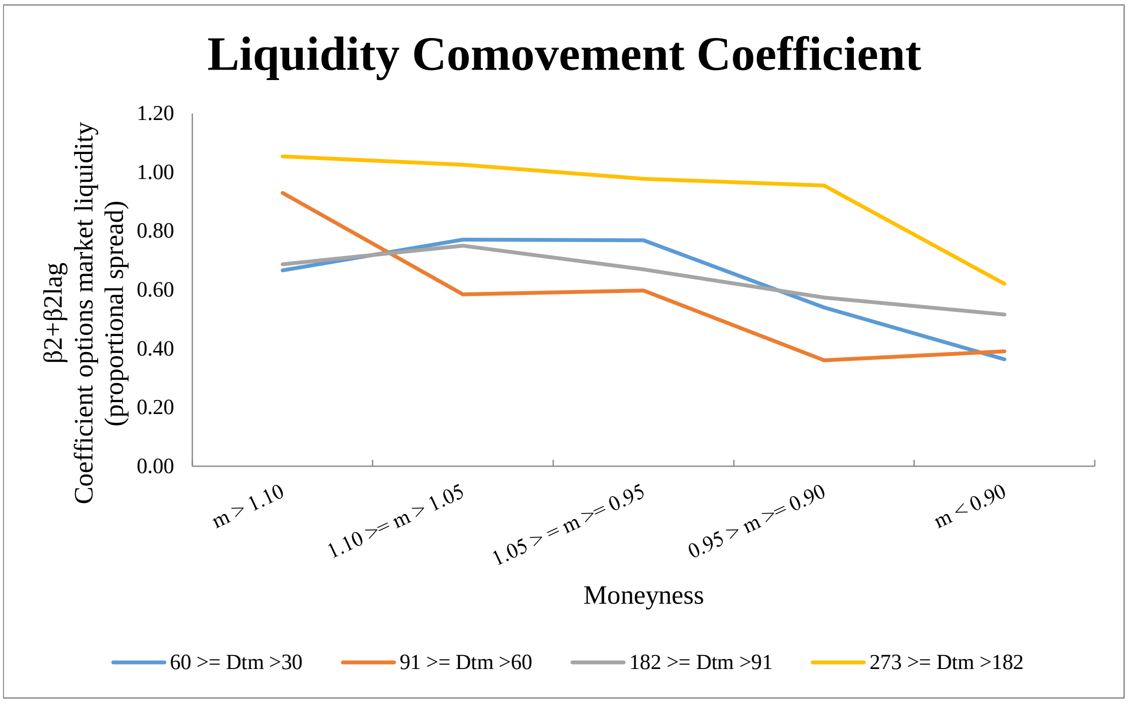
Table A5 reports the estimation results of Equation 4.1 for liquidity comovement between put options and their market. We use the option percentage spread as the liquidity measure.

The results are not different from those obtained when the proportional bid-ask spread is used as the measure of liquidity. The average coefficient (across stocks in each portfolio) on the underlying stock liquidity is insignificant and has mixed signs. The average coefficient on the liquidity comovement between options and their markets is positive and significant for most portfolios. It is higher (ranges from 0.1003 to 0.9919) than that obtained by using the proportional bid-ask spread (0.0174 to 0.7106). The coefficients on the lagged options market liquidity have mixed signs and are mostly insignificant. The sum of the coefficients on lagged and contemporaneous option market liquidity is positive and significant for all portfolios except the DOTM portfolio with maturity above 272 days.

The coefficient on the stock return variable is negative and significant for all portfolios. This is in contrast to the results for put options when using proportional spreads. Stock volatility negatively affects option liquidity. The coefficient of the 2009 year dummy is mostly insignificant and has mixed signs, whereas the coefficient of the 2010 year dummy is mostly significant with positive values. We plot the liquidity comovement betas in Figure 4.5.

**Figure 4.5 Liquidity Comovement Betas for Put Options (Percentage Spread)**

This figure shows liquidity comovement between options and their market estimated in Equation 4.1. For each portfolio, we first add the coefficients of current and lagged market liquidity (proportional bid-ask spread) from the time-series market model for each stock in the moneyness and maturity portfolio. We then take an average of this combined liquidity comovement coefficient across all stocks in that portfolio.




In Figure 4.5, 30-60 day options show an inverted U shape for liquidity comovement between options and their market in moneyness. The rest of the portfolios, however, show a decreasing trend with decreasing moneyness.

***All Options***

Table A6 reports the estimation results of Equation 4.1 using the percentage bid-ask spread as the measure of liquidity.

The results for liquidity comovement between all (call and put) options and their market are strong for all options. The average coefficient (across stocks in each portfolio) on the underlying stock liquidity is insignificant and has mixed signs. The average coefficient on liquidity comovement between options and their markets is positive and significant except for one portfolio with DOTM options and maturity greater than 272 days, which is positive but not significant. The lagged liquidity comovement coefficient has mixed signs. The sum of the coefficients of lagged and contemporaneous options market liquidity variables is positive and significant for all portfolios except DOTM options with maturity greater than 272 days. This ranges from 0.1097 to 1.0579.

**Figure 4.6 Liquidity Comovement Betas for All Options (Percentage Spread)**

This figure shows liquidity comovement between options and their market estimated in Equation 4.1. For each portfolio, we first add the coefficients of current and lagged market liquidity (proportional bid-ask spread) from the time-series market model for each stock in the moneyness and maturity portfolio. We then take an average of this combined liquidity comovement coefficient across all stocks in that portfolio.

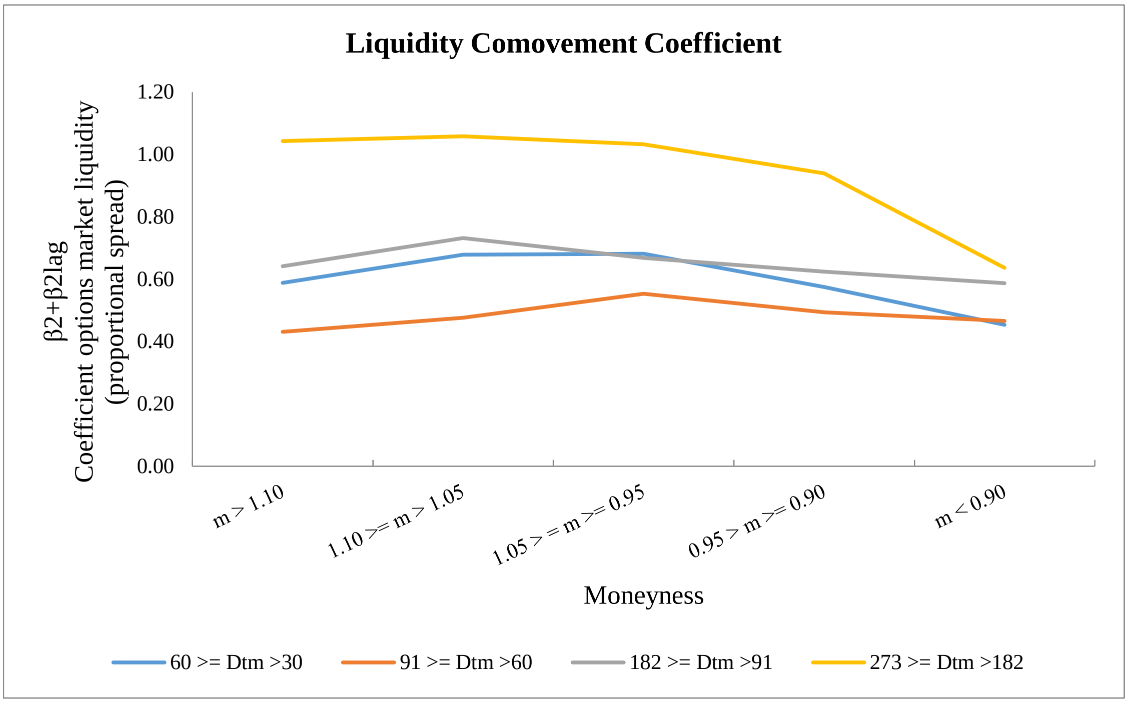



Figure 4.6 shows that the liquidity comovement between options and their market (using the percentage spread) is higher for high maturity options but does not decrease in decreasing moneyness as the comovement observed when we measured option liquidity with the proportional spread.

The coefficient on contemporaneous stock market residual $\beta_3$ has mixed sign but is significant for positive coefficients. This suggests that liquidity shocks from the stock market to the options market may also explain the spreads in options. Similar to the $\beta_3$ finding, the combined coefficient for options market liquidity $(\beta_3 + \beta_{3lag})$ has mixed signs, but is significant for some of the portfolios with positive coefficients.

The impact of the stock return on the percentage change in option percentage spread was reported positive for call options and negative for put options. When we analyse all options together, we find that the coefficient is negative and significant for most portfolios. The stock's instantaneous volatility has mostly significant and positive coefficient $\beta_5$. This impact decreases with decreasing moneyness, which is contrary to what we find for all options using the proportional spread.

The coefficient $\beta_6$ on the 2009 year dummy has mixed sign, and is negative and significant for most portfolios. The coefficient $\beta_7$ on the 2010 year dummy is mostly positive and significant. Its value is higher than the 2009 year dummy in most cases.

### 4.5.2 Size Effect in Liquidity Comovement between Options and their Market

We now investigate the size effect in option portfolios. We sort the stocks into four quartiles of market capitalization based on the daily average market capitalization over the sample period from 22 February 2008 to 31 December 2010. Some portfolios have only 19 stocks (especially those with maturity greater than 273 days) and some have 70 stocks. The cross-sectional statistics of the liquidity comovement coefficient for each size quartile in each portfolio are calculated. We report the results in Tables A7 and A8 for the proportional bid-ask spread and the percentage bid-ask spread, respectively.

We only report the results for the options market liquidity coefficient (which is interpreted as the liquidity comovement between options and their market). These are reported separately for call options, put options, and all options in Tables A7(a), A7(b), and A7(c), respectively.

The results for call options show a significant small firm effect. Options of small firm stocks show high liquidity comovement with their market relative to those of big firm stocks. However, we do not observe a monotonic relationship with size. Within a size quartile, there is no apparent trend in liquidity comovement over different maturities. However, for options of more than 30 days maturity, the results for the smallest firms (first quartile) show that the liquidity comovement between options and their market increases with moneyness.

The results for put options in Table A7(b) also show a small firm effect. Options of small firm stocks exhibit high liquidity comovement with their market relative to those of big firm stocks. The column entitled ‘B-S’ shows the difference between the coefficient of the 4th quartile (B) and that of the 1st quartile (S). There is no particular pattern in this difference across maturity and moneyness. Options with maturity greater than 91 days on small stocks show higher liquidity comovement for higher moneyness.

The results for all options combined (both call and put) are presented in Table A7(c). These show a small size effect in liquidity comovement between options and their market. However, OTM and ATM options with maturity up to 30 days, and OTM options with maturity between 31 and 60 days, show that options of big firm stocks have high liquidity comovement with their market. Particularly for the 1st quartile, options with maturity above 91 days show a similar liquidity comovement pattern to that for call and put options. For such portfolios, liquidity comovement increases with moneyness.

We also test if this firm size effect in liquidity comovement is significant for the other liquidity measure, the percentage bid-ask spread. The results are report in Tables A8(a), A8(b) and A8(c) for call, put, and all options, respectively. These results suggest that options of small firm stocks exhibit higher liquidity comovement than those of big firms. The difference between the coefficients of the 1st and 4th quartiles is, on the main, larger for the percentage spread than for the proportional spread. Liqudity comovement as measured by the percentage spread does not exhibit any particular pattern across moneyness and maturity as observed when liquidity was measured by the proportional spread. In general, these results show that liquidity comovement between options and their market is stronger for small firms for both liquidity proxies.

Our results are in line with Cao and Wei (2010) but do not support the results reported by Chordia et al. (2000). The plausible explanation of the small firm effect in liquidity comovement between options and their market is that small firms are more sensitive to inventory risk and information asymmetry relative to big firms.

### 4.5.3 Volatility Effect in Liquidity Comovement between Options and their Market

Tables A9 and A10 report the results of volatility effects for the proportional option spread and the percentage option spread, respectively. Tables A9(a), A9(b) and A9(c) report the results for call, put, and all options, respectively, using the proportional bid-ask spread as the liquidity measure for both options and their market.

Table A9(a) for call options shows mixed results for the volatility effect. Portfolios of options of 30-days maturity and moneyness of 1.05–1.10 and 0.95–1.05, as well as 61-91 days maturity and moneyness of 1.05–1.10, show that options of high volatility stocks exhibit high liquidity comovement with their market, whereas other portfolios reported in the tables show the opposite effect. The difference between the coefficient of the 4$^{th}$ (high volatility stocks) and the 1$^{st}$ (low volatility stocks) quartiles is significantly negative. In the case of put options, reported in Table A9(b), the majority of portfolios show this difference to be significantly negative. In the case of combined (call and put) portfolios, reported in Table A9(c), those of 30-day maturity and all the three moneyness categories reported show that the 4$^{th}$ volatility quartile has high liquidity comovement relative to the 1$^{st}$ volatility quartile. Other portfolios show a volatility effect for low volatility stocks.

Using the percentage bid-ask spread, reported in Table A10(a), the volatility effect in liquidity comovement is high for low volatility stocks relative to high volatility stocks for most portfolios. However, compared to the proportional spread measure, less call option portfolios show this effect. In particular, portfolios of shorter maturity (30 days or less) show high liquidity comovement for high volatility stocks and low liquidity comovement for low volatility stocks. The results for put option portfolios, reported in A10(b), and for all option portfolios, reported in Table A10(c), are qualitatively similar.

This observed volatility effect is contrary to what is reported by both Cao and Wei (2010) for CBOE equity options and Chordia et al. (2000) for NYSE stocks. Intuitively, one would expect stocks with high implied volatility options to show high liquidity comovement as the stock would be riskier and the market maker would increase the spread when the spread in the overall market increases.

The finding that option portfolios with short maturities (option with maturity of less than 30 days) show a high liquidity comovement for high implied volatility stocks seems intuitive as short maturity options are more volatile than to long-term options (see Table 3.7 for implied volatility across maturities).

### 4.5.4 Liquidity Comovement between Options and the Stock Market

We now investigate liquidity comovement of options with that of their underlying market. Following the methodology described in Section 3.4.4, we have thirty option portfolios constructed from five moneyness and six maturity categories.

The idea behind this portfolio classification is to investigate the liquidity comovement between options and their underlying stock market (as derivative hedge theory suggests), and how liquidity comovement behaves across moneyness and maturity. We also test the size and volatility effects.

#### 4.5.4.1 Preliminary Evidence

We report the results of the liquidity comovement between options and their stock market after controlling for underlying stock liquidity, stock returns, stock returns squared, year dummies, lagged options market liquidity, and lagged residual from a regression of stock market liquidity and options market liquidity. We estimate the time-series market model for options on each stock in a moneyness and maturity portfolio. We report the cross-sectional average of coefficients across stocks in each option portfolio.

We report the coefficients, their significance (denoted by superscripts 1, 2, and 3 for significance levels of 1%, 5%, and 10%, respectively), and the associated t-statistics. We also report the sum of the coefficients on the current and lagged stock market liquidity and current and lagged residuals of the regression of the stock market liquidity on the options market liquidity.

#### 4.5.4.2 Results using the Proportional Bid-Ask Spread

We report the results of liquidity comovement between options and their underlying stock market using the proportional spread as the liquidity measure of options. These are in Tables A11, A12, and A13 for call, put, and all options, respectively.

***Call Options***

Table A11 reports the results of liquidity comovement between call options and their underlying stock market. These show that the liquidity comovement between call options and their stock market is significant and positive for most call option portfolios. Only DITM and DOTM portfolios do not show significant coefficients across all maturity portfolios. This suggests that stock market liquidity plays a significant role in call option liquidity, but exceptions include the extreme moneyness portfolios of DITM and DOTM call options. Call option portfolios with maturity of 30 days and 60 days show that a high liquidity comovement for ATM options compared to OTM and ITM options. Estimates of the coefficient $\beta_2$ range from 0.0014 (insignificant, for DOTM options with maturity between 61 and 91 days) to 0.1142 (significant at 1% for DITM options with maturity between 61 and 91 days). There is no apparent trend in liquidity comovement over different maturities.

The coefficient $\beta_{2lag}$ on lagged stock market liquidity has mixed sign, with positive coefficients being significant for most portfolios. The coefficient on contemporaneous stock market liquidity $\beta_2$ is higher than that on lagged stock market liquidity. The combined coefficient (total liquidity comovement) for the current and lagged stock market liquidity is positive for all portfolios and significant for most of them. More than half of the stocks in a portfolio have positive liquidity comovement between options and stock market liquidity, with ATM portfolios showing the largest proportion.

The coefficient on the contemporaneous stock market residual $\beta_3$ is significant and positive for all portfolios except that of DITM options with 30-day maturity. ATM option portfolios across all maturity categories show a higher coefficient than OTM and ITM options portfolios. This is evidence that shocks in stock market liquidity that are unexplained by options market liquidity do explain the option spread. The coefficients on lagged stock market liquidity has mixed sign and significance.

As expected, the coefficients on the stock return and the stock volatility are negative and positive, respectively. The coefficient for volatility is not significant for all portfolios.

***Put Options***

Table A12 reports the results of liquidity comovement between put options and their underlying stock market. Similar to call options, the regression results show that liquidity comovement between put options and their stock market is significant and positive for most of the portfolios but, unlike call options, it is negative and insignificant for a few portfolios. Both ITM and OTM put portfolios of all maturities have lower liquidity comovement than ATM portfolios. This suggests that stock market liquidity plays a significant role in put option liquidity, supporting the derivative hedge theory. The coefficient $\beta_2$ ranges from -0.0172 (insignificant for DOTM portfolio with maturity of

31-60 days) to 0.1245 (significant for OTM portfolio with maturity between 61-91 days) which is a wider range than what was reported for call option portfolios. Moreover, there are three put option portfolios for which the average coefficient $\beta_2$ is negative, whereas none of the call option portfolios have negative liquidity comovement. $\beta_{2lag}$ is mostly insignificant and has mixed sign. The combined effect of the coefficients on contemporaneous and lagged options market liquidity is mostly positive and significant suggesting that liquidity of the underlying stock market is a source of liquidity comovement.

This evidence of liquidity comovement between options and the underlying stock market can have pricing implications on options. Evidence of a positive liquidity comovement would imply that a negative liquidity shock in the underlying stock market would lead to a decrease in option liquidity. In this case, a marginal investor who is willing to buy that option would demand a liquidity risk premium to cover the increased costs of hedging due to the liquidity comovement. Evidence of a negative liquidity comovement, on the other hand, would imply that options become liquid when there is a negative liquidity shock in the underlying stock market. Such options offer a better liquidity hedge. A marginal investor who wants to trade in that option would need to pay a premium as market makers would be bearing the high costs of hedging in the illiquid stock market.

The coefficient on the contermporaneous stock market residual $\beta_3$ is significant and positive for all portfolios, except those with maturity category 6 (more than 273 days). Like call option portfolios, ATM put portfolios of all maturity categories usually have a higher coefficient compared to OTM and ITM portfolios. This shows that shocks to stock market liquidity that are unexplained by the options market liquidity, help explain the option spreads. The coefficient on lagged stock market liquidity has mixed signs.

***All Options***

The results for liquidity comovement between all options and their stock market are reported in Table A13. We combine both call and put options on each stock and then estimate the regression model.

In general, the results are not different from those reported above for call and put options separately. The coefficient on stock market liquidity $\beta_2$ is positive for all portfolios and significant for most portfolios. Separate analyses for call and put options show that all call option portfolios have positive liquidity comovement whereas some put portfolios have negative but insignificant liquidity comovement. The results for all options show that the specific results of call options dominate. Estimates of $\beta_2$ range from 0.0090 (insignificant; DOTM option portfolio with maturity greater than 273 days) to 0.1551 (significant DITM option portfolio with maturity 61-91 days).

### 4.5.4.3 Results for Percentage Bid-Ask Spread

We now report the results of liquidity comovement between options and their stock market using the percentage bid-ask spread as the option liquidity measure. The results are in Tables A14, A15, and A16 for call, put, and all options, respectively.

#### *Call Options*

Table A14 reports the results of market model regressions for liquidity comovement between call options and their underlying market using the percentage spread. The liquidity comovement is no longer positive for all call option portfolios as was the case with the proportional bid-ask spread. However, only positive coefficients are significant. Moreover, $\beta_2$ is not showing higher liquidity comovement for ATM options of all maturity categories. However, options that are ITM show higher liquidity comovement in most maturity categories. The coefficient $\beta_2$ using the percentage spread ranges from -0.0133 (insignificant for OTM with maturity of 30 days) to 0.1021 (significant for ITM with maturity of 182-273 days). The coefficient $\beta_{2lag}$ has mixed signs and is mostly negative and insignificant for maturity portfolios of up to 30 days. The average combined coefficient $\beta_2 + \beta_{2lag}$ is mostly positive and significant and shows a similar trend to $\beta_2$.

The coefficient $\beta_3$ is mostly positive and significant for all call options suggesting that shocks in stock market liquidity that are unexplained by options market liquidity, affect the liquidity of an option.

#### *Put Options*

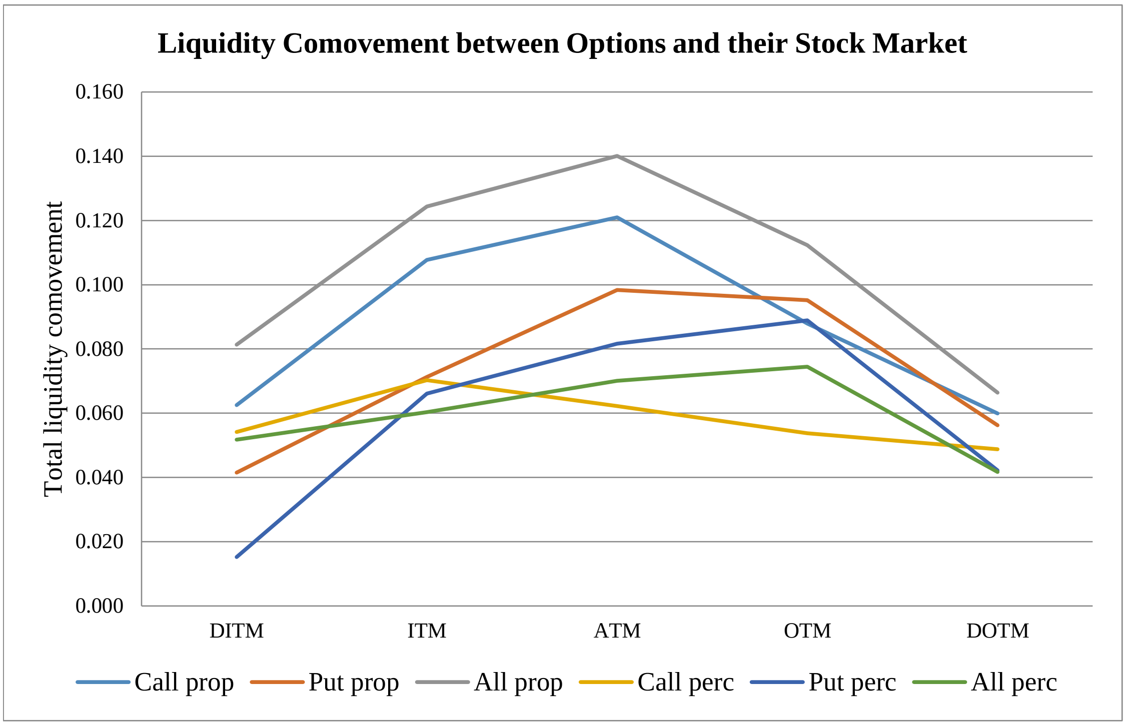
Table A15 reports the results of market model regressions for liquidity comovement between put options and their stock market using the percentage spread. The results are different from those obtained by using the proportional spread as the measure of liquidity. The coefficient on the underlying stock liquidity is mostly insignificant for all portfolios. The coefficient $\beta_2$ is positive and significant for most portfolios. Across moneyness, we find that the liquidity comovement is higher for near-the-money options. In some maturity categories, even ITM options have higher liquidity comovement, and this decreases with decreases in moneyness. The combined coefficient of contemporaneous and lagged stock market liquidity (total liquidity comovement) is mostly higher than that on conetmporaneous liquidity comovement, since $\beta_{2lag}$ has mixed sign but mostly positive for option portfolios with maturity greater than 30 days.

***All Options***

Table A16 reports the results of time-series market model regressions using the percentage spread as the measure of option liquidity. The results are not much different from those reported for call and put option portfolios separately, but the average (across maturities) coefficient on combined contemporaneous and lagged stock market liquidity is higher than that reported separately for call option portfolios. Put options have higher liquidity comovement than both call and all options, and call options have the lowest average liquidity comovement across maturities. However, for the proportional spread measure, put options have the lowest and all options have the highest average liquidity comovement across maturities. A comparison between the two liquidity measures for average liquidity comovement is given in Figure 4.7.

**Figure 4.7 Liquidity Comovement between Options and their Stock Market - Comparison**

The figure shows average total (current and lagged) liquidity comovement between options and their stock market across maturity portfolios estimated in Equation 4.4. The average coefficient calculation involves three steps. First, the coefficients on current and lagged stock market liquidity are added to get total liquidity comovement for each stock regression. Second, these are averaged across stocks in a portfolio to get a total liquidity comovement across stock in a moneyness and maturity portfolio. Third, these are again averaged across maturity portfolios to get liquidity comovement for each deep-in-the-money (DITM), in-the-money (ITM), at-the-money (ATM), out-the-money (OTM), and deep-out-the-money (DOTM) portfolios.




## 4.5.5 Size Effect in Liquidity Comovement between Options and the Stock Market

In this section we investigate the size effect of liquidity comovement between options and their underlying market. Following the methodology in Section 3.4.5, we first assign stocks to size quartiles and then create portfolios of options in these four size quartiles for each moneyness and maturity. We report the results in Tables A17 and A18 for two liquidity proxies for options: the proportional bid-ask spread and the percentage bid-ask spread, respectively.

The results of the stock market liquidity coefficient (which is interpreted as liquidity comovement between options and the stock market) are reported separately for call, put, and all options in Tables A17 (a), A17 (b), and A17 (c), respectively.

Firm size is related to inventory risk (Lesmond, 2005; Stoll, 2000), as large firms would have reduced risk of finding a counterparty, and from the hedging argument of Cho and Engle (1999) that liquidity in derivative markets is determined by liquidity in the underlying market because hedging is the primary motive for investors in the derivative markets. When investors find it difficult to hedge their net positions by deriving liquidity in the underlying market, the variability in liquidity in derivative markets would be high. This suggests that the liquidity comovement between options and their underlying market would tend to be higher. Based on this hypothesis, one would expect small firms to have high liquidity comovement between their stock options and the underlying stock market relative to large firms. The results of option portfolios are mixed across size quartiles. Liquidity comovement is high for small firms for some portfolios and low for others. Some even do not show any significant differences between small and big firms' liquidity comovements. There is also no apparent patterns in liquidity comovement across moneyness and maturity for small or big firm portfolios. These results are similar for both liquidity measures: the proportional bid-ask spread and the percentage bid-ask spread.

### 4.5.6 Volatility Effect in Liquidity Comovement between Options and the Stock Market

We follow a similar methodology to that used in Section 3.4.5 to construct volatility quartile portfolios. We report the results for the implied volatility effect in Tables A19 and A20 for the proportional option bid-ask spread and the percentage option bid-ask spread, respectively.

The size quartile results for call, put, and all options show mixed sign for liquidity comovement between options and their underlying stock market. In each quartile, the liquidity comovement is significant for only positive coefficients, which is supportive of the derivative hedge theory. However, high volatility stocks do not show higher liquidity comovement in all option portfolios. The volatility effect that higher volatility stocks have higher liquidity comovement between options and their stock market is observed across more put option portfolios (see Table A20(b)) than call option portfolios (see Table A20(a)). Since high volatility is often associated with declining stock markets, investors would face more costs of hedging in the market, which leads to a higher liquidity comovement between options and their stock market.

### 4.5.7 Summary Tables for Liquidity Comovement

As a summary, we report results of variables of interest like option liquidity comovement with options and stocks markets, size effect, volatility effect for moneyness and maturity portfolios in the tables below.

**Table 4.3 Liquidity Comovement**

This table reports the combined liquidity comovement coefficient for each moneyness and maturity portfolio of calls and puts.

| Maturity | Moneyness | Option Liquidity Comovement with | | | |
|---|---|---|---|---|---|
| | | Options Market | | Stock Market | |
| | | Calls | Puts | Calls | Puts |
| 1 | DITM | 0.250 | 0.661*** | 0.036 | -0.076 |
| 1 | ITM | -0.033 | 0.398*** | 0.058 | -0.025 |
| 1 | ATM | 0.432*** | 0.743*** | 0.121*** | 0.016 |
| 1 | OTM | 0.381*** | 0.594*** | -0.017 | -0.042 |
| 1 | DOTM | 0.422* | 0.488** | 0.136 | 0.005 |
| 2 | DITM | 0.552*** | 0.293*** | 0.022 | 0.1156** |
| 2 | ITM | 0.649*** | 0.531*** | 0.169*** | 0.152*** |
| 2 | ATM | 0.602*** | 0.622*** | 0.231*** | 0.187*** |
| 2 | OTM | 0.527*** | 0.603*** | 0.215*** | 0.169*** |
| 2 | DOTM | 0.146** | 0.301*** | 0.128** | 0.052 |
| 3 | DITM | 0.390*** | 0.410*** | 0.113*** | 0.070 |
| 3 | ITM | 0.374*** | 0.482*** | 0.049 | -0.011 |
| 3 | ATM | 0.571*** | 0.773*** | 0.037 | 0.107** |
| 3 | OTM | 0.366*** | 0.546*** | 0.069 | 0.186*** |
| 3 | DOTM | 0.152*** | 0.283*** | -0.016 | 0.099** |
| 4 | DITM | 0.469*** | 0.489*** | 0.068*** | 0.079*** |
| 4 | ITM | 0.481*** | 0.634*** | 0.139*** | 0.154*** |
| 4 | ATM | 0.494*** | 0.605*** | 0.128*** | 0.112*** |
| 4 | OTM | 0.433*** | 0.543*** | 0.096*** | 0.095*** |
| 4 | DOTM | 0.220*** | 0.296*** | 0.035** | 0.090 |
| 5 | DITM | 0.445*** | 0.484*** | 0.074*** | 0.021 |
| 5 | ITM | 0.477*** | 0.565*** | 0.123*** | 0.085** |
| 5 | ATM | 0.514*** | 0.577*** | 0.087*** | 0.069*** |
| 5 | OTM | 0.365*** | 0.480*** | 0.075** | 0.067** |
| 5 | DOTM | 0.248*** | 0.450*** | 0.016 | 0.036 |
| 6 | DITM | -0.008 | 0.151* | 0.082*** | 0.108*** |
| 6 | ITM | 0.126** | 0.080 | 0.139*** | 0.092** |
| 6 | ATM | 0.071 | 0.192*** | 0.070** | 0.032 |
| 6 | OTM | 0.013 | 0.102 | 0.141*** | 0.112** |
| 6 | DOTM | 0.114*** | 0.059 | 0.075** | 0.061* |

**Table 4.4 Size and Volatility Effect in the Liquidity Comovement.**

This table reports the coefficient of liquidity comovement for Big minus Small firms and for High Minus Low volatility stocks in each moneyness and maturity portfolio.

| Maturity | Moneyness | Size [Big - Small] | | Volatility [High - Low] | |
|---|---|---|---|---|---|
| | | Calls | Puts | Calls | Puts |
| 1 | ITM | 0.121 | -0.182*** | 0.784*** | -0.297*** |
| 1 | ATM | -0.232*** | 0.001 | 0.084 | -0.145*** |
| 1 | OTM | -0.442*** | -0.313*** | -0.311*** | -0.473*** |
| 2 | ITM | -0.508*** | -0.317*** | -0.428*** | -0.256*** |
| 2 | ATM | -0.138*** | 0.018 | -0.512*** | -0.326*** |
| 2 | OTM | -0.219*** | -0.242*** | -0.410*** | -0.349*** |
| 3 | ITM | -0.467*** | -0.451*** | 0.234*** | -0.012 |
| 3 | ATM | 0.167 | -0.695*** | 0.081 | -0.405*** |
| 3 | OTM | -0.292*** | -0.422*** | -0.280*** | -0.435*** |
| 4 | ITM | -0.489*** | -0.180*** | -0.272*** | -0.117*** |
| 4 | ATM | -0.409*** | -0.482*** | -0.331*** | -0.554*** |
| 4 | OTM | -0.408*** | -0.269*** | -0.425*** | -0.444*** |
| 5 | ITM | -0.285*** | -0.487*** | -0.413*** | -0.143*** |
| 5 | ATM | -0.201*** | -0.299*** | -0.370*** | -0.381*** |
| 5 | OTM | -0.103*** | -0.193*** | -0.437*** | -0.760*** |

### 4.5.8 Inventory Risk, Information Asymmetry and Options Market Liquidity

As discussed in Section 4.3.6, the spread in option markets may be explained by the inventory, the information asymmetry, and/or the derivative hedge theory(ies). We estimate the following multivariate time-series regressions for all, call, and put options. The results are reported in Tables A21, A22, and A23, respectively:

$$DOL_{i,t} = \gamma_{0,i} + \gamma_{1,i}DSL_{i,t} + \gamma_{2,i}DT_{i,t} + \gamma_{3,i}DOI_{i,t} + \gamma_{4,i}DV_{i,t} + \gamma_{4lag,i}DV_{i,t-1} + \gamma_{5,i}DSV_{i,t}^{res} + \gamma_{5lag,i}DSV_{i,t-1}^{res} + \gamma_6\, r_{i,t} + \gamma_7\, r^2{}_{i,t} + \gamma_8\, D_{1,t} + \gamma_9\, D_{2,t} + \varepsilon_{i,t} \qquad (4.8)$$

First, we estimate this equation for each stock and then calculate the average coefficients across all stocks in each maturity and moneyness portfolio. We expect $\gamma_1 > 0, \gamma_2 > 0, \gamma_3 > 0,$ and $\gamma_4 < 0$.

The coefficient on the percentage change in stock spreads ($\gamma_1$) is insignificant for most portfolios, except for five 'all option' portfolios (Table A21), two call option portfolios (Table A22), and three put option portfolios (Table A23) that show a significant and negative coefficient. This suggests that spreads on stocks may not necessarily explain spreads in the options market, which contradicts the derivative hedge theory (Cho and Engle, 2004).

The coefficient on the percentage change in the number of distinct options ($\gamma_2$) has a mixed sign for various option portfolios. For example, the results for all options portfolios (Table A21) show that options with maturity category 3 and moneyness categories 3, 4, and 5, options with maturity category 4 and moneyness categories 3, 4, and 5, and options with maturity category 6 and moneyness category 5, have significant and positive coefficients. This suggests that, in our sample, information asymmetry explains the spreads of ATM and OTM options with maturity higher than 60 days. We find similar results for both call and put options when the analysis is repeated separately for these types. We also observe that information asymmetry is higher for options with lower moneyness. Since OTM options provide more leverage, the impact of information asymmetry tends to be higher in these options.

The coefficient on the percentage change in open interest ($\gamma_3$) also has mixed sign and significance. Some ITM option portfolios have significantly negative coefficients and some OTM portfolios have significantly positive coefficients. This, again, suggests that inventory risk is higher for OTM options. Similar results are observed for call and put options in a separate analysis (reported in Tables A22 and A23).

As volume can be a proxy for inventory risk, we expect its coefficient $\gamma_4$ to be negative. In the case of all options, we find that this coefficient is positive and significant for most ATM, OTM and ITM options for almost all maturity categories. For call options, the coefficient is insignificant for most portfolios. Similarly, for put options, the coefficient is mostly insignificant and positive.

The finding that the coefficient on the percentage change in option volume is positive, is similar to that of Cao and Wei (2010) for CBOE equity options. It implies that an increase in option volume is related to a widening of option spreads, which is inconsistent with the predictions of the inventory risk theory.

Option volume is considered a proxy for inventory risk, but it can also proxy for information asymmetry. Due to the leverage inherent in options, informed option traders may choose to trade when they have to choose between stocks and options for informed trading (Black, 1975; Easley et al., 1998; Pan and Poteshman, 2006). Pan and Poteshman (2006) show that option trading volume can predict stock prices. If option trading volume is suggestive of informed trading, then option market makers would want to widen the spread when an increase in option volume is expected or observed. Easley and O'Hara (1998) also argue that increased volume signals tha arrival of new information.

## 4.6 Robustness Check

The graph of percentage spread of options and the underlying stock markets in Figure A1 shows that in the last quarter of 2008 and the first two quarters of 2009, the markets were quite volatile in terms of liquidity as well. The liquidity comovement between options and their market during this period can be affected by such volatile period. In order to investigate whether our results are not affected by such volatile period, we perform robustness checks for both calls and puts liquidity comovement for a sub-sample starting from 1$^{st}$ July 2009 and ending at 31$^{st}$ December 2010 for options with a maturity between 92 days and 182 days. We report the results for all moneyness portfolios in Table A24 and A25.

The results indicate that call options on average have higher liquidity commonality with the options market, coefficient of 0.681 significant at 1% level for ATM options, compared to the coefficient of 0.494 significant at 1% level for ATM options, when the whole sample is considered. However, the pattern and significance of liquidity commonality coefficient across moneyness is similar. Moreover, adjusted R-squared ranges between 5.46 and 29.84 for DITM to DOTM call options compared to the range between 4.27 and 28.96 when the whole sample was considered.

When compared to the full sample, results for put options are also qualitatively similar. The coefficient of liquidity comovement has similar pattern (high for DITM options and low for DOTM options) and adjusted R-square is very similar. The main difference is in the magnitude of the coefficient for moneyness portfolios. Puts also show higher liquidity comovement with options market when the volatile liquidity period is excluded from the sample.

To conclude whether results using the full sample affect the conclusions, we find that qualitatively the results are same, however, if we consider the liquidity comomvement coefficients, the liquidity comovement is marginally stronger when the volatile liquidity period is excluded. Moreover, based on the adjusted-R squared, we find that the explanation power of the variables is similar in both samples.

## 4.7 Conclusion

Liquidity is regarded in the literature as a characteristic of a security that comoves with market-wide factors (e.g., Stoll, 1978a; Amihud and Mendelsen, 1986; Glosten and Harris, 1998; Vijh, 1990). One of these factors is the liquidity of the market (Chordia et al., 2000; Huberman and Halka, 2001, Hasbrouk and Seppi, 2001, Cao and Wei, 2010; Acharya and Pedersen, 2005). Comovement of liquidity of a security with market wide liquidity is identified as one of the channels of liquidity risk. One of the implications of the existence of such risk is on asset pricing. In asset pricing, along with the liquidity level of a security (Amihud and Mendelsen, 1986; Acharya and Pedersen, 2005), liquidity risk of a security is identified as an important factor in explaining variations in security returns. Intuitively, a marginal investor would require a premium for holding (buying) an illiquid stock, and a risk premium for holding a stock that might be liquid but has liquidity risk, which is the risk that its liquidity will change over time due to changes in some market wide factor when she liquidates the stock (Acharya and Pedersen, 2005).

We argue that in options, there are two channels of liquidity comovement. First, the liquidity of an option might vary with the liquidity of the options market as a whole. Second, the liquidity of an option might vary with the liquidity of the underlying (stock) market. This second liquidity risk source has the hedging argument as a primary reason for trading in the derivatives market (Cho and Engle, 1999).

Like Chordia et al. (2000) and Cao and Wei (2010), we find strong liquidity comovement between options and their market across all moneyness and maturity portfolios for equity call and put options as well as for all options combined. Generally, the coefficient on options market liquidity is positive and significant for options on most of the stocks in almost all portfolios in all three option ‘markets’, but the coefficient on the lagged options market liquidity shows mixed effects and significance for options on some stocks in most of the portfolios.

Liquidity comovement is generally higher for ATM options than for OTM and ITM options, whereas DOTM options show the lowest liquidity comovement. A possible reason for ATM options having higher liquidity comovement is that ATM options are most actively traded and are more sensitive to changes in the stock price and volatility. For the combined coefficients on the contemporaneous and lagged option market liquidity, the results suggest that when call and put options are combined for analysis, the liquidity comovement is higher than when calls and puts are analysed separately. In general, put options show higher liquidity comovement than call options. We do not see any particular pattern in liquidity comovement across option maturities.

The results on liquidity comovement are qualitatively similar when either the proportional spread or the percentage spread is used as the liquidity measure. However, the percentage spread shows positive and higher liquidity comovement between options and their market for all portfolios when calls, puts, and all options are analysed separately. The patterns across moneyness and maturity are robust to the use of the percentage spread as an alternative liquidity measure.

Options of small firms generally have higher liquidity comovement with the options market, which is consistent with the view that inventory risk and information asymmetry are higher for small firms. After stratifying portfolios further into four size quartiles based on average market capitalization of stocks, we test if the liquidity comovement between options and their market is higher for small firms than for big firms. We find a small firm size effect across most call and put option portfolios. However, for all options, we find a small firm size effect for portfolios of options with maturity greater than 91 days, and we observe that bigger firms have higher liquidity comovement for ITM and OTM portfolios with maturity of 30 days and OTM portfolios with maturity of 31-60 days. We also observe for call options with 30 days maturity that liquidity comovement for firms within the first size quartile increases with moneyness. A similar effect is observed for portfolios of put options and all options with maturity greater than 91 days.

The firm size effect is robust to the use of the percentage spread as an alternative liquidity measure, where we find similar results. However, the difference in liquidity comovement between small and big firms is greater for the percentage bid-ask spread than for the proportional bid-ask spread.

One of the determinants of liquidity is volatility and higher volatility in the market leads market-makers to widen their bid-ask spreads (Chordia et al., 2000). Higher volatile stocks may also exhibit higher liquidity commonality. We test for these effects by first stratifying option portfolios into four quartiles based on the average implied volatility assigned to the stocks.

We find mixed results for implied-volatility (IV) effects in call, put, and all option portfolios. Call options show higher liquidity comovement for low IV stocks for most of the portfolios except ITM and OTM portfolios with 30-day maturity and the ITM option portfolio with 61-91 day maturity. For put options, most of the portfolios show higher liquidity comovement for low IV stocks. Moreover, only ITM, ATM and OTM 'all option' portfolios with 30-day maturity show higher liquidity comovement for high IV stocks. High IV stocks show high liquidity comovement for near to expiration call, put, and all options portfolios. This suggests that if there is a liquidity shock in the options market, the liquidity of the options written on high volatility stocks tend to be higher. In general, we find a mixed result for the implied volatility effect in the options market.

We also find evidence of liquidity comovement between options and their underlying stock market. In particular, ATM call, put, and all option portfolios exhibit higher liquidity comovement than ITM and OTM portfolios. Liquidity comovement is positive for all call option portfolios, and negative for put option portfolios but insignificant for some of the put option portfolios. The range of liquidity comovement across put option and all option portfolios is wider than for call option portfolios. On the main, liquidity comovement for all options combined is higher than that for call and put options separately. Liquidity comovement between options and their underlying stock market, which ranges from 0.0014 to 0.1142 for call options portfolios, is much lower than the liquidity comovement between options and their options market, which ranges from -0.0003 to 0.6496.

The evidence of a liquidity comovement between options and their underlying stock market suggests that liquidity in the stock market plays an important role in explaining liquidity in options. This is supportive the hedging argument of derivative hedge theory (Cho and Engle, 1999). This finding also suggests that comovement of liquidity of options arises from both the options market and their underlying stock market, with the options market showing higher liquidity comovement than the stock market.

Liquidity comovement with the stock market also has implications for the pricing of options. The evidence presented on this comovement implies that it is one of the liquidity risk factors, and investors trading options may pay or receive a premium for this risk. A positive liquidity comovement between options and the stock market implies that a negative liquidity shock in the stock market would lead to a decrease in the liquidity in options, thereby increasing the transactions costs for hedging and, therefore, an option buyer would demand a liquidity risk premium. Similarly, when liquidity comovement is negative, a negative liquidity shock in the stock market would make the options more liquid and an investor willing to hold such an option will be willing to pay a liquidity risk premium as the options market maker would now bear the high cost of hedging in the stock market since the stock market is illiquid but the option traded is liquid.

The results on the liquidity comovement are robust (in calls, puts and all options) to the use of the percentage spread as a measure for liquidity. Similar to the proportional spread, liquidity comovement between options and the stock market is higher for ATM option portfolios relative to ITM and OTM portfolios. Across call, put and all options portfolios, put options show the highest liquidity comovement and call options show the lowest liquidity comovement.

Liquidity comovement between options and the underlying stock market displays mixed results across size quartiles for option portfolios. For some portfolios, it is stronger for small firms and for others it is either weak or insignificant. Moreover, as observed for liquidity comovement between options and their market, the liquidity comovement between options and their underlying stock market does not exhibit any pattern across moneyness and maturity in any size quartile.

The volatility effect in the liquidity comovement between options and their stock market is not robust across all portfolios of call, put, and all options. The volatility effect hypothesis suggests that options on stocks with higher volatility tend to show higher liquidity comovement with their underlying stock market. Higher volatility in the stock market generally occurs when market prices are declining. Further, since declining markets are related to higher illiquidity, hedging costs may increase in the stock market for option market makers. Therefore, liquidity comovement should be higher for higher volatility stocks. However, the results do not show such evidence. Comparatively more put option portfolios show volatility effects than call option portfolios.

The analysis presented in the chapter then investigates what explains the liquidity comovement in options. We estimate multivariate time-series regressions for each stock and average the coefficients across stocks in each option portfolio. The model incorporates variables that may help explain whether derivative hedge, inventory risk, and/or information asymmetry theory(ies) of microstructure explain variations in option liquidity.

With regard to these variables, the percentage change in the spread of the underlying stock is a proxy for testing the derivative hedge argument; the percentage change in the number of distinct options and the percentage change in open interest are proxies for testing inventory risk; and the percentage change in volume is a proxy for testing information asymmetry. It is argued, however, that volume proxies for both inventory risk and/or information asymmetry. Due to the inherent leverage in options, informed traders may choose to trade options whenever they have a choice of trading in either the underlying stocks or in the options (Black, 1975; Pan and Poteshman, 2006). If option volume is suggestive of informed trading, options market-makers would widen the option spreads if option volume is increased (Easley and O'Hara, 1998).

Derivative hedge theory does not help explain the option spreads observed for most of the option portfolios, whereas we find that information asymmetry theory helps explain the spreads of ATM and OTM options with maturity greater than 60 days. We conclude that since OTM options provide high leverage, the impact of information asymmetry tends to be higher in these options. This may also suggest that investors may be hiding their information by trading in options with high leverage to exploit information asymmetries. OTM options show a higher and positive relation between the percentage change in option spreads and the percentage change in open interest (proxy for inventory risk). However, some ITM options show a negative relationship. We conclude that inventory risk is higher for OTM options. From an inventory risk perspective, we expect volume to have a negative relationship with option spreads. However, our findings suggest that this is not the case for all portfolios. Amongst all option portfolios, the relationship is positive and significant for most OTM, ATM, and ITM option portfolios. Call option portfolios show an insignificant relationship and most of the put portfolios show a positive and insignificant relationship. This finding is contrary to what inventory theory suggests, since we find a positive (though mostly insignificant) relationship. Black (1975), Easley and O'Hara (1998), and Pan and Poteshman (2006), however, suggest that because of the inherent leverage, traders with information may opt to trade options. In fact, Pan and Poteshman (2006) show that option volume can predict stock prices. With our finding of a positive and significant relationship for ITM, ATM and OTM portfolios of all options, we conclude that the most likely candidate to explain information asymmetry theory is the spreadin the options market, since the higher option volume may be an indication of the arrival of new information.

# CHAPTER 5
# OPTION RETURN SENSITIVITY

## 5.1 Introduction

This chapter presents an empirical analysis that investigates the sensitivity of option returns to liquidity in the options market and in the underlying stock market. Liquidity of an asset is found to be risky because it changes over time with fluctuations in market forces. One such market force is market liquidity. The literature on stock and bond markets suggests that the liquidity and the return of an asset may vary over time with market-wide liquidity. In the Liquidity Capital Asset Pricing Model of Acharya and Pedersen (2005), the return of an asset net of transaction costs is related to an illiquidity premium, a market risk premium, and a liquidity risk premium. In the stock market, the premium associated with liquidity risk is due to the three covariances. The first is the covariance between stock liquidity and stock market liquidity. The second is covariance between stock return and stock market liquidity. The third is covariance beween stock liquidity and stock market return.

In the pervious chapter, we investigated liquidity risk due to the covariance between liquidity of an asset (in our case option liquidity) and liquidity of its market (in our case option market liquidity. This is also known as liquidity comovement between option and its market. Moreover, we also argued and investigated yet another source of liquidity risk which is liquidity comovement between option and its underlying market.

The next step is to identify yet another source of liquidity risk, covariance between asset return and asset market liquidity as in Acharya and Pedersen (2005) model. Therefore, in this chapter, we investigate liquidity risk due to the covariance between asset return and market liquidity, for equity options.

Amihud (2002) investigates the time-series and cross-sectional effects of market liquidity on returns of stocks listed on the New York Stock Exchange. Several papers have also investigated market liquidity in equity options. In particular, Cao and Wei (2010) are the first to investigate liquidity commonality in the CBOE equity options market. They find that liquidity comovement in the options market is strong, and that call options show higher liquidity comovement than put options.

Liquidity risk due to the covariation between asset returns and market liquidity has not yet been investigated in the equity options market. It is important to investigate this source of liquidity risk as it would help in identifying potential factors related to liquidity risk that may be priced in equity options. This pricing issue is investigated in Chapter 6.

In this chapter, we follow the methodology of Amihud (2002) and investigate the time-series effects of option market liquidity and stock market liquidity on the returns of call and put option portfolios. Although several papers have investigated the effect of liquidity of a stock and an option written on that stock, on option prices, the question of whether option returns covary with option market liquidity and stock market liquidity has not been investigated. For example, Chou et al. (2013), Feng et al. (2013) and Christoferssen et al. (2015) document that the expected return of an option includes a premium for option illiquidity and a discount for the underlying stock illiquidity. Although the illiquidity of the underlying stock is an important determinant of an option price, liquidity risk due to an illiquid underlying stock in the theoretical frameworks of Frey (2000) and Cetin et al. (2004 & 2006) is also identified as an important determinant of the option price.

We investigate the sensitivity of option returns to changes in the option market liquidity and to changes in the stock market liquidity. Since liquidity is persistent (Amihud, 2002), expected liquidity can be separated from unexpected liquidity by modelling the persistence in liquidity (e.g., through an autoregressive model). By disecting liquidity into expected and unexpected components, we investigate each component's effect on option returns. The first is the effect of expected illiquidity in the market on option returns. The second is the effect of unexpected illiquidity in the market on option returns. Since the motives for trading an option can be liquidity, hedging, or speculation, we investigate the effects of expected and unexpected illiquidity in both the option and stock market on option returns.

The persistence in liquidity implies that if the market in the current period is liquid, the market in the next period is likely to also be liquid. In order to hold an option, a trader expecting the market to be less liquid in the next period, would want to be compensated for the illiquidity in the next period. Accordingly, the trader will pay a lower price (and a higher expected return) for buying an illiquid option (compared to an otherwise liquid option). Therefore, we hypothesize that expected illiquidity in the options market will have a positive effect on the contemporaneous option return. A lower option price means a higher option return. This suggests that a lower expected liquidity in the options market leads to a higher option return.

The other implication of persistence of illiquidity is that illiquidity is partially unexpected. By unexpected illiquidity we mean an illiquidity shock, in which the liquidity of an asset declines or increases more than expectations. As discussed earlier, in a market with the lower expected liquidity a trader pays a lower price for the asset compared to when the market is more liquid. But when there is an illiquidity shock in the market, to hold an option, an option trader will want to be compensated for the illiquidity shock by paying a price lower than the expected price, thus asking for a higher return. Accordingly, unexpected illiquidity in the options market will have a negative effect on contemporaneous option returns.

An option trader who trades options for hedging purposes would be concerned about the liquidity of the underlying stock. When changes in the liquidity of a stock are affected by the changes in the liquidity of the stock market (liquidity comovement), an option trader would be concerned about the sensitivity of the option return to the illiquidity in the underlying stock market. The literature documents evidence of liquidity commonality in the stock market.[18] Moreover, according to the derivative hedge theory of Cho and Engle (1999), liquidity measured by the spread in the derivative market is determined by the spread in the underlying market, if market makers in the derivative market are able to completely hedge their positions by trading in the underlying market. These hypotheses related to the time-series effects of expected and unexpected illiquidity in the stock market on option return are investigated in this chapter.

To investigate these research questions and hypotheses, the methodology of French et al. (1987) and Amihud (2002) is used. The approach adopted here is slightly different in the sense that Amihud (2002) investigates the time-series impact of market liquidity on

[18] There is vast literature on liquidity commonality in the stock market. This is discussed mainly in the chapter on literature review (Chapter 2). For reference please refer to the main articles of Chordia et al. (2001) and Acharya and Pedersen (2005)

market returns, while in this chapter call and put option portfolios based on the moneyness and maturity of the option are investigated.

The rest of the chapter is organized as follows: Section 5.2 contains a brief literature review mainly related to the impact of market liquidity on asset returns, Section 5.3 discusses the empirical model and hypotheses, Section 5.4 describes the data and the variables used, Section 5.5 presents and discusses the results of estimating regression models for call and put portfolios, Section 5.6 describes robustness results, and Section 5.7 concludes.

## 5.2 Literature Review

Standard asset pricing theory assumes that markets are frictionless and competitive. Consequently, there are no bid-ask spreads or transaction costs, and no lack of liquidity. Standard asset pricing theory may not apply when these assumptions are relaxed (Chou et al., 2013) and liquidity (measured by bid-ask spread), may be priced. Considering the role of liquidity in security pricing, documented in the recent literature, it is now accepted that liquidity is an important determinant of stock and bond returns (*using turnover or volum*: Haugen and Baker, 1996; Datar, Naik and Radcliffe, 1998; *using bid-ask spread*: Amihud and Mendelsen, 1986a, 1991; Kamara, 1994; Eleswarapu, 1997; *using price impact:* Brennan and Subrahmanyam, 1996; Acharya and Pedersen, 2005;). There is evidence that liquidity of an option is important in its pricing. For example, OTC FX options issued by the Bank of Israel are priced 21% less than the exchange-traded options (Brenner et. al, 2001). Brenner et al. (2001) argue that this discount is due to non-tradability of the OTC FX options. Similarly, Bollen and Whaley (2004) and Garleanu et al. (2009) conclude that options are expensive due to their high demand. Moreover, the demand patterns in options also help in explaining the expesiveness and skew of index options compared to equity options. Additionally, Chou et al. (2013) and Christoferssen et al. (2015) document that the expected return of an option includes a premium for its illiquidity. These findings in options of different underlying assets imply that the liquidity of an option is an important determinant of its return.

Liquidity of an asset may not remain constant over an investor's holding period. In this case, an investor may be concerned with liquidity over the holding period, which will have implications on pricing. Chordia et al. (2000), Hasbrouck and Seppi (2001), Amihud (2002), and Korajczyk and Sadka (2007), amongst others, find that liquidity of a stock comoves with market-wide liquidity. In the derivative markets, Cao and Wei (2010) provide evidence of liquidity comovement between equity options and their market using the bid-ask spread, volume, and the price impact. They also report that liquidity in the option market shows asymmetric effect in bear and bull stock markets.[19] Call options react more in bull underlying markets and put options react more in bear underlying markets.

It is may not only be the liquidity of an option that comoves with options market liquidity. Acharya and Pedersen (2005) present evidence suggesting that market-wide liquidity systematically moves with changes in liquidity and returns of a stock. They suggest that liquidity risk in the stock market can be ascribed to three sources: liquidity comovement between individual stocks and their market, comovement between the return of individual stocks and market liquidity, and comovement between individual stock liquidity and market return. Moreover, liquidity risk due to the comovement between the return of an asset and market-wide liquidity is positively related to return of an asset. For example, Pastor and Stambaugh (2003) suggest that the return of a stock includes a premium for the sensitivity of its returns to fluctuations in market liquidity. They find that stocks whose returns show high sensitivity to fluctuations in aggregate market liquidity exhibit higher returns.

The effects of stock return sensitivity to market liquidity are also noted in the theoretical models of Holstrom and Tirole (2000) and Lustig (2001). Holstrom and Tirole (2000) examine implications of the corporate demand for liquidity (Liquidity Adjusted Pricing Model) and Lustig (2001) studies the equilibrium implications of the solvency constraints. Like Pastor and Stambaugh (2003), Sadka (2002) and Wang (2002) suggest that these effects are consistent.

The literature identifies liquidity to be persistent. Its persistence helps us disect the sensitivity of option returns to expected and unexpected illiquidity in the markets. Moreover, in the stock market, the persistence of liquidity has two implications for stock returns (Chordia et al., 2001; Jones, 2001; Acharya and Pedersen, 2005). First, liquidity helps predict future returns. Acharya and Pedersen (2005) suggest that current high

[19] Chordia et al. (2001) found that the market spread reacts asymmetrically to up and down movements in the market. The percentage bid-ask spread declines in bull markets and increases in bear markets. They suggested that this is due to the increase risk aversion of market makers to inventory risk in bear markets.

liquidity predicts high liquidity in the next period, implying a low required return. Similarly, Jones (2001) documents an empirical evidence that expected annual return of the stock market increases with the bid-ask spread in previous year and decreases with the turnover in previous year. This finding would imply that investors expect the stocks to be illiquid, suggesting that illiquidity is assumed to be persistent. Moreover, Amihud (2002) finds that liquidity predicts returns of the market portfolio and size portfolios, and Bakaret et al. (2003) find that liquidity predicts returns of emerging markets. Second, a negative conditional covariation between contemporaneous returns and liquidity exists (Acharya and Pedersen, 2005). Intuitively, higher illiquidity suggests a higher return. However, a shock in illiquidity will depress the current price leading to a lower return. This intuition is valid only when liquidity is persistent. Chordia et al. (2001), Jones (2001), and Pastor and Stambaugh (2003) find a negative relation between return and corresponding liquidity in the stock market which is in accordance with the above argument.

Given that options are contingent claims, the arbitrage pricing theory would suggest that liquidity of an asset is important for pricing options (Frey, 1998; Frey, 2000; Liu and Yong, 2005; Cetin et al., 2004; Cetin et al., 2006; and Chou et al., 2013).[20] Cho and Engle (1999) propose a derivative hedge theory, which purports that liquidity and spread in derivative market are determined by liquidity and spread in the underlying asset market if market-makers are able to hedge their derivative positions by trading in the underlying asset market.

Chou et al. (2013) study the impact of liquidity of spot (underlying asset) and liquidity of option on option prices. They use implied volatility as a proxy for option price, and find that implied volatility increases with illiquidity of the underlying asset, which is consistent with the hedging costs argument of Cetin et al. (2006), and decreases as the illiquidity of options increase, which is consistent with the illiquidity premium hypothesis of Amihud and Mendelsen (1986).

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[20] Frey (200) and Liu and Yong (2005) in their model consider the costs involved under the presence of price impact when replicating a European option. Cetin et al. (2004) and Cetin et al. (2006) derive a pricing formula for European call option by modeling liquidity with a stochastic supply curve. Cetin et al. (2006) find empirically that the impact of illiquidity depends on the moneyness of options.

Feng et al. (2013) develop a liquidity-adjusted option pricing model which shows how liquidity risk through liquidity discount factor affects stock prices.[21] The liquidity discount factor considers the mean-reversion of stochastic market liquidity as well as the sensitivity of stock prices to market illiquidity.

Considering the above discussion, illiquidity persistence in both the stock market (Amihud, 2002; and Acharya and Pedersen, 2005) and in the options market can influence option returns.

## 5.3 Methodology and Hypotheses

This chapter investigates the sensitivity of option returns to options market illiquidity and stock market illiquidity. As discussed earlier, persistence in illiquidity has two implications for stock returns. First, liquidity helps predict future returns. Second, a negative covariation between contemporaneous return and liquidity exists. This second implication suggests that when there is an unexpected illiquidity, the price will decrease leading to a decrease in the expected return.

Further, an option is a contingent security whose payoff is dependent on the underlying stock price. In frictionless markets, transaction costs do not exist, but Cetin et al. (2003) provide evidence that transaction costs in the underlying stock market are important when replicating options.

In light of the above discussion, illiquidity persistence in the stock market has two implications for option returns. It implies that illiquidity today predicts illiquidity the next period. Therefore, illiquidity can be separated into expected and unexpected components. The first implication is that expected illiquidity in the stock market would affect option returns positively. Due to the illiquidity persistence, the price of the underlying asset should decrease as investors require a high return. A lower price in the stock market would imply a lower price in the options market, since an option price is an instantaneous function of the stock price. Investors would require higher option return for low expected liquidity in the stock market. Chou et al. (2013) investigate the impact of stock liquidity on option prices and find that liquidity of the underlying asset has a negative effect on the

[21] The model of Feng et al. (2013) is based on the model of Brunetti and Caldarera (2006). Brunetti and Caldarera (2006) incorporate a liquidity discount factor into the demand function of a stock to capture the impact of liquidity on stock prices.

level of the implied volatility curve, which would translate into a positive effect on option returns. This chapter investigates the impact on option returns of liquidity in the stock market, as measured by the proportional bid-ask spread.

The second implication is that an illiquidity shock (unexpected illiquidity) in the stock market affects the option return negatively. As discussed, persistence in illiquidity implies that investors would require a higher expected return on the option. However, an unexpected decrease in liquidity (or unexpected illiquidity) in the stock market would depress stock prices further, which would decrease the expected option return.

We further propose that illiquidity persistence in the options market has two implications for option returns. First, expected illiquidity in the options market would positively affect option returns. The line of argument follows from Amihud and Mendelsen's (1986) 'illiquidity premium' hypothesis. Amihud and Mendelsen (1986) find that stock returns are a concave function of the proportional bid-ask spread. Chou et al. (2013) investigate the effect of option illiquidity on implied volatility and find a positive relation. Unlike Chou et al. (2013), we investigate the sensitivity of option returns to illiquidity in the options market. Second, illiquidity in the options market means that an unexpected decrease in liquidity in the options market would depress option prices since the expected return on options would be higher due to options market expected illiquidity.

The ensuing analysis follows the methodology of French et al. (1987) and Amihud (2002). French et al. (1987) study market risk effect on the stock excess return. Amihud (2002) examines the sensitivity of stock market return to stock market illiquidity. However, this chapter investigates the sensitivity of option return to stock and options markets' illiquidity.

Amihud (2002) suggests that the ex-ante effect of stock market illiquidity on stock excess return is given by:

$$E\left(RM_y - Rf_y \middle| \ln AILLIQ_y^E\right) = f_o + f_1 \ln AILLIQ_y^E \quad (5.1)$$

where, $RM_y$ is the annual market return for year $y$; $Rf_y$ is the risk-free annual yield, and $\ln AILLIQ_y^E$ is the market expected illiquidity for year $y$ based on information in $y-1$.

Market illiquidity is measured by the natural logarithm of Amihud's Absolute ILLIQ measure.

### 5.3.1 Sensitivity of Option Return to Options Market Illiquidity

Following Amihud (2002), we describe the ex-ante effect of options market illiquidity on option excess return by the following model:

$$E\left(OR_{jt} - Rf_t | OSprop_t^E\right) = a_o + a_1 E(RSM_t - Rf_t) + a_2\ OSprop_{mt}^E \qquad (5.2)$$

where, $OR_{jt}$ is the day t average return across all options on stock $j$ for a specific option maturity and moneyness group, $RSM_t$ is the stock market return at day $t$, $Rf_t$ is the risk-free rate at day $t$, and $OSprop_{mt}^E$ is the options market expected illiquidity at day $t$ based on information at $t-1$. The null hypothesis that $a_2 > 0$ suggests that expected illiquidity in the option market positively affects the average expected excess return across options.

Our model is different from Amihud (2002) in that we include the underlying stock market excess return. In this way, it is similar to a market model but with an additional option market expected illiquidity as an additional variable. Options market illiquidity, $OSprop_{mt}$, is measured by the average illiquidity across all options on all stocks at time $t$ (option proportional spread) for a specific option maturity and moneyness group.

In Equation (5.2), $a_1$ is the coefficient on the market expected excess return. When stock prices rise, a call option would be more in-the-money whereas a put option would be more out-the-money. Accordingly, one would expect $a_1$ to be positive for call options and negative for put options. It is important, therefore, to estimate separate regressions for call and put options.

Investors are assumed to predict the options market illiquidity at day $t$ based on information that is available at day $t-1$. Using this prediction, they set prices such that it generates the desired expected return at day $t$. Options market illiquidity is assumed to be persistent and follows an autoregressive process of order $p$, $AR(p)$:

$$OSprop_{m,t} = c_o + c_1\ OSprop_{m,t-1} + \cdots + c_p\ OSprop_{m,t-p} + \varepsilon_t \qquad (5.3)$$

where, $c_o$ , $c_1, \dots, c_p$ are coefficients and $\varepsilon_t$ is the error. It is expected that $c_1 > 0, c_2 > 0, c_3 > 0 \dots\ c_p > 0$ .

At the start of day $t$, investors compute the expected illiquidity for the day, $OSprop^E_{mt}$, based on information up to day $t-1$:

$$OSprop^E_{mt} = E(OS_{prop_{m,t}}) = \widehat{c_o} + \widehat{c_1} OSprop_{m,t-1} + \cdots + \widehat{c_p}\ OSprop_{m,t-p} \qquad (5.4)$$

Based on this estimate of options market expected illiquidity, market prices are set at day $t$. The assumed model (4.2), can be re-written as a regression model:

$$OR_{jt} - Rf_t = a_o + a_1(RSM_t - Rf_t) + a_2 OSprop^E_{m,t} + u_t \qquad (5.5)$$

Considering the plausible sign of the expected and unexpected parts of options market illiquidity, we assume that the options market follows an AR(1) process for simplicity in the following derivation. However, an appropriate lag structure for the AR($p$) model is estimated based on the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC) for options market illiquidity in the empirical analysis.

The AR(1) specification is

$$E(OSprop_{m,t}) = c_o + c_1\ OSprop_{m,t-1} \qquad (5.6)$$

Substituting Equation (5.6) into Equation (5.5), one gets:

$$OR_{jt} - Rf_t = a_o + a_1(RSM_t - Rf_t) + a_2[c_o + c_1 \cdot OSprop_{m,t-1}] + e_t \qquad (5.7)$$

$$OR_{jt} - Rf_t = [a_o + a_2 c_o] + a_1(RSM_t - Rf_t) + [a_2 c_1]\ OSprop_{m,t-1} + e_t \qquad (5.8)$$

Define:

$g_o = a_o + a_2 c_o$, $g_1 = a_1$ and $g_2 = a_2 c_1$.

Equation (5.8) can then be written as:

$$OR_{jt} - Rf_t = g_o + g_1(RSM_t - Rf_t) + g_2\, OSprop_{m,t-1} + e_t \qquad (5.9)$$

Unexpected option excess return is denoted by the residual $e_t$. The null hypothesis $g_2 > 0$ would suggest that lower expected market liquidity (higher $OSprop_{m,t-1}$) leads to higher ex-ante option excess return.

Amihud (2002) suggests that unexpected illiquidity in the market should affect contemporaneous unexpected return in the market negatively. This is due to $c_1 > 0$. This implies that illiquidity in the option market today raises expected illiquidity in the market the following day. If expected illiquidity causes ex-ante option returns to increase, an unexpected increase in option market illiquidity should depress option prices. Consequently, the relationship between unexpected market illiquidity and contemporaneous option returns should be negative. These two hypotheses are tested in the model below:

$$OR_{jt} - Rf_t = g_o + g_1(RSM_t - Rf_t) + g_2\, OSprop_{m,t-1} + g_3\, OSprop^{\,U}_{m,t} + w_t \qquad (5.10)$$

where $OSprop^{\,U}_{m,t}$ is unexpected illiquidity in the options market at day $t$, which is the residual from the AR(1) estimation for options market illiquidity, and $OSprop_{m,t-1}$ is a measure of expected illiquidity in the options market when options market illiquidity follows an AR(1) process.

In our empirical analysis, the regression model can be rewritten as:

$$OR_{jt} - Rf_t = g_o + g_1(RSM_t - Rf_t) + g_2 eliq_{om,t} + g_3\, ueliq_{om,t} + w'_t \qquad (5.11)$$

where, $eliq_{om,t}$ is expected illiquidity in the options market at time $t$ and, $ueliq_{om,t}$ is the unexpected illiquidity in the options market obtained as residual from the AR(p) in Equation (5.3).

**Hypotheses: Relation between Option Excess Return and Options Market Illiquidity**

Hypothesis 1 (H4)

*Options market expected illiquidity positively affects option ex-ante excess returns*.

H4*:* $g_2 > 0$

Hypothesis 2 (H5)

*Options market unexpected illiquidity has a negative impact on contemporaneous option excess return.*

H5: $g_3 < 0$

### 5.3.2 Sensitivity of Option Return to Stock Market Illiquidity

We assume that stock market illiquidity is persistent and follows an $AR(p)$ process. Following the above methodology, Equation (4.10) can be re-written to construct hypotheses for testing the impact of expected and unexpected illiquidity in the stock market on option excess returns.

$$OR_{jt} - Rf_t = h_o + h_1(RSM_t - Rf_t) + h_2\, SSprop_{m,t-1} + h_3\, SSprop^{\,U}_{m,t} + \xi_t \qquad (5.12)$$

where, $h_0$ is the intercept, $h_1$ is the option beta, $h_2$ is the sensitivity of option excess return to expected illiquidity in the stock market ($SSprop_{m,t-1}$) when stock market illiquidity follows an AR(1) process, and $h_3$ is the sensitivity of option excess return to unexpected illiquidity in the stock market ( $SSprop^{\,U}_{m,t}$).

When illiquidity in the stock market follows an AR($p$) process, the expected illiquidity would be the predicted values of the proportional bid-ask spread, and the unexpected illiquidity would be the residual of the AR(p) specification. The lag length is selected using the Akaike Information Criteria (AIC) and/or the Bayesian Information Criteria (BIC). The regression model for the sensitivity of option returns to the expected and unexpected illiquidity in the stock market is:

$$OR_{jt} - Rf_t = h_o + h_1(RSM_t - Rf_t) + h_2\, eliq_{sm,t} + h_3\, ueliq_{sm,t} + \xi'_t \qquad (5.13)$$

where, $eliq_{sm,t}$ is the stock market *expected illiquidity* at time $t$, and $ueliq_{sm,t}$ is the stock market unexpected illiquidity calculated as a residual of the autoregression in Equation (4.3).

**Hypotheses: Relation between Option Excess Return and Stock Market Illiquidity**

Hypothesis 3 (H6)
*Expected stock market illiquidity positively affects option ex-ante excess returns*.

H6*:* $h_2 > 0$

Hypothesis 4 (H7)
*Unexpected stock market illiquidity has a negative impact on contemporaneous option excess returns.*

H7: $h_3 < 0$

## 5.4 Data and Variables

This section provides a brief description of the data, definition of the variables used in the regression analysis, the classification of options into moneyness and maturity portfolios, and descriptive statistics of liquidity in the stock market, liquidity in the options market, and option returns.

### 5.4.1 Data

The sample consists of equity options data obtained from the NYSE Euronext LIFFE, data on the stocks obtained from Datastream, and the UK zero-curve interest rates from Inter Capital through Datastream. The sample period runs from 22 February 2008 to 31 December 2010.

As discussed in Chapter 3, screening criteria are applied to obtain a final set of options data (see Section 3.3) and thirty portfolios of options are created based on moneyness and maturity (see Section 3.5).

Moreover, for this analysis we need to construct variables of option illiquidity, options market illiquidity, stock illiquidity, stock market illiquidity, option return, and stock market return. The definition and formula for these variables are provided in Section 3.4.

### 5.4.2 Descriptive Statistics

In this section, summary statistics of option and stock illiquidity measures, the correlation between option return and options market illiquidity, the correlation between option return and stock market illiquidity, and the correlation between stock and options market illiquidity, are reported and discussed.

**Summary Statistics**

Table 5.1 reports summary statistics of the proportional bid-ask spread and its natural log for all options, call options, put options, and stocks (stocks in the FTSE 100 index). The LIFFE London equity options market has a higher percentage trading cost than the FTSE 100 stock market. The average proportional bid-ask spread is similar for both call (22.01%) and put options (22.33%), while the percentage costs for trading a FTSE 100 stock is only 0.12%. The option transaction cost as measured by the proportional bid-ask spread in the LIFFE London options market is approximately 176 times the average transaction cost of the underlying stocks. The spread for stocks is skewed to the right (skewness: 7.56) and has fat tails (kurtosis: 109.99), this is mainly due to the large values related to the widened bid-ask spread during the volatile period of October 2008 and Decebmer 2008. However, the spread for calls, puts, and all options is quite close to the normal distribution as skewness is close to zero and kurtosis is close to 3. One of the assumptions that underlay ordinary least squares regressions is that the variables are normally distributed. Moreover, unexpected illiquidity is measured as the residual from an AR($p$) specification. Therefore, it is important that our results are not affected by the high skewness and fat tails of the distribution of bid-ask spreads. Two possible ways of dealing with this are: either by winsorization or by taking the natural logarithm of the variable. First, we choose to winsorize at the 5% level and only for upper tail of the distribution is due to two main reasons. First, we choose only the upper tail of the distribution for winsorization because we do not observe outliers on the lower tail of the distribution. Second, we choose 5% level of winsorization after investigating winsorization at lower and higher levels as well. If we choose 1% level, skewness and kurtosis are substantially higher at 1.617 and 6.564 respectively. If we choose 10% level,

**Table 5.1 Summary Statistics for Liquidity of Markets**

The table presents the mean, median, 5th percentile, 95th percentile, skewness, and kurtosis of the proportional bid-ask spread for calls, puts, all options and the stock market. Panel A reports the statistics for proportional bid-ask spread before and after winsorization at the 5% upper tail of the distribution. Panel B reports the statistics for the natural logarithm of the proportional bid-ask spread before and after winsorization at the 5% upper tail of the distribution.

| **Panel A:** *Proportional Bid-Ask Spread* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Before winsorizing* | | | | *After winsorizing* | | | |
| | **Calls** | **Puts** | **All** | **Stock** | **Calls** | **Puts** | **All** | **Stock** |
| Mean | 22.01 | 22.33 | 21.12 | 0.12 | 21.89 | 22.29 | 21.07 | 0.12 |
| Median | 21.63 | 22.80 | 21.18 | 0.11 | 21.63 | 22.80 | 21.18 | 0.11 |
| 5th Percentile | 16.12 | 16.71 | 16.62 | 0.07 | 16.12 | 16.71 | 16.62 | 0.07 |
| 95th Percentile | 29.56 | 26.46 | 25.09 | 0.22 | 29.56 | 26.46 | 25.09 | 0.22 |
| Standard deviation | 4.05 | 3.01 | 2.57 | 0.07 | 3.73 | 2.91 | 2.46 | 0.04 |
| Skewness | 0.70 | -0.50 | -0.02 | 7.56 | 0.29 | -0.76 | -0.31 | 0.78 |
| Kurtosis | 3.72 | 3.69 | 3.02 | 109.99 | 2.48 | 3.12 | 2.36 | 2.76 |
| Observations | 691 | 691 | 691 | 754 | 691 | 691 | 691 | 754 |
| **Panel B:** *ln(Proportional Bid-Ask Spread)* | | | | | | | | |
| | *Before winsorizing* | | | | *After winsorizing* | | | |
| | **Calls** | **Puts** | **All** | **Stock** | **Calls** | **Puts** | **All** | **Stock** |
| Mean | 3.08 | 3.10 | 3.04 | -2.17 | 3.07 | 3.09 | 3.04 | -2.18 |
| Median | 3.07 | 3.13 | 3.05 | -2.20 | 3.07 | 3.13 | 3.05 | -2.20 |
| 5 Percentile | 2.78 | 2.82 | 2.81 | -2.67 | 2.78 | 2.82 | 2.81 | -2.67 |
| 95 Percentile | 3.39 | 3.28 | 3.22 | -1.54 | 3.39 | 3.28 | 3.22 | -1.54 |
| Standard deviation | 0.18 | 0.14 | 0.12 | 0.37 | 0.17 | 0.14 | 0.12 | 0.33 |
| Skewness | 0.16 | -0.98 | -0.37 | 1.00 | -0.08 | -1.12 | -0.55 | 0.25 |
| Kurtosis | 2.96 | 4.15 | 2.89 | 5.64 | 2.54 | 4.10 | 2.67 | 2.10 |
| Observations | 691 | 691 | 691 | 754 | 691 | 691 | 691 | 754 |

although skewness decreases to 0.389, kurtosis decreases substainstially to 1.93. It is therefore, we choose 5% winsorization for the upper tail of the distribution. When winsorizing at the 5% level of the upper side of the distribution, skewness and kurtosis of the proportional bid-ask spread for calls, puts, and all options, does not change much, suggesting that the proportional bid-ask spread behaves like a normal distribution. Moreover, the distribution of the proportional bid-ask spread for the stock market improves substantially. Skewness reduces from 7.56 to 0.78 and kurtosis reduces from 109.99 to 2.76. Second, after calculating the natural logarithm of the proportional bid-ask spread (Panel B of Table 5.1), skewness and kurtosis for calls, puts, and all options change but remain close to zero and three, respectively. However, they reduce substantially for the stock market to 1.00 and 5.64, respectively. Accordingly, winsorizing the proportional bid-ask spread rather than calculating the natural logarithm provides a better approximation to the normal distribution. In light of the above observation, the proportional bid-ask spread is winsorized at the 5% level of the upper side of the distribution, and this would be a better measure of stock market illiquidity for subsequent regression analyses.

**Figure 5.1a Illiquidity in the Options Market**

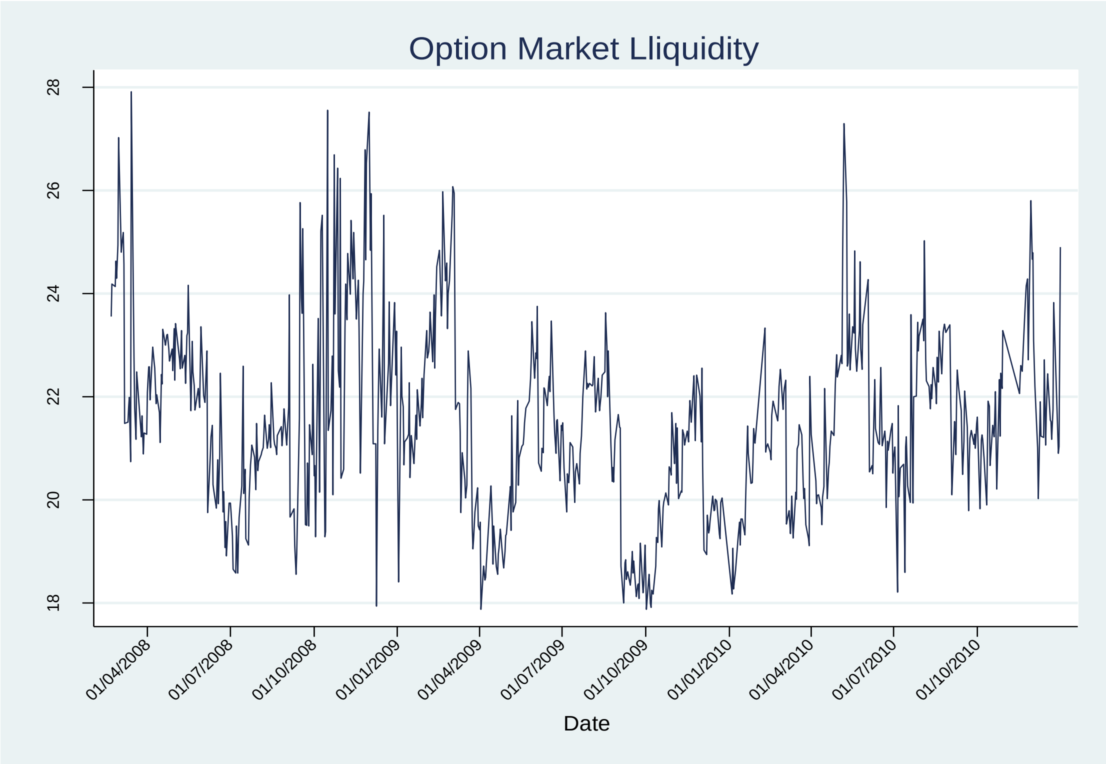
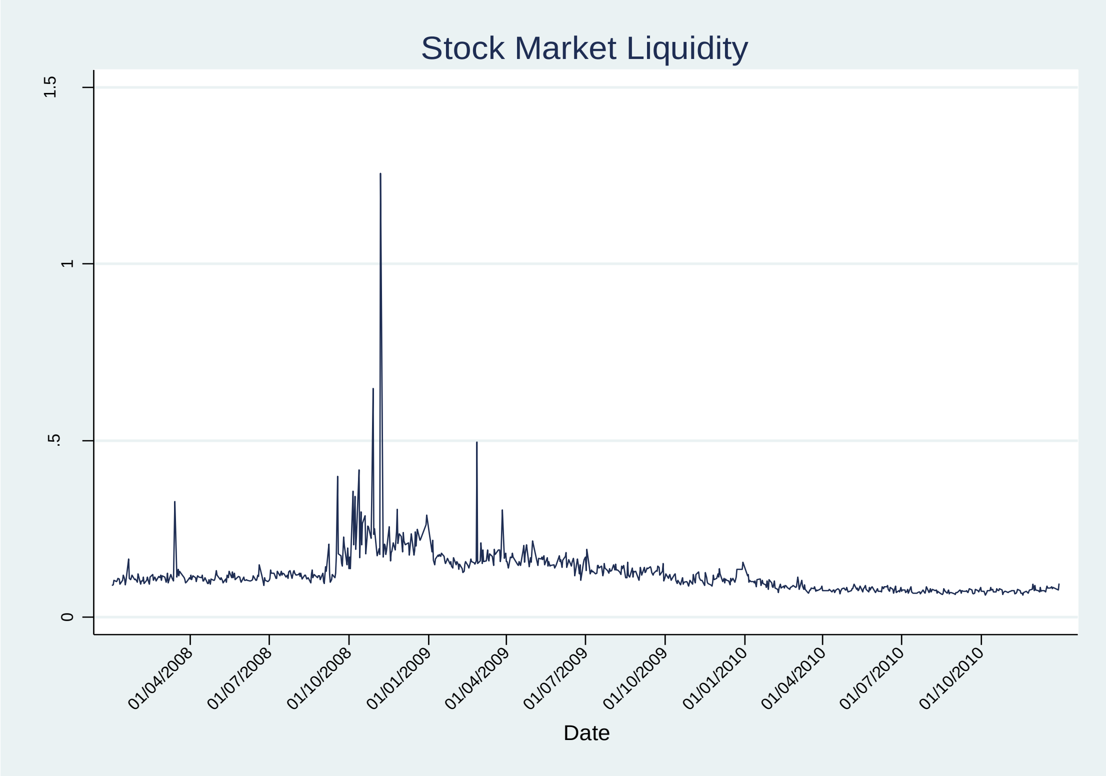



Figure 5.1 plots illiquidity of the option and the stock markets. It shows that illiquidity, measured by the proportional bid-ask spread, is extremely volatile from early October 2008 to 19 December 2008. In the options market, periods of low liquidity are followed by periods of high liquidity. However, such patterns are different and not as pronounced in the stock market. The standard deviation of liquidity of all options is high (2.57) compared to 0.07 for the stock market (see Panel A of Table 5.1). Illiquidity in the stock market is slightly less persistent than illiquidity in the options market, since the first-order autocorrelation in stock market illiquidity is 0.74 compared to 0.84 (see Table 5.3) for options market illiquidity, both significant at 1% level. However, the lag length of AR(*p*) model for illiquidity in each market is selected using the Akaike Information Criterion (AIC) and Bayesian Information Criteria (BIC).

**Figure 5.1b Illiquidity in the Stock Market**




**Correlations of Option Return with Illiquidity in Options and Stock Markets**

Table 5.2 presents the average (across stocks) correlation between option return and the illiquidity of the options market, and the average (across stocks) correlation between option returns and illiquidity of the stock market. The illiquidity is measured by the proportional bid-ask spread. The number of stocks that have a positive correlation between their option rerturn and illiquidity in the market is also reported. In order to calculate correlation between option return and stock market illiquidity, we follow the following steps. First, average return of an option is calculated across all options written on a stock. Second, time-series correlation between the average returns of options on a stock and the proportional bid-ask spread in the options market is calculated for each stock. Lastly, the average correlation across stocks and its significance is calculated and reported in Panel A of Table 5.2. These steps are repeated to report average across stocks of correlations between option returns and the options market illiquidity for each moneyness and maturity portfolio. The average correlations across stocks for each moneyness portfolio and maturity portfolio are presented separately in Panels B and C of Table 5.2. The purpose of reporting these correlations is to investigate if option portfolios based on option type (call or put), moneyness, and maturity provide any preliminary evidence of the sensitivity of option returns to market liquidity.

## Table 5.2 Correlations between Option Return and Market Illiquidity

Table shows the average correlations of option returns with the current and lagged proportional spreads in the options and stock markets. Panel A reports the average correlations across stocks. Panel B reports the average correlations across stocks for moneyness portfolios. Panel C reports the average correlations across stocks for maturity portfolios. For each stock, a time-series correlation between option returns and the market proportional spread is calculated. Then, the cross-sectional average across stocks in a portfolio is reported. Column 'Corr' gives the correlation coefficient. Column '+ve corr' indicates the number of stocks having positive correlation.

| Option | Moneyness /Maturity | Options market | | | | Stock Market | | | | Stocks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Current Illiquidity | | Lagged Illiquidity | | Current Illiquidity | | Lagged Illiquidity | | |
| | | Corr | +ve corr | Corr | +ve corr | Corr | +ve corr | Corr | +ve corr | |
| **Panel A:** | | | | | | | | | | |
| Call | | -0.198*** | 0 | 0.126*** | 58 | -0.017*** | 15 | -0.007* | 33 | 71 |
| Put | | -0.199*** | 0 | 0.165*** | 71 | -0.016*** | 10 | 0.009*** | 50 | 71 |
| **Panel B:** | | | | | | | | | | |
| Call | DITM | -0.092*** | 6 | 0.038*** | 50 | 0.046*** | 53 | 0.038*** | 60 | 71 |
| Call | ITM | -0.099*** | 2 | 0.039*** | 45 | 0.025*** | 45 | 0.016*** | 49 | 71 |
| Call | ATM | -0.195*** | 2 | 0.225*** | 68 | -0.009*** | 22 | -0.003 | 31 | 71 |
| Call | OTM | -0.180*** | 1 | 0.154*** | 65 | -0.001*** | 33 | 0.011*** | 44 | 71 |
| Call | DOTM | -0.153*** | 0 | 0.097*** | 55 | -0.018*** | 19 | -0.011*** | 29 | 71 |
| Put | DITM | -0.116*** | 0 | 0.056*** | 55 | -0.0002 | 29 | 0.012** | 40 | 71 |
| Put | ITM | -0.108*** | 1 | 0.077*** | 62 | -0.006 | 37 | 0.009 | 36 | 71 |
| Put | ATM | -0.206*** | 5 | 0.236*** | 71 | -0.013*** | 22 | 0.011*** | 44 | 71 |
| Put | OTM | -0.178*** | 2 | 0.187*** | 71 | -0.007** | 25 | 0.014*** | 52 | 71 |
| Put | DOTM | -0.167*** | 1 | 0.150*** | 71 | -0.020*** | 12 | 0.001 | 39 | 71 |
| **Panel C:** | | | | | | | | | | |
| Call | 15-30 | -0.152*** | 3 | -0.006 | 29 | -0.027*** | 26 | -0.050*** | 20 | 71 |
| Call | 31-60 | -0.162*** | 1 | 0.054*** | 50 | 0.001*** | 31 | 0.006 | 41 | 71 |
| Call | 61-91 | -0.213*** | 0 | 0.148*** | 60 | -0.025*** | 17 | 0.011** | 41 | 71 |
| Call | 92-182 | -0.202*** | 0 | 0.136*** | 60 | -0.014*** | 17 | -0.001 | 33 | 71 |
| Call | 183-365 | -0.105*** | 1 | 0.233*** | 66 | -0.009*** | 21 | 0.005 | 42 | 71 |
| Call | >365 | -0.146*** | 1 | 0.185*** | 21 | -0.022*** | 3 | -0.030*** | 2 | 22 |
| Put | 15-30 | -0.122*** | 8 | 0.041*** | 47 | 0.013* | 41 | 0.037*** | 52 | 71 |
| Put | 31-60 | -0.100*** | 11 | 0.061*** | 51 | -0.013** | 27 | -0.008 | 29 | 71 |
| Put | 61-91 | -0.204*** | 2 | 0.179*** | 68 | -0.016*** | 19 | 0.001 | 41 | 71 |
| Put | 92-182 | -0.216*** | 1 | 0.185*** | 71 | -0.011*** | 23 | 0.013*** | 51 | 71 |
| Put | 183-365 | -0.116*** | 1 | 0.279*** | 71 | -0.014*** | 24 | 0.006 | 43 | 71 |
| Put | >365 | -0.164*** | 0 | 0.221*** | 22 | -0.025*** | 3 | -0.024*** | 3 | 22 |

From Panel A, the average correlations between option returns and market illiquidity (current and lagged) are small but significant for calls and puts. As discussed in Section 5.3.1, options expected return decreases when unexpected illiquidity in the market increases. Accordingly, a negative correlation is expected given that option illiquidity is persistent. Table 5.2 shows negative correlations between option returns and unexpected illiquidity (the contemporaneous proportional bid-ask spread) in the options market for both calls and puts. It is also anticipated that the option expected return is higher when higher illiquidity in the market is expected. This is confirmed from the values reported in the table, where we observe a positive correlation between option returns and expected illiquidity (lagged proportional bid-ask spread) in the options market. Therefore, this is considered as preliminary evidence of the sensitivity of option return to expected and unexpected illiquidity in the options market. The average correlation of option returns and stock market illiquidity is much smaller than the average correlation of option returns with option market illiquidity. Also, the number of stocks showing positive correlation is higher for unexpected illiquidity in the stock market. The higher number of stocks showing positive correlation could be due to the hedging demand. When a stock is less liquid and there is a hedging demand for that stock, expected return of an option increases resulting in a positive correlation between option return and a stock liquidity. Moreover, call options show a negative and significant (at 10%) correlation with stock market lagged proportional spreads.

Panel B reports the average correlation across stocks when options are binned into five moneyness categories. The average correlation between option returns and current option market illiquidity is significantly negative, and the correlation between option returns and lagged option market illiquidity is significantly positive. Moreover, ATM options show higher negative correlation than ITM and OTM options. Since ATM options are more actively traded than OTM and ITM options (Chaudhury, 2010), they would be more sensitive to unexpected illiquidity in the market. The average correlation of option returns with current and lagged stock market illiquidity shows mixed signs and significance. Only two portfolios, DITM and ITM, of calls show positive and significant average correlations between option returns and illiquidity in the stock market. Only DITM and ITM put portfolios do not show any significant correlation between option returns and current stock market illiquidity. This might suggest that ITM call options are not sensitive to current illiquidity in the stock market. Since DITM and ITM options provide less leverage, require higher stock positions for hedging purposes, and are less sensitive to price movements in the underlying stock, the unexpected illiquidity in the stock market does not seem to matter. Option returns do not show significant correlations with lagged stock market illiquidity for all moneyness portfolios of calls and puts. This indicates that investors in the options market are more concerned with liquidity in the options market than with liquidity in the stock market.

Panel C reports the average correlations across stocks with options divided in six maturity bins. The average correlations of option return with the current and lagged options market illiquidity are significantly negative and positive, respectively. This is so across stocks in each moneyness bin except for stocks with calls that have maturity of 15-30 days, which show an insignificant negative correlation. The average correlation between option returns and current stock market illiquidity is significant across maturity portfolios of calls and puts. However, correlations with lagged stock market illiquidity have mixed sign and significance, and range from -0.05 to 0.011 across call portfolios, and -0.024 and 0.037 across put portfolios.

The average correlations of option returns with current and lagged options market illiquidity differ across moneyness. Accordingly, we run regressions for call and put portfolios separately. Moreover, the average correlations between option returns and proportional spreads in the market differ for moneyness and maturity portfolios (see Table 5.2 in Section 5.4.3). Therefore, we run regressions separately for calls and puts for each moneyness and maturity group.

**Correlations between Stock and Options Market Illiquidity**

Table 5.3 presents a time-series correlation matrix of the proportional bid-ask spread (illiquidity) for calls, puts, all options, and the stock market. One would expect high absolute values among calls, puts, and all options. We observe a high correlation between

**Table 5.3 Correlation Matrix of Illiquidity in Call, Put, All Options and Stock Markets**

Table 5.3 shows the time-series correlation matrix of proportional bid-ask spreads in calls, puts, all options and stock markets.

| Markets | All Option | Call | Put |
|---|---|---|---|
| **Call** | 0.712*** | 1 | |
| **Put** | 0.346*** | -0.412*** | 1 |
| **Stock** | 0.129*** | 0.303*** | -0.243*** |

calls and all options only. From the table these values are 0.712 for calls with all options, 0.346 for puts with all options and -0.412 for calls with puts. Moreover, the correlations between the stock market and options (calls, puts, and 'all options') are lower but significant. Illiquidity of put options has a lower (in magnitude) correlation with that of the stock market than call options. Low correlations in liquidity between options and the underlying stock market are desirable for mitigating multi-collinearity when analysing the impact of expected and unexpected illiquidity in the options and stock markets on option returns.

## 5.5 Empirical Results

In this section, we present the empirical results for the sensitivity of option returns to liquidity in the options and stock markets. In Section 5.5.1, we discuss the selection of the AR($p$) specification for liquidity in the call options market, put options market, all options market, and the stock market. In Section 5.5.2, we discuss the results of analysing the sensitivity of option returns to options market liquidity. In Section 5.5.3, we discuss the results of analysing the sensitivity of option returns to stock market liquidity. Section 5.5.4 reports the results of analysing the sensitivity of option returns to stock and options market liquidity. In Section 5.5.5, we discuss the results of the fixed-effects model for option returns to option and stock market illiquidity.

### 5.5.1 Persistence of Illiquidity

To test the hypotheses of the sensitivity of option returns to the expected and unexpected illiquidity in the options and stock markets, it is essential to estimate expected and unexpected illiquidity in these markets. Expected and unexpected illiquidity are estimated by the AR($p$) specification assumed to capture the persistence in the dynamics of the proportional bid-ask spread (illiquidity). This spread for calls, puts, and all options is highly persistent with a first order autocorrelation of 0.893, 0.847 and 0.841, respectively. However, it is less persistent in the stock market with a first order autocorrelation coefficient of 0.736. Amihud (2002) reports a first order autocorrelation of 0.768 in illiquidity (using $\ln ILLIQ$ measure) in the NYSE stock market during the period from 1964 to 1997. Accordingly, the first order autocorrelation coefficient for the proportional bid-ask spread in the FTSE 100 stocks during the period from 22 February 2008 to 31 December 2010 is similar to the persistence in the ILLIQ measure reported by Amihud (2002) for the NYSE stock market. Rather than assuming an AR(1) specification for illiquidity in the option and stock markets, an appropriate autoregressive lag structure is checked.

### Table 5.4 AR(*p*) lag-structure Selection of Market Illiquidity

This table reports the AR(*p*) specifications of proportional spread and log proportional spread of all options, call options, put options and the stock market.

| Variable | | *Proportional bid-ask spread* | | | | *ln(proportional bid-ask spread)* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Calls** | **Puts** | **All** | **Stock** | **Calls** | **Puts** | **All** | **Stock** |
| AR(1) | Lag 1 | 0.89*** | 0.85*** | 0.84*** | 0.74*** | 0.91*** | 0.85*** | 0.85*** | 0.89*** |
| | AIC | 2266 | 2097 | 1973 | -1678 | -1210 | -1235 | -1352 | -265.8 |
| | BIC | 2274 | 2105 | 1982 | -1669 | -1202 | -1226 | -1343 | -257.1 |
| | Obs | 539 | 539 | 539 | 596 | 539 | 539 | 539 | 596 |
| AR(2) | Lag 1 | 0.62*** | 0.63*** | 0.48*** | 0.39*** | 0.64*** | 0.67*** | 0.49*** | 0.46*** |
| | Lag 2 | 0.30*** | 0.25*** | 0.43*** | 0.52*** | 0.29*** | 0.22*** | 0.40*** | 0.49*** |
| | AIC | 1664 | 1544 | 1442 | -1166 | -874.3 | -886.7 | -985.6 | -214.9 |
| | BIC | 1676 | 1556 | 1454 | -1154 | -862.3 | -874.8 | -973.7 | -202.6 |
| | Obs | 393 | 393 | 393 | 439 | 393 | 393 | 393 | 439 |
| AR(3) | Lag 1 | 0.57*** | 0.59*** | 0.33*** | 0.157 | 0.61*** | 0.64*** | 0.38*** | 0.286 |
| | Lag 2 | 0.35*** | -0.0717 | 0.26*** | 0.32** | 0.29*** | -0.0858 | 0.25*** | 0.37*** |
| | Lag 3 | 0.0164 | 0.38*** | 0.31*** | 0.45*** | 0.0429 | 0.35*** | 0.27*** | 0.31*** |
| | AIC | 1094 | 1009 | 960.2 | -678.9 | -522.2 | -550.2 | -580.7 | -101.1 |
| | BIC | 1108 | 1023 | 974.3 | -664.3 | -536.3 | -536.0 | -594.8 | -86.47 |
| | Obs | 251 | 251 | 251 | 286 | 251 | 251 | 251 | 286 |

Table 5.4 reports coefficient estimates, Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC) and the number of observations for AR(1), AR(2) and AR(3) specifications for the proportional bid-ask spread for calls, puts, all options, and the stock market.

Only specifications with up to three lags are reported since higher order specifications show one or more lagged coefficients to be insignificant. The AIC and BIC criteria suggest optimal lags at which the estimated values of these criteria are lowest. We also consider the significance of the AR(*p*) coefficients, when deciding on the lag-structure. For the proportional bid-ask spread measure of illiquidity, call, put and all options markets have lowest AIC and BIC for the AR(3) specification. However, for calls and puts, one of the three lagged-coefficients in insignificant. For the stock market liquidity, although the AR(3) specification has the lowest AIC and BIC values, we use the AR(1) specification since the the first lag coefficient in the AR(3) specification turns negative. Therefore, we choose the AR(2) specification for calls, puts, and all options markets, and the AR(1) specification for the stock market. Therefore, we choose AR(1) specification for the stock market for the proportional bid-ask spread measure of illiquidity. Similarly, when illiquidity is measured by the natural logarithm of the proportional bid-ask spread, calls, puts, and all options follow an AR(2), and the stock market follows an AR(1).

**Table 5.5 Kendal Bias Corrected (KBC) Autoregressive Coefficients (AR(p))**

This table reports the estimated and the Kendal (1954) bias-corrected (KBC) coefficients from the autoregressive models (AR(p)) for the proportional bid-ask spread and the log proportional bid-ask spread measures of illiquidity in the markets.

| | Market | Model | Lag 1 | Lag 2 | Constant | Obs |
|---|---|---|---|---|---|---|
| *Panel A: Proportional Bid-Ask Spread* | | | | | | |
| Coefficient | Calls | AR(2) | 0.619*** | 0.298*** | 1.972*** | 393 |
| KBC Coefficient | | | 0.626 | 0.303 | 1.990 | |
| Coefficient | Puts | AR(2) | 0.632*** | 0.249*** | 2.809*** | 393 |
| KBC Coefficient | | | 0.639 | 0.253 | 2.833 | |
| Coefficient | All Options | AR(2) | 0.467*** | 0.429*** | 2.375*** | 393 |
| KBC Coefficient | | | 0.473 | 0.435 | 2.396 | |
| Coefficient | Stock | AR(1) | 0.736*** | | 0.0345*** | 596 |
| KBC Coefficient | | | 0.741 | | 0.036 | |
| *Panel B: ln Proportional Bid-Ask Spread* | | | | | | |
| Coefficient | Calls | AR(2) | 0.637*** | 0.288*** | 0.235*** | 393 |
| KBC Coefficient | | | 0.644 | 0.293 | 0.239 | |
| Coefficient | Puts | AR(2) | 0.668*** | 0.218*** | 0.359*** | 393 |
| KBC Coefficient | | | 0.676 | 0.222 | 0.364 | |
| Coefficient | All Options | AR(2) | 0.492*** | 0.404*** | 0.322*** | 393 |
| KBC Coefficient | | | 0.498 | 0.410 | 0.327 | |
| Coefficient | Stock | AR(1) | 0.887*** | | -0.237*** | 596 |
| KBC Coefficient | | | 0.893 | | -0.229 | |

**Table 5.6 Summary Statistics of Expected and Unexpected Illiquidity**

This table reports the mean and standard deviation (SD) of expected and unexpected illiquidity in calls, puts, all options and stocks. Expected and unexpected illiquidity values are in terms of the proportional bid-ask spread.

| Market | Expected Illiquidity | | Unexpected Illiquidity | |
|---|---|---|---|---|
| | Mean | SD | M | SD |
| All Options | 22.533 | 1.56 | -0.286 | 1.26 |
| Call Options | 22.334 | 3.58 | -0.283 | 1.86 |
| Put Options | 22.742 | 2.58 | -0.288 | 1.55 |
| Stock Market | 0.1226 | 0.039 | -0.0026 | 0.017 |

Amihud (2002) suggests that AR coefficient estimates are biased downwards when estimated from finite samples. He suggests the correction proposed by Kendall (1954).

This correction increases the estimated coefficient by the term $\frac{(1+3\,\widehat{c_p})}{T}$, where $\widehat{c_p}$ is the AR($p$) coefficient and $T$ is the total number of observations in the sample. Applying the same correction to the estimated coefficients from the AR($p$), the actual and adjusted coefficients are presented in Table 5.5.

The residuals of the AR($p$) specification for each market represent unexpected illiquidity in that market. The residuals of the AR($p$) specifications following Kendall's correction (given in Table 5.5) are plotted in Figure 5.2a and Figure 5.2b. During the period from early October 2008 to 19 December 2008, markets experienced higher volatility in illiquidity (see also Figure 5.1). These Kendall's corrected coefficients are used to calculate the expected and unexpected illiquidity of the options and stock markets.

After measuring expected and unexpected illiquidity in the respective markets, the time-series regressions in Equations (5.11) and (5.13) are estimated for each portfolio of calls, puts, and all options. The results are reported in the next two subsections.

**Figure 5.2a Unexpected Illiquidity (Proportional Bid-Ask Spread)**

This figure shows the residuals from the AR(p) specification after correcting for Kendal's (1954) term for the proportional bid-ask spread in the options markets.

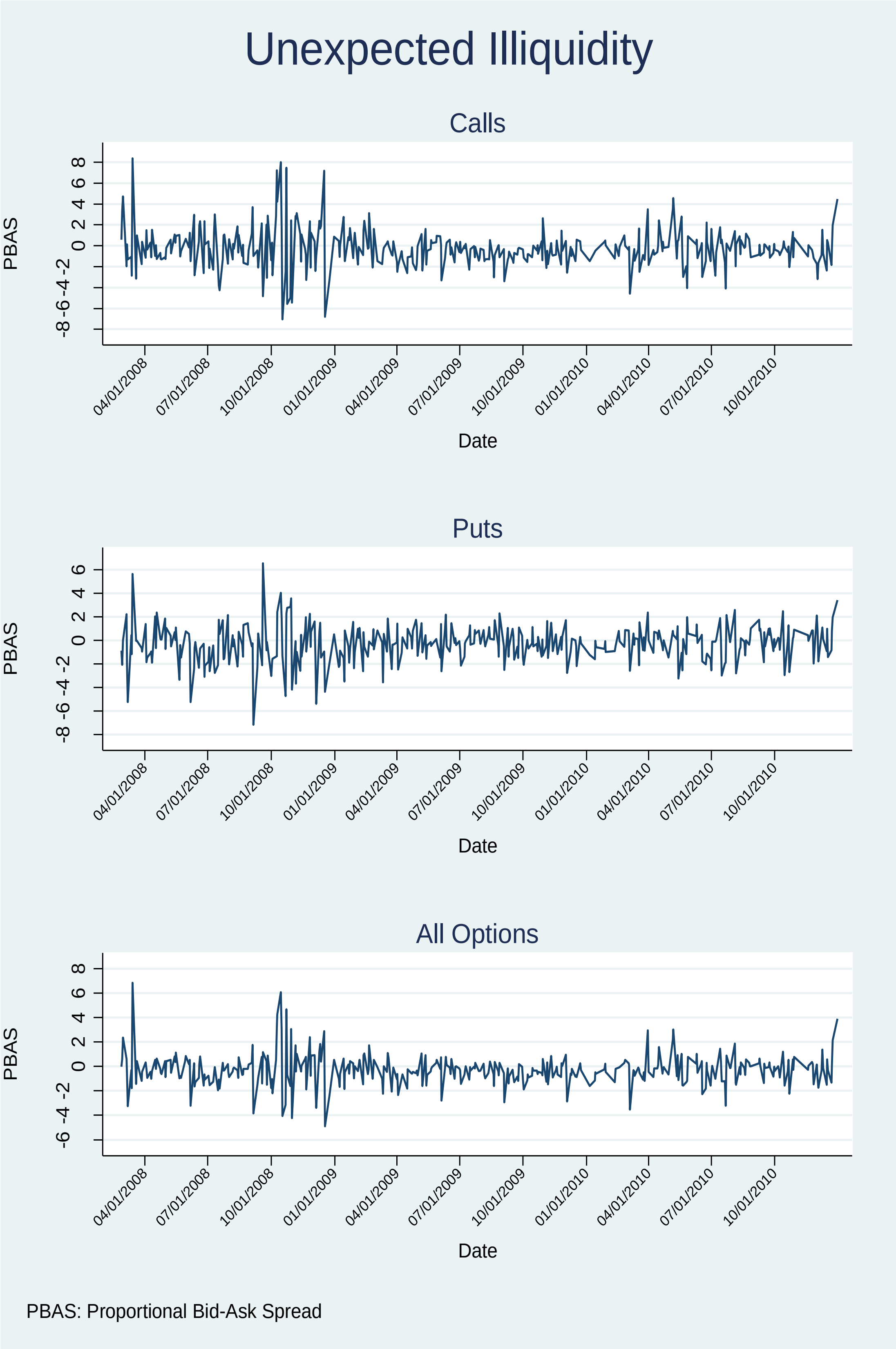
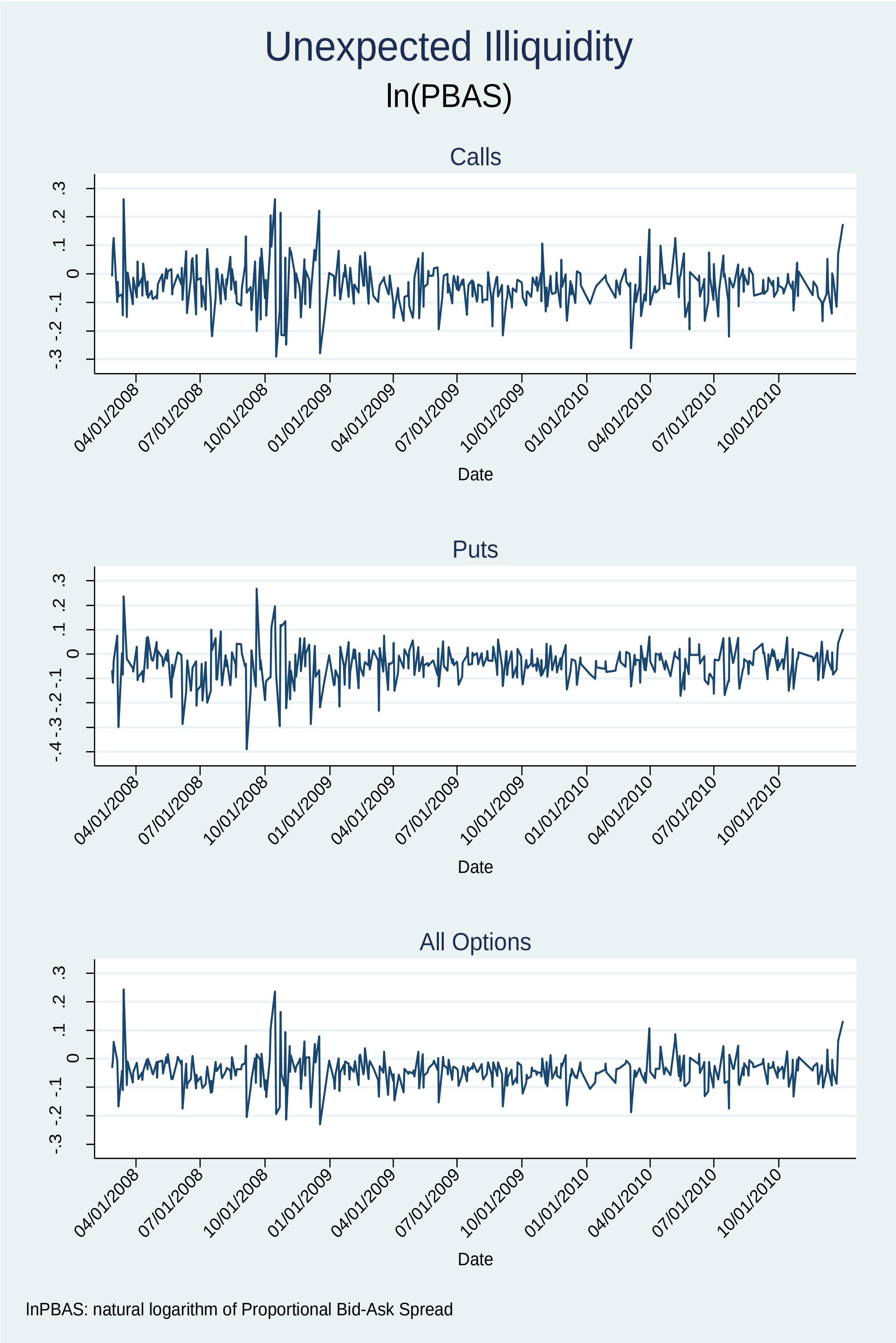


**Figure 5.2b Unexpected Illiquidity (Natural log Proportional Bid-Ask Spread)**

This figure shows the residuals from the AR(p) specification after correcting for Kendal's term (1954) for the natural log of proportional bid-ask spread in the options markets.



### 5.5.2 Sensitivity of Option Return to Options Market Illiquidity

We first estimate Equation (5.11) and name it Model (1). Second, we control for volatility using the average log implied volatility, $ln(iv)_{om,t}$, re-estimate the regression and name it Model (2). The results of Models (1) and (2) are reported in Tables B1, B2 and B3 for calls, puts, and all options, respectively. The regression models with and without the volatility control variable are as follows.

Model (1):

$$OR_{jt} - Rf_t = g_o + g_1(RSM_t - Rf_t) + g_2\, eliq_{om,t} + g_3\, ueliq_{om,t} + w_t \quad (5.14)$$

Model (2):

$$OR_{jt} - Rf_t = g'_o + g'_1(RSM_t - Rf_t) + g'_2\, eliq_{om,t} + g'_3\, ueliq_{om,t} + g'_4 \ln(iv)_{om,t} + w'_t \quad (5.15)$$

The coefficients on the stock market excess return $(RSM_t - Rf_t)$, expected illiquidity in the options market ( $eliq_{om,t}$), and unexpected illiquidity in the options market ($ueliq_{om,t}$) are interpreted as the option beta, the sensitivity of option returns to expected illiquidity in the options market, and the sensitivity of option returns to unexpected illiquidity in the options market.

The coefficients of expected and unexpected illiquidity for calls and puts as estimated in Equation (5.14) are summarized in Table 5.7 given below. These are discussed next.

**Table 5.7 Summarized Results of Option Return Sensitivity to Expected and Unexpected Illiquidity in the Options Market**

This table reports the results of the empirical model presented in Equation (5.14) for call and put option moneyness and maturity portfolios. $eliq_{om}$ is expected illiquidity and unexpected illiquidity ($ueliq_{om}$) is unexpected illiquidity in the stock. $ueliq_{om}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | Call Options | | Put Options | |
|---|---|---|---|---|---|
| | | $eliq_{om}$ | $ueliq_{om}$ | $eliq_{om}$ | $ueliq_{om}$ |
| DITM | 1 | 0.388** | -0.670*** | -0.301 | -1.408*** |
| ITM | 1 | 0.282** | -1.199*** | 0.0818 | -0.796 |
| ATM | 1 | 0.380** | -1.945*** | -0.0297 | -1.583*** |
| OTM | 1 | 0.397 | -1.712*** | -0.244 | -1.700** |
| DOTM | 1 | 0.18 | -1.086 | 0.318 | -0.757 |
| DITM | 2 | 0.281*** | -0.436** | 0.105 | -0.638*** |
| ITM | 2 | 0.327*** | -0.762*** | 0.14 | -1.069*** |
| ATM | 2 | 0.306** | -1.177*** | 0.0686 | -1.542*** |
| OTM | 2 | 0.520*** | -1.297*** | -0.0323 | -2.032*** |
| DOTM | 2 | 0.353 | -1.243*** | 0.254 | -1.821*** |
| DITM | 3 | 0.238** | -0.447*** | -0.0214 | -0.515** |
| ITM | 3 | 0.232** | -0.674*** | 0.00629 | -0.751*** |
| ATM | 3 | 0.208* | -0.766*** | 0.00357 | -0.867*** |
| OTM | 3 | 0.217 | -0.837*** | 0.0552 | -1.080*** |
| DOTM | 3 | -0.00902 | -0.673* | -0.0344 | -0.972*** |
| DITM | 4 | 0.247*** | -0.377*** | -0.0216 | -0.348*** |
| ITM | 4 | 0.193*** | -0.547*** | -0.0192 | -0.559*** |
| ATM | 4 | 0.148* | -0.721*** | -0.0204 | -0.669*** |
| OTM | 4 | 0.180* | -0.756*** | -0.0138 | -0.851*** |
| DOTM | 4 | 0.113 | -0.762*** | -0.0195 | -0.780*** |
| DITM | 5 | 0.218*** | -0.272** | -0.0158 | -0.348*** |
| ITM | 5 | 0.308** | -0.466*** | -0.054 | -0.369*** |
| ATM | 5 | 0.186*** | -0.553*** | -0.0472 | -0.368*** |
| OTM | 5 | 0.158* | -0.578*** | -0.0181 | -0.497*** |
| DOTM | 5 | 0.0972 | -0.637*** | 0.00107 | -0.377 |
| DITM | 6 | 0.211*** | -0.239** | -0.0182 | -0.433** |
| ITM | 6 | 0.173*** | -0.578*** | -0.071 | -0.310*** |
| ATM | 6 | 0.229*** | -0.521** | -0.00605 | -0.318** |
| OTM | 6 | 0.114** | -0.542*** | -0.0377 | -0.564*** |
| DOTM | 6 | 0.0713 | -0.48 | 0.0719 | -0.522*** |

**Call Options: Model (1)**

Table B1 in the Appendix reports the results of estimating Model (1) for moneyness and maturity portfolios of call options.

The coefficient on the stock market excess return is positive and significant across all moneyness and maturity portfolios. When stock prices increase, call option prices increase and, hence, the observed positive relationship between stock market excess returns and call option excess returns is as expected. Table B1 also shows that the coefficient on the stock market excess return (option beta) in general increases with decreases in the moneyness of an option. This effect can be explained by the call option elasticity. Elasticity of an OTM call option is higher than ATM or ITM call option on the same underlying stock.

Call option elasticity is defined as: $\Omega = \frac{S\Delta}{C}$,

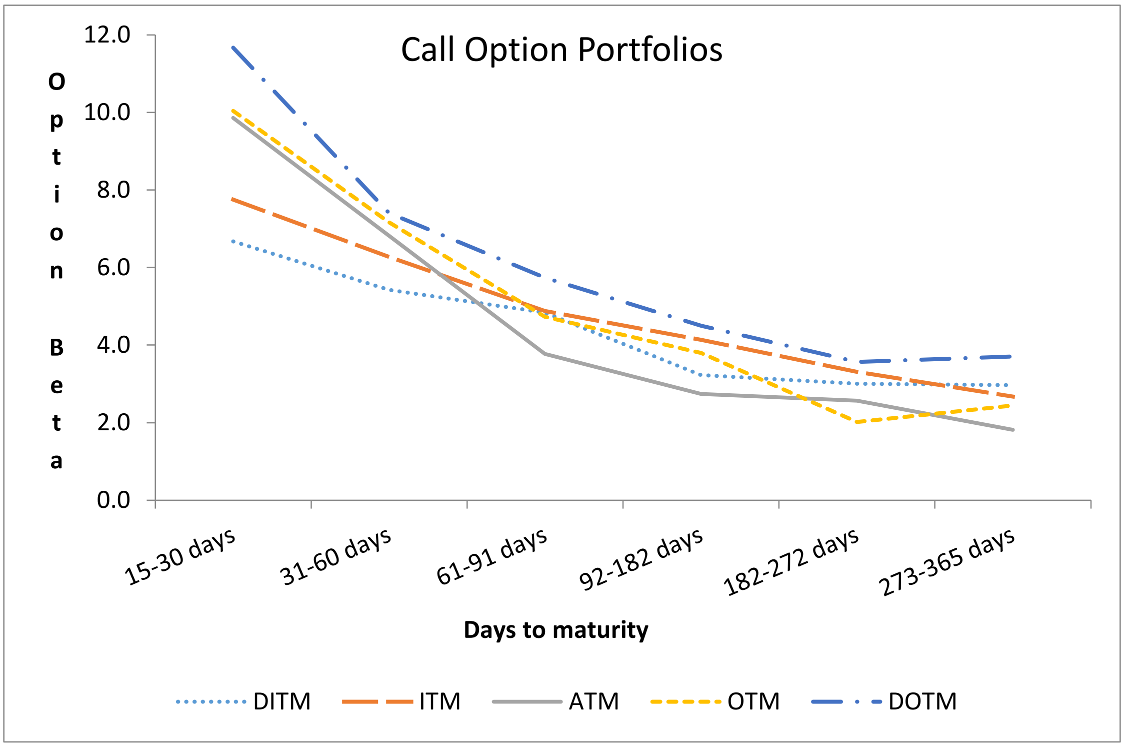
where, $S$ is the price of a stock, $\Delta$ is the delta of a call option, and $C$ is the price of a call option.

Out-the-money call options are more sensitive to changes in the underlying stock price since they carry more leverage. Therefore, option beta is larger for out-the-money compared to in-the-money call options. We observe this general effect in the moneyness bins of all maturity categories. Further, the effect of stock return is higher for options with shorter maturity than options with the longer maturity. This is also shown in Figure 5.3. Options close to maturity are more sensitive to changes in the underlying stock price than options that are further away from maturity.

The coefficient of expected illiquidity in the options market is positive across all portfolios and is significant for most portfolios. DITM, ITM and ATM portfolios show significance across all maturity categories. However, DOTM options show insignificance throughout. OTM options show significance only for options with up to one month to maturity. This suggests that ex-ante expected illiquidity in calls affects expected option returns. Although a striking pattern is not observed, the results show that the sensitivity of option returns to expected illiquidity in the options market generally decreases with the maturity for DITM, ATM and OTM calls.

**Figure 5.3 Call Option Betas across Moneyness and Maturity Portfolios**

This figure shows the option beta for call option portfolios, which is the coefficient on the stock market excess return, as reported under Model (1) in Table B1.




Amihud (2002) reports that the coefficient of lag illiquidity in the stock market is positive and significant for NYSE stocks. The finding that the effect of expected illiquidity on option returns is lower for options with long maturity than short maturity suggests that traders consider expected illiquidity to be important for short maturity options than long maturity options, and in times of illiquid option markets such options could act as insurance for the holders of these options.

The second hypothesis H2 in Section 5.3.1 implies that unexpected illiquidity in the options market has a negative impact on contemporaneous option excess returns. The results show that, except for two portfolios that are DOTM with the shortest maturity (15-30 days) and longest maturity (365 and above), all call portfolios show significant negative sensitivity to unexpected illiquidity in the options market. Thus, calls are sensitive to shocks in illiquidity in the call options market. Since investors do not like unexpected illiquidity in the market, they will pay lower option prices when faced with unexpected illiquidity. This is consistent with the findings of Amihud (2002) and Acharya and Pedersen (2005) that illiquidity shocks in the market depress stock prices. The absolute coefficient of unexpected illiquidity in the options market generally decreases in moneyness and maturity. OTM options are more sensitive to unexpected illiquidity. Moreover, the coefficient of expected illiquidity is generally smaller than the coefficient of unexpected illiquidity when comparing absolute values. This implies that an investor dislikes unexpected illiquidity in the options market more than expected illiquidity and, therefore, the impact of unexpected illiquidity is larger.

The coefficients of expected and unexpected illiquidity in the options market for ATM options with maturity of 31-60 days are 0.208 and -0.766, respectively. When expected illiquidity in calls increases by one standard deviation (i.e., 3.58, see Table 5.7), ATM option return increases by 0.745 per cent, ceteris paribus. One standard deviation in unexpected illiquidity in calls (1.86, see Table 5.6) leads to 1.424 per cent decrease in expected ATM call option excess return. This suggests that unexpected illiquidity in the market has a dominating effect on option returns.

In general, the results indicate that return on a call option is more sensitive to unexpected illiquidity than to expected illiquidity in the call options market. The sensitivity to unexpected illiquidity increases in the moneyness and maturity. However, sensitivity of a call option to expected illiquidity does not depend on the moneyness for similar maturity options, and decreases for long maturity options.

**Call Options: Model (2)**

Bakshi et al. (2003) suggest that options are expensive since options provide insurance for uncertainty in the market. Therefore, investors pay a volatility risk premium when buying options. Model (2) controls for volatility by adding the natural log of average implied volatility across options in the options market. The estimation results are reported under Model (2) in Table B1.

After controlling for implied volatility of an option, we find similar results as in the previous specification. However, we observe that the coefficient on expected illiquidity in the call market decreases in magnitude and significance compared to the estimated coefficients in Model (1), but the coefficient of unexpected illiquidity remains similar in magnitude and significance. The log implied volatility is positive and significant for mainly DITM option portfolios.

**Put Options: Model (1)**

Table B2 reports the estimation results of Model (1) for moneyness and maturity put portfolios.

As discussed in Section 5.3.1, the effect of the stock market excess return on call option excess return is expected to be positive, because call premia increase when underlying stock prices increase. In contrast, the value of a put option increases with a decrease in the underlying stock price. Thus, the relationship of stock market excess return with put option excess return is expected to be negative. The results reported in Table B2 for puts are consistent, and show that the coefficient of stock market excess return is negative and significant for all put portfolios. This coefficient is interpreted as the option beta. The negative sign is explained by the elasticity of a put option( $\Omega_p$), given below:

$$(\Omega_{\mathrm{p}}) = \frac{S\Delta_p}{P}$$

where $S$ is the price of a stock, $\Delta_p$ is the delta of a put option (which is negative) and $P$ is the value of a put option. Since the delta of a put option is negative, $\Omega_{\mathrm{p}}$ is negative and beta is also negative.

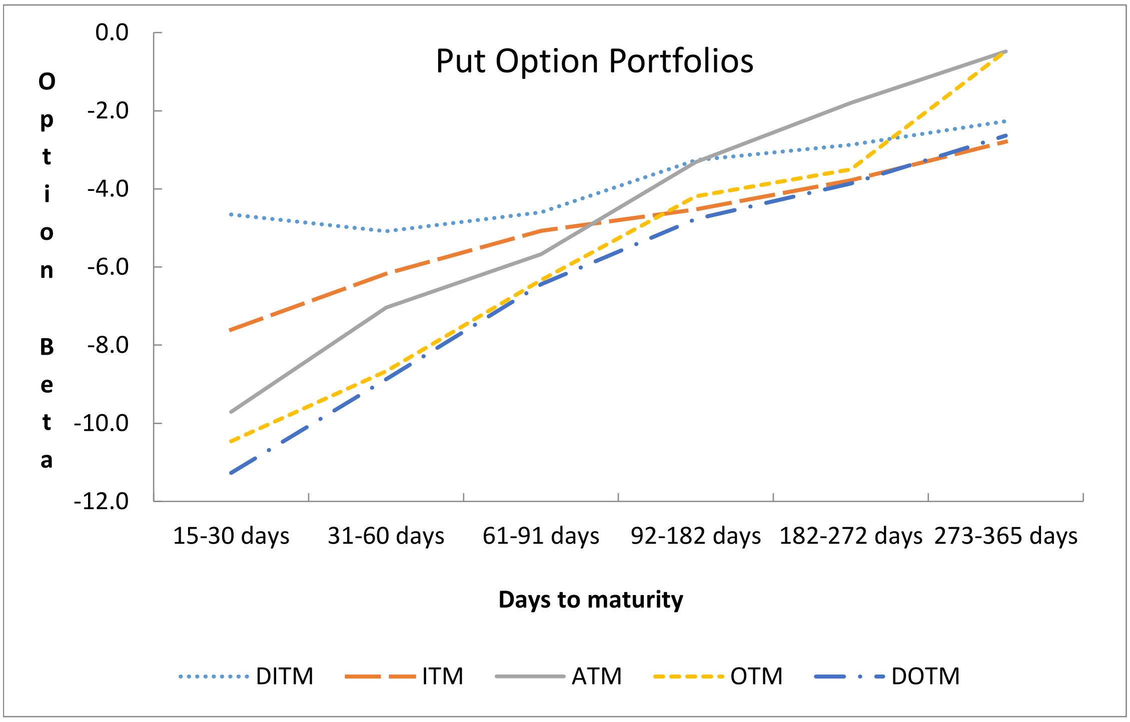
The put option beta is plotted in Figure 5.4. It generally increases in absolute terms with decreases in moneyness. This effect conforms to the leverage argument that investment in out-the-money options is low, and these options provide high return when the market moves. Moreover, the short maturity options are more sensitive to excess returns in the stock market compared to long maturity options. With regard to the coefficient on the option market expected illiquidity, put option portfolio's expected return does not seem sensitive to expected illiquidity in the options market, as suggested by the non-significant coefficient. It seems that the first hypothesis of a positive relation between expected option excess return and expected illiquidity in the options market does not hold for puts.

In contrast, the second hypothesis H2 in Section 5.3.1 holds well for put options. Put option returns seem to be sensitive to unexpected illiquidity in the options market, as the relevant coefficient is significant for all put portfolios. The exceptions are the DOTM portfolios with maturities of 15-30 days and of 183-365 days. When controlling for the log implied volatility of the put options, only one portfolio, DOTM with maturity between

15 and 30 days, remains insignificant and all other portfolios show a significant effect of unexpected illiquidity in the put options market on option excess returns.

**Figure 5.4 Put Option Betas across Moneyness and Maturity Portfolios**

This figure shows the option beta of put option portfolios, which is the coefficient of stock market excess return, as reported under Model (1) in Table B2.




Unlike calls, puts do not show a striking pattern across moneyness in this relationship. However, this sensitivity of put option excess returns to unexpected illiquidity in the option market is generally decreasing (in absolute terms) in maturity, i.e., the higher the maturity, the higher the sensitivity. ATM puts show a clear decreasing pattern (in absolute terms) across maturity.

To quantify the impact of expected illiquidity in the options market, appropriate calculations for ATM options with maturity of 31-60 days are reported. The coefficient on unexpected illiquidity is -0.867. One standard deviation increase in unexpected illiquidity in puts (i.e., 1.55, see Table 5.6) would imply a decrease in expected option excess return by 1.344 per cent, ceteris paribus. Due to a small standard deviation in illiquidity in puts, the effect of unexpected illiquidity on option returns is small when compared to the call options market. The only significant effect on put option excess return is that of unexpected illiquidity (illiquidity shocks) in the options market.

**Put Options: Model (2)**

Table B2 also reports the estimation results of Model (2) that controls for option implied volatility. When the log implied volatility of put options is controlled for, the coefficients of stock market excess return, expected illiquidity, and unexpected illiquidity have similar signs, magnitude, and significance as reported in Model (1). The coefficient of the log implied volatility is generally insignificant for most put portfolios. Similar to calls, puts show high sensitivity to unexpected illiquidity in the options market. It is interesting to note that even after controlling for the log implied volatility of the put options, the effect of expected illiquidity on the option returns is still not significant. This implies that when pricing an option, a put option buyer is not concerned about expected illiquidity, but focuses on unexpected illiquidity in the options market. Moreover, in downmarkets, illiquidity is generally high and puts would provide positive returns to the option holder. Therefore, if the markets are expected to decline, it is unexpected illiquidity that would matter for put option returns.

**All Options**

The regression in Equation (5.11) is re-estimated when options market illiquidity is measured using an average of the proportional bid-ask spread of all options across stocks. In the previous sections, illiquidity in the options market was based on either calls or puts separately.

The average illiquidity in the options market (average across calls and puts) follows an AR(2) process (see Section 4.5.1, Table 5.5). Expected illiquidity in the options market is now the predicted value of this AR(2) process, and unexpected illiquidity is the residual. The estimation results of Models (1) and (2) for calls and puts are reported in Table B3 in the Appendix for all moneyness and maturity portfolios.

As reported in Table 5.2 in Section 5.3.3, illiquidity in calls is negatively correlated with illiquidity in puts. Illiquidity in the all options market is correlated more with illiquidity in calls than with illiquidity in puts. Illiquidity in call and put options has correlations of 0.712 and 0.346, respectively, with the all options market. The correlation between all options and puts is less than half that with calls. When the market liquidity is measured by the average of all options instead of the average of either calls or puts, the sensitivity of option returns to the options market liquidity might be different.

The results presented in Table B3 relate to the measurement of liquidity in the 'all options market' by the liquidity of all options. The results show that the coefficient on stock market excess return is significant and has the expected positive sign across all portfolios. The coefficients of expected and unexpected illiquidity in the 'all options market' are mostly insignificant. Most long-maturity call portfolios show significant coefficients on expected illiquidity in the options market. For puts, only one portfolio shows a significant coefficient of expected illiquidity and none shows a significant coefficient for unexpected illiquidity.

Since illiquidity in puts and calls has a negative correlation (see Table 5.3), the impact of illiquidity on option returns is insignificant when illiquidity is measured as the average across all options in the options market. However, as was reported in Table B1, when illiquidity is measured by the average across the same type of option (e.g., for calls: the average across calls in the market), call option return sensitivity to both expected and unexpected illiquidity is significant.

### 5.5.3 Sensitivity of Option Return to Stock Market Illiquidity

In this section, we present the results of the sensitivity of option returns to stock market illiquidity. The equations that are estimated are versions of Equation 5.13:

Model 1:

$$OR_{jt} - Rf_t = h_o + h_1(RSM_t - Rf_t) + h_2\ eliq_{sm,t} + h_3\ ueliq_{sm,t} + \xi_t \tag{5.16}$$

Model 2:

$$OR_{jt} - Rf_t = h'_o + h'_1(RSM_t - Rf_t) + h'_2\ SSprop^E_{m,t} + h'_3\ SSprop^U_{m,t} + h'_4 \ln(iv)_{om,t} + \xi'_t \tag{5.17}$$

As discussed in Section 5.4.3, the correlations between option return and stock market illiquidity across moneyness and maturity portfolios (see Table 5.1) were mostly negative and significant. As discussed in the literature review (Chapter 2), Feng et al. (2013) theoretically develop an option pricing model in the presence of stochastic liquidity risk. They suggest that when replicating an option, a trader affects the price of the underlying stock. The price moves against the trader thereby increasing the liquidity cost. They incorporate the impact of liquidity risk on stock prices using a liquidity discount factor.

This factor incorporates liquidity in the underlying stock market and the sensitivity of the stock price to stock market liquidity. Their model suggests that the sign of the stock market liquidity variable depends on whether there is short or excess supply in the market. In the case of excess supply, the impact of illiquidity in the stock market on stock prices will be negative. Therefore, lower stock prices would also imply lower call option prices.

Due to persistence in illiquidity in the stock market, two implications for option returns have been discussed in Sections 5.2 and 5.3.2. The two hypotheses formulated to investigate the time-series impact of illiquidity in the stock market on option expected returns are: expected illiquidity in the stock market positively affects option returns (H3), and unexpected illiquidity in the stock market negatively affects option returns (H4). However, based on the argument of Feng et al. (2013), the sign of the coefficient on illiquidity in the stock market may depend on the short or excess supply in the underlying stock market.

The estimation results of Equations 5.16 and 5.17 are reported in Table B4 and Table B5 for calls and puts, respectively. Also the coefficients of expected and unexpected illiquidity for calls and puts are summarized in Table 5.8 given below. These are discussed next.

**Table 5.8 Summarized Results of Option Return Sensitivity to Expected and Unexpected Illiquidity in the Stock Market**

This table reports the results of the empirical model presented in Equation (5.16) for call and put option moneyness and maturity portfolios. $eliq_{sm}$ is expected illiquidity and unexpected illiquidity ($ueliq_{sm}$) is unexpected illiquidity in the stock. $ueliq_{sm}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient and *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | Call Options | | Put Options | |
|---|---|---|---|---|---|
| | | $eliq_{sm}$ | $ueliq_{sm}$ | $eliq_{sm}$ | $ueliq_{sm}$ |
| DITM | 1 | 20.89 | 53.51** | 18.66 | -28.89 |
| ITM | 1 | 8.064 | 24.39 | -10.02 | -23.33 |
| ATM | 1 | 18.74 | 49.49* | -1.701 | -43.81 |
| OTM | 1 | 42.12* | 70.29* | 21.89 | -54.49 |
| DOTM | 1 | -19.17 | 88.03 | 0.842 | -79.85* |
| DITM | 2 | 15.94** | 21.36* | 5.967 | 0.367 |
| ITM | 2 | 11.11 | 22.52 | -7.34 | 5.57 |
| ATM | 2 | 11.37 | 23.23 | -5.697 | -2.401 |
| OTM | 2 | 28.60** | 29.17 | -0.257 | -12.85 |
| DOTM | 2 | -0.123 | 45.23 | -6.478 | -16.27 |
| DITM | 3 | 18.15*** | 17.39 | 15.68** | 6.86 |
| ITM | 3 | 13.70* | 12.78 | -1.465 | -15.77 |
| ATM | 3 | 6.051 | 27.27* | 1.594 | -9.077 |
| OTM | 3 | 13.27 | 37.27** | -0.815 | 2.943 |
| DOTM | 3 | -7.59 | 31.16 | -1.957 | -5.676 |
| DITM | 4 | 20.24*** | 13.43* | 4.901 | 0.474 |
| ITM | 4 | 11.66** | 15.31* | -1.066 | -4.966 |
| ATM | 4 | 6.888 | 18.39* | -0.693 | -6.158 |
| OTM | 4 | 8.687 | 24.36** | -0.954 | -2.13 |
| DOTM | 4 | -1.465 | 26.74* | -4.117 | 3.265 |
| DITM | 5 | 20.79*** | 11.20* | 6.512** | 0.882 |
| ITM | 5 | 18.13*** | 19.98* | 2.692 | -1.443 |
| ATM | 5 | 8.215* | 17.11** | 1.272 | 0.847 |
| OTM | 5 | -0.115 | 22.37** | -4.661 | 3.551 |
| DOTM | 5 | -7.628 | 20.00* | -4.64 | 4.974 |
| DITM | 6 | 17.44*** | 15.85** | 9.834** | 2.52 |
| ITM | 6 | 4.435 | 24.02*** | 1.992 | -1.522 |
| ATM | 6 | 6.124 | 21.37 | 4.172 | -3.845 |
| OTM | 6 | 4.144 | 19.79** | 2.659 | -3.448 |
| DOTM | 6 | -13.88 | 23 | -10.35** | -9.647 |

**Calls**

Table B4 in the Appendix reports the results for moneyness and maturity portfolios of calls. The sign, significance, and pattern across moneyness and maturity of option beta are consistent with the results discussed in Section 5.5.2. The coefficient on expected illiquidity in the stock market shows mixed signs across portfolios, but only for the cases where the coefficient estimate is insignificant. Only eleven portfolios show a significant and positive effect of expected illiquidity in the stock market on option returns. Except for 15-30 day maturity DITM, all other DITM portfolios show significant option return sensitivity to expected illiquidity in the stock market. When log implied volatility is controlled for, all moneyness portfolios with maturity of 15-30 days have a significant and positive coefficient on log volatility, but insignificant coefficient on expected illiquidity in the stock market. This is an interesting result and suggests that traders are more concerned about the volatility of short-term options rather than illiquidity in the underlying stock market. Moreover, it seems that only DITM options with maturities greater than 30 days are sensitive to expected illiquidity in the stock market and it could be because deep-in-the-money call options act like stocks.

However, the sensitivity of option returns to unexpected illiquidity in the stock market is positive for all portfolios. Portfolios with a maturity of 60 days or more show significant sensitivity to unexpected illiquidity in the stock market. Based on the argument of persistence in illiquidity, the coefficient of unexpected illiquidity should be negative but is found to be positive. Following the argument of Feng et al. (2013) that the impact of illiquidity in the market on stock prices depends on the excess supply or short supply, the positive coefficient of unexpected illiquidity suggests that the market during the sample period is in short supply and, therefore, traders require a higher return for an illiquidity shock.

**Puts**

Table B5 in the Appendix reports the results for moneyness and maturity portfolios of puts. The coefficient of stock market excess return, i.e., the option beta, has expected negative sign, significance and patterns across all moneyness and maturity portfolios, consistent with the results in Section 5.5.2.

The coefficient of expected illiquidity in the stock market has mixed signs across put portfolios. Only three DITM with maturity of 61-92 days, 183-365 days and above

365days (e.g., Mon 1 and Mat 3 identify a portfolio of options that are DITM with maturity of 61-92 days) are positive and significant. Moreover, only one DOTM with maturity above 365 days has a negative and significant coefficient of expected illiquidity in the stock market. When log implied volatility of puts is controlled for, most of the significant portfolios no longer have significant coefficients on expected illiquidity in the stock market. Moreover, the coefficient of unexpected illiquidity in the stock market is not significant across all portfolios of puts, regardless of whether or not log volatility is controlled for.

Thus, hypotheses H3 and H4 do not hold in general for put portfolios regardless of whether or not volatility is controlled for. Illiquidity in the stock market does not seem to have a significant impact on put option returns over time. This result is contrary to the findings of Chou et al. (2013) and the hedging cost argument. Chou et al. (2013) find that the level of the implied volatility curve increases with an increase in the illiquidity of the stock. The hedging cost argument states that the price of an option increases when the trading cost of the underlying stock increases. Therefore, a higher price of an option due to a higher transaction price in the underlying stock market would imply a negative relationship between option returns and transaction costs.

However, Feng et al. (2013) suggests that the discount factor depends on the level of stock market liquidity and the sensitivity of the stock to the level of stock market liquidity. When there is no excess or shortage in the market, the discount factor does not change and, therefore, the impact of illiquidity on the option prices is insignificant. With this line of argument, one might suggest that there is no excess supply in the market as we do not observe a significant impact of expected or unexpected illiquidity in the stock market on option returns. If this was the case, calls should not have been sensitive to the illiquidity in the stock market. However, as discussed earlier, calls show significant sensitivity to both expected and unexpected illiquidity. The only explanation for such asymmetric behaviour of calls and puts towards the illiquidity in the stock market could be related to the option type. Since put options provide an insurance against market declines, and their payoff increases when the underlying stock value declines, option traders might not worry about illiquidity in the underlying market at all.

### 5.5.4 Sensitivity of Option Return to Stock and Options Market Illiquidity

In this section, we report regression results of option returns on stock market excess return, expected and unexpected illiquidity in the options market, and expected and unexpected illiquidity in the stock market.

The results for calls in Table B6 (in the Appendix) suggest that the coefficients on expected and unexpected illiquidity in the options market are positive and negative, respectively. The coefficient of unexpected illiquidity in the options market is significant across call portfolios except DITM calls with maturity 15-30 days and above 365 days. Expected illiquidity in the stock market is important only for DITM options as observed in Section 5.5.3. Unexpected illiquidity in the stock market affects option returns for ATM calls with maturity above 61 days. The coefficient of unexpected illiquidity in the stock market is positive, contrary to what was hypothesized based on the persistence in illiquidity and the hedging cost argument. In Section 5.5.3, we found a similar result and argued that it could be due to the short supply in the stock market. Instead of unexpected illiquidity decreasing the price, it would push it higher. Therefore, unexpected illiquidity in the stock market would have a positive impact on option returns.

The results for puts in Table B7 (in the Appendix) suggest that put option returns are sensitive only to unexpected illiquidity in the options market. The coefficient on unexpected illiquidity in the options market is significant and negative across all portfolios except DOTM with maturity of 15-30 days.

In general, these results are consistent to what we find when we run separate analysis for the sensitivity of options returns to expected and unexpected illiquidity in the options and stock markets. These results are new and indicate that the sensitivity of option returns does not only depend on the maturity and moneyness of the options but also on the type of the option. The most important implication of these findings relate to option pricing. For example, call options show significant positive sensitivity to expected options market illiquidity and significant negative sensitivity to unexpected options market illiquidity decreasing in the moneyness, whereas put options show sensitivity to unexpected illiquidity in the options market. This suggests that a pricing model for options should consider the different impact of expected and unexpected illiquidity in the options market and, accordingly, such a model would be different for calls than for puts.

### 5.5.5 Fixed-Effect Model: Impact of Market Illiquidity on Options Market Returns

As discussed in Section 5.4, each option portfolio has different characteristics. Accordingly, to account for individual portfolio characteristics, a fixed-effects model is estimated to investigate the sensitivity of option returns to expected and unexpected illiquidity in the options and stock markets.

**Option Return Sensitivity to Options Market Illiquidity**

Table B8 in the Appendix reports the results of fixed-effect regressions of option return on expected and unexpected illiquidity in the options market. The results of Model (1) show that the stock market excess return has a positive and significant coefficient for calls (Panel A) and a negative and significant coefficient for puts (Panel B). Moreover, it remains stable in magnitude and significance in the multi-variate specifications (5), (6), (7) and (8). For calls in Panel A, the coefficients of the independent variables have their expected sign and are significant except for log volatility. For puts in Panel B, expected illiquidity has a negative coefficient in the univariate model but becomes positive and significant when the stock market excess return variable is added to the specification. However, it is insignificant in specification (8) where all variables considered are included. Unexpected illiquidity in puts is negative and significant in all the specifications.

Comparing the call option results with those of the put in specification (8), call returns are sensitive to both expected and unexpected illiquidity in the options market, and put returns are sensitive to unexpected illiquidity in the options market only. However, put options are more sensitive than call options to unexpected illiquidity. The results show that both H4 and H5 are not rejected for calls, but only H5 is not rejected for puts.

**Option Return Sensitivity to Stock Market Illiquidity**

Table B9 in the Appendix reports the fixed-effect regression results of option return on expected and unexpected illiquidity in the stock market. Two additional control variables are introduced: the natural log of the implied volatility in the options market, and the residual obtained from regressing illiquidity in the options market on illiquidity in the stock market. The latter is the orthogonalized liquidity variable based on the derivative hedge argument of Cho and Engle (1999) that illiquidity in the options market is determined by illiquidity in the stock market. Under the univariate estimations of specifications (1) to (4), the coefficients of variables for calls are significant, except for log volatility, and they have the expected sign. The coefficients on expected and unexpected illiquidity change sign when volatility is controlled for in specifications (9) and (10). This is due to the correlation between those two variables. Therefore, when the log volatility variable is excluded but the residual obtained from the regression of options market illiquidity on stock market illiquidity is controlled for (included), the coefficient has a positive sign for both expected and unexpected illiquidity. As discussed previously in Section 4.5.3, the positive sign for unexpected illiquidity may be due to short supply in the stock market.

Panel B of Table B9 in the appendix reports the results for puts. The coefficients of expected illiquidity and unexpected illiquidity have negative signs under the univariate specifications. Both change sign, however, when market excess return and other variables are controlled for in all the multivariate specifications.

The fixed-effects regression results suggest that call and put option returns are sensitive to expected and unexpected illiquidity in the stock market, and one cannot reject H3 and H4. However, the sign of the coefficients is not stable in both the univariate and multivariate specifications. Additionally, calls show a higher sensitivity to expected illiquidity in the stock market when compared to puts. Puts show a higher sensitivity to unexpected illiquidity in the stock market compared to calls.

## 5.6 Robustness Checks

The summary statistics reported in Table 5.1 show that the average proportional bid-ask spreads in the options market are much higher than those in the stock market. The distributions have high skewness and kurtosis, especially for the stock market. When the proportional bid-ask spread is transformed by taking the natural logarithm, the skewness and kurtosis decrease. Amihud (2002) also uses this natural logarithm transformation of the illiquidity measure. As a first robustness check, the regressions are re-estimated using the log proportional spread to investigate whether our results are affected by the choice of the liquidity measure, and whether they are affected by the higher skewness and kurtosis. The results are reported in Tables B10 and B11 in the Appendix for the sensitivity to illiquidity in the options and stock markets respectively. These are discussed in Section 5.6.1 below.

The second robustness check concerns the sample period selection. The graph of the proportional bid-ask spreads are reported in Figure 5.1 and the graph of the residuals obtained from the AR($p$) specification of the proportional bid-ask spreads (unexpected illiquidity) are reported in Figure 5.2a and Figure 5.2b. The graphs show that there are regions in which the proportional bid-ask spread is volatile, and these are specifically in the options market from 22 February 2008 to 27 March 2008, from 12 September 2008 to 20 October 2008, and from 9 December 2008 to 19 December 2008. When comparing the graphs of illiquidity in the options and the stock markets (Figure 5.1), the proportional bid-ask spreads in the stock market appear volatile in the latter quarter of 2008. This is investigated further by reverting to the options data files to check why the option spread is volatile in other periods. It is found that the option files during these periods only report data for very few options. On some days during these periods, there are as few as 16 put options on 5 stocks. It is, therefore once again, important to check whether the results are sensitive to the sample selection. Accordingly, we analyse a sub-sample from January 2009 to December 2010. The results of this second robustness check are reported in Tables B12 and B13 in the Appendix, and are discussed in Section 5.6.2 below

The third robustness check concerns the expiry cycle followed by the options. Stocks on which options are traded fall into two expiry-cycle categories. The first category of stocks has options issued with maturities in each quarter of a year and with maturities in the next three months. These stocks have options with monthly maturities available for the next three months. The second category of stocks has options issued in each quarter of a year with the longest maturity of nine months. To investigate whether the earlier estimated results are not biased by the different expiry cycles followed by options on some stocks, a third robustness check is performed. We estimate the regressions for a subsample that includes the data of the first category of stocks with the expiry cycle that includes option maturity in each quarter of the year along with monthly maturity for the next three months. This category is chosen because options on these stocks fill in all the moneyness and maturity portfolios and, therefore, should provide a better comparison with the previous results. The results of this robustness check are reported in Tables B14 and B15 in the Appendix, and are discussed in Section 5.6.3 below.

### 5.6.1 Robustness Check 1: Natural Log of Liquidity Measure

The re-estimated results on sensitivity of option reutrns to illiquidity in the options market are reported in Tables B10a and B10b in the Appendix for calls and puts, respectively.

The re-estimated results for the sensitivity of option returns to illiquidity in the stock market are reported in Tables B11a and B11b in the Appendix for calls and puts, respectively.

It can be seen from Table B10 that the significance and sign of the coefficients of expected and unexpected illiquidity are robust with regard to the measure of illiquidity used. Similar to the results reported in Section 5.5.2, hypotheses H4 and H5 cannot be rejected for most call portfolios. For puts, only unexpected illiquidity in the options market is found to be important which is similar to the findings reported above when illiquidity was measured by the proportional bid-ask spread.

The results on the sensitivity of option returns to illiquidity in the stock market, reported in Table B11, are robust to the use of the natural log of the proportional spreads as a measure of illiquidity in the stock market. The log transformation of the proportional bid-ask spread to address the skewness and kurtosis data issue does not have a material effect on the main findings reported in the previous section. The results are similar to those when illiquidity is measured by the proportional bid-ask spread.

### 5.6.2 Robustness Check 2: Sample Period Selection

The data in 2008 for the option and stock markets suggests that both markets were volatile during the latter part of the last quarter of 2008 (see Figures 5.1 and 5.2). Therefore, the regressions in Equation (5.11) and (5.13) are re-estimated for a sub-sample period from January 2009 to December 2010. The results of the sensitivity of option returns to illiquidity in the options and stock markets are reported in Tables B12 and B13 in the Appendix, respectively.

The results for the sensitivity of option returns to illiquidity in the options market (Tables B12a and B12b) show that both expected and unexpected illiquidity have significant coefficients across a few portfolios of calls and puts. Put returns are only sensitive to unexpected illiquidity in the options market, but the significance has decreased for most portfolios (compared to the results presented in Section 5.5.2 above for the full sample). The coefficient on the stock market excess return is higher in absolute terms compared to the coefficients obtained with full sample estimation. Moreover, the effects of expected illiquidity and unexpected illiquidity remain similar but with slightly higher coefficients for some portfolios. This difference could be due to the exclusion of the volatile 2008 period from the analysis.

The results for the sensitivity of option returns to illiquidity in the stock market as reported in Table B13a and B13b are also robust to the choice of sample period, as both the coefficients on the expected and unexpected illiquidity variables have mixed signs and significance. In this sub-sample, few portfolios show significant coefficients for expected and unexpected illiquidity in the stock market. Hypotheses H3 and H4 are rejected for most portfolios of calls and puts and, hence, the results are consistent with those reported previously for the whole sample.

### 5.6.3 Robustness Check 3: Underlying Stocks with Different Maturity Cycles.

The third robustness check is performed to address the issue of stocks with options having different maturity cycles. A subsample is selected that includes the data on the first category of stocks with the expiry cycle that includes option maturity in each quarter of the year along with monthly maturitities available for the next three months. As mentioned previously, this category is chosen because options on such stocks fill in all the moneyness and maturity portfolios and, therefore, should provide a better comparison with the previous results.

The regressions in Equations (5.11) and (5.13) are re-estimated for this subsample. The results for the sensitivity of option returns to illiquidity in the options market and the stock market are reported in Tables B14 and Table B15 in the Appendix, respectively.

The results for the sensitivity of option returns to illiquidity in the options market (see Tables B14a and B14b) are robust to this sub-sample. Hypotheses H4 and H5 cannot be rejected for most call option portfolios as was found for the whole sample. The coefficients of expected and unexpected illiquidity in the options market have the expected sign and significance across all call portfolios. As observed in the earlier reported results for puts, only the coefficient on unexpected illiquidity in the options market is significant and negative across most portfolios.

The results in Tables B15a and B15b are also robust to the expiry cycles of the options issued. Accordingly, the sensitivity to expected and unexpected illiquidity does not appear to depend on the expiry cycles of the options.

## 5.7 Conclusion

This chapter presents an analysis of the sensitivity of option returns to illiquidity in the options and stock markets across moneyness and maturity portfolios of calls and puts. In the stock market, Amihud (2002) investigates the time-series effects of stock market liquidity on stock market returns. He suggests that stock market returns are positively affected by expected illiquidity in the market and negatively affected by unexpected illiquidity in the market. In the options market, although several papers, including Chou et al. (2013) and Feng et al. (2013), have investigated the impact of option and stock illiquidity on option prices, the impact of option market illiquidity and stock market illiquidity on option returns have not been analysed, neither in a time series nor in a cross-sectional context. We fill the gap in the literature by investigating the time-series effects of option market illiquidity and stock market illiquidity on option returns.

In the literature on liquidity risk, the comovement of liquidity with market-wide factors is found to be an important determinant of returns in the stock market (Amihud, 2002; Acharya and Pedersen, 2005) and in the options market (Frey, 2000; Cetin et al., 2004 and 2006). In this regard, Acharya and Pedersen (2005) derive a liquidity-adjusted CAPM and identify three sources of liquidity risk, other than market risk, that explain the variation in stock returns. These are: the comovement between stock illiquidity and stock market illiquidity, the comovement between stock illiquidity and stock market returns, and the sensitivity of stock return to stock market illiquidity. In the options market, however, only one source of liquidity risk, which is the comovement between option illiquidity and stock market illiquidity, has been documented. We, therefore, contribute by investiagting the comovement between option return and market liquidity using the methodology of Amihud (2002).

Amihud (2002) suggests that illiquidity is persistent, and this has two main implications for market returns. The first is that liquidity predicts future returns, at least partially. When liquidity is persistent, high liquidity today will predict high liquidity the next day, implying a low required return (Acharya and Pedersen, 2005). The second implication is that a negative conditional co-variation between contemporaneous returns and liquidity exists (Acharya and Pedersen, 2005). Intuitively, when liquidity is unexpectedly low, the already higher required return that compensates for expected illiquidity decreases because of a decrease in the price of the stock due to unexpected illiquidity. For individual options on a stock, illiquidity in both the options market as well as in the stock market could have time-series effects on the returns of these individual options. Therefore, we investigate both implications on moneyness and maturity portfolios of equity options.

Two hypotheses are developed based on the effect of expected and unexpected illiquidity on option returns. The first hypothesis is that expected illiquidity in the options market has a positive effect on expected option returns. The second hypothesis is that unexpected illiquidity in the options market has a negative effect on the contemporaneous option return. Intuitively, persistence in illiquidity in the stock market implies that if the stock market is illiquid today, it would also be illiquid the next day. This would result in a decrease in the current underlying asset price as investors demand a higher return. Lower stock prices in turn will result in lower call prices and higher put prices. This suggests that higher stock market illiquidity leads to higher call option expected returns. When there is an illiquidity shock in the stock market (unexpected illiquidity), current stock prices will decrease, thereby reducing the contemporaneous option returns.

The analysis in this chapter tests these hypotheses by estimating time-series regressions of option returns on expected and unexpected illiquidity in the options or the stock market. Illiquidity, measured by the proportional bid-ask spread, in the stock market is less persistent (AR(1) coefficient of 0.736) than illiquidity in the options market (0.847). For each market, an AR($p$) process is assumed for the proportional bid-ask spread with lag structure determined by the AIC and BICcriteria. Using the AR($p$) specification followed by the proportional bid-ask spread in stocks, calls, puts, and all options markets, illiquidity is separated into expected and unexpected components for each market.

The first hypothesis says that option returns are sensitive to expected illiquidity in the options market. The empirical results show that the sensitivity of option returns to expected illiquidity is positive and significant for most moneyness and maturity portfolios of call options. Generally, the effect is lower for long maturity calls than short maturity calls. This implies that traders consider expected illiquidity more important for short rather than long maturity options. The effect on returns of ATM calls implies an increase by 0.745 per cent due to one standard deviation increase in expected illiquidity in the call options market, ceteris paribus. Returns of the put portfolios, however, are not sensitive to expected illiquidity in the options market.

The second hypothesis says that unexpected illiquidity in the options market has a negative impact on the contemporaneous option excess return. Calls have decreasing sensitivity to unexpected illiquidity in both moneyness and maturity. Moreover, the coefficient on expected illiquidity is generally smaller than that on unexpected illiquidity for calls. The effect on returns of the ATM call portfolio with maturity of 31-60 days implies a decrease by 1.424 per cent when unexpected illiquidity increases by one standard deviation. Put option returns do not show any obvious pattern over moneyness for the impact of unexpected illiquidity. However, they show higher sensitivity to unexpected illiquidity for higher maturities. ATM puts show a decreasing absolute coefficient of unexpected illiquidity in the options market with maturity. A positive shock of one standard deviation in illiquidity leads to a 1.344 per cent decrease in put option return.

The results also suggest that option return is not generally sensitive to stock market illiquidity for most call and put portfolios. We find that option return sensitivity is significant to expected illiquidity in the stock market for eleven out of thirty calls and three out of thirty put option portfolios. Five DITM call portfolios with maturity greater than 30 days are sensitive to expected illiquidity in the stock market. This may be due to the delta-effect. DITM calls act more like a stock as their delta is close to one. Moreover, calls with long maturities show significant return sensitivity to unexpected illiquidity in the stock market. However, puts do not show any such return sensitivity. A possible explanation could be due to asymmetric response to the shocks in stock market illiquidity based on upward or downward movement of the stock market.

Since moneyness and maturity characteristics distinguish options from each other, fixed-effects regressions are estimated to take into account individual fixed effects of option moneyness and maturity portfolios. Call option returns have positive sensitivity to expected illiquidity in the options and stock markets. However, the coefficient on unexpected illiquidity is significant but changes sign when volatility is controlled for. Moreover, put returns have a positive return sensitivity to expected illiquidity in the options market as well as in the stock market, as expected. However, puts show negative return sensitivity to unexpected illiquidity in the options market but positive sensitivity to unexpected illiquidity in the stock market. This may be due to short supply in the underlying stock market during the sample period.

These findings are robust to the measure of illiquidity, the sample period, and the expiry cycles of options. As a first robustness check we re-estimate all regression models using the natural log of the proportional bid-ask spread as a measure of illiquidity. As a second robustness check we re-estimate all regressions using a sub-sample period from January 2009 to December 2010 to avoid the thin data on a few options and volatility in option spreads during the last quarter of 2008. As a third robustness check we consider a sub-sample of stocks with option expirations in each quarter of the year and monthly maturities for the next three months. The results of each robustness check are largely similar to the original findings.

The findings in this chapter are important as they have direct implications on the pricing of options, since call and put option returns are found sensitive to illiquidity in the options market and stock markets. The impact of stock market illiquidity on option returns is found to be only due to unexpected illiquidity component, and is positive for calls and negative for puts. For example, call option returns show significant positive sensitivity to expected illiquidity in the options market and significant negative sensitivity to unexpected illiquidity in the options market. This sensitivity decreases in the moneyness. Put options, however, show return sensitivity only to the unexpected illiquidity in the options market.

This result is contrary to the findings of Chou et al. (2013) and the hedging cost argument. Chou et al. (2013) report that the level of the implied volatility curve increases with an increase in the illiquidity of the stock. Considering the hedging cost argument, a higher price of an option due to a higher transaction price in the underlying stock market would imply a negative relationship between option returns and transaction costs. On the other hand, Feng et al. (2013) suggest that the discount factor in their pricing model depends on the level of stock market liquidity and the sensitivity of the stock to the level of stock market liquidity. When there is no excess or shortage in the market, the discount factor does not change and, therefore, the impact of illiquidity on the option prices is insignificant. With this line of argument, one might suggest that there is no excess supply in the market as we do not observe a significant impact of expected or unexpected illiquidity in the stock market on option returns. If this was the case, calls should not have been sensitive to the illiquidity in the stock market. However, as discussed earlier, calls show significant sensitivity to both expected and unexpected illiquidity. The only explanation for such asymmetric behaviour of calls and puts towards the illiquidity in the stock market could be related to the option type. Since put options provide an insurance against market declines, and their payoff increases when the underlying stock value declines, option traders might not worry about illiquidity in the underlying market at all.

This suggests that when pricing options, an investor would need to consider the expected and unexpected illiquidity in the options market for calls but only unexpected illiquidity for puts. Accordingly, it is, interesting to investigate how much premium an investor would require for the sensitivity of option returns to illiquidity in the options and stock markets. This is investigated in the next chapter.

# CHAPTER 6
# PRICING LIQUIDITY

## 6.1 Introduction

This chapter investigates the pricing of illiquidity in the NYSE Euronext LIFFE London equity option market. In the stock and bond markets, an illiquid asset provides a higher return. This higher return includes the premium for illiquidity of the asset as well as a premium for liquidity risk. However, in option markets, the payoff of an option depends on the payoff of the underlying asset, and since an option can be replicated by trading delta shares in the underlying stock, illiquidity of both the option and the underlying stock markets become relevant.

In Chapter 4 and Chapter 5, we investigated four sources of liquidity risk. These sources of liquidity risk are comovement between option liquidity and its market liquidity, comovement between option liquidity and its underlying stock market, comovement between option return and option market liquidity and comovement between option return and underlying stock market liquidity. We find that these comovements are important for both calls and puts and are different across different portfolios of moneyness of calls and puts. However, we have not yet investigated if these sources of liquidity risk are priced across options on stocks. Therefore, in this chapter we investigate the pricing of liquidity of option, its underlying stock and various sources of liquidity risk, including four which we investigated in the previous chapter.

The analysis in this chapter investigates three research questions related to illiquidity premia. The first research question is whether the price of an option includes a premium for the illiquidity of an option. This is referred to as the liquidity premium hypothesis. Similar to the argument for stocks and bonds, it is hypothesized that an illiquid option will trade at a lower price than an otherwise similar but liquid option.

The second research question is whether the price of an option includes a premium for the liquidity of its underlying stock. It is referred to as the hedging cost hypothesis. The hedging cost hypothsis uses the hedging argument to support that an option price will include a premium for buying an option on an illiquid stock since the costs of hedging will be higher for an illiquid stock. In other words, higher transaction costs for trading a stock increase the costs of replicating an option and, hence, the price of the option. When illiquidity is defined by the bid-ask spread, a higher bid-ask spread would mean higher illiquidity. To replicate an option by buying delta units of an illiquid stock will be more costly when transaction costs are higher, which would result in a higher option price and therefore a lower option return.

The third research question asks, which sources of liquidity risk are important for pricing options. From the asset pricing literature we know that liquidity risk emanates from three main comovements (Acharya and Pedersen, 2005). The first is the covariation of liquidity of a stock with market liquidity (referred to as liquidity commonality, or liquidity comovement). The second source is the covariation of the return of a stock with market liquidity (referred to as the stock return sensitivity to market liquidity). The third source of liquidity risk is the covariation of liquidity of a stock with market return (referred as the liquidity sensitivity to market return). However, since options are replicative securities whose payoff depends on the payoffs in the underlying stock, the sources of liquidity risk can emanate from both the underlying stock market and the options market. Option excess return, option liquidity, and stock liquidity are important factors that may comove with stock market excess return, stock market liquidity and option market liquidity. When the return of an asset covaries with the return of the market, it is referred to as market risk. Beside market risk, however, there are eight other covariances. We refer to these as sources of liquidity risk and we investigate their pricing potential in this chapter. We call them sources of liquidity risk for two reasons. First, one of the two variables involved in each covariance is related to the market (either the option market or the stock market) and the other variable is related to the option or its underlying stock. Second, one of the two variables is a liquidity variable of either the market or the security (stock or option). The first two sources of liquidity risk are due to the comovement of option excess return with stock market illiquidity, and option market illiquidity. The second three sources of liquidity risk are due to the comovement of option illiquidity with stock market excess return, stock market illiquidity, and option market illiquidity. The third three sources of liquidity risk are due to the comovement of stock illiquidity with stock market excess return, stock market illiquidity, and option market illiquidity.

To investigate these sources, this analysis employs the delta-hedging portfolio strategy of Bakshi et al. (2003) to measure option portfolio returns, and uses the proportional bid-ask spread as a measure of illiquidity for both options and stocks. Moreover, to investigate the risk premia associated with these liquidity variables and sources of liquidity risk in the cross section, the Fama-MacBeth (1973) two-pass regression procedure is adopted.

The rest of the chapter is organized as follows: Section 6.2 briefly reviews the literature relating to the pricing of liquidity and liquidity risk, Section 6.3 discusses the hypotheses, Section 6.4 presents the methodology used to investigate the research questions, Section 6.5 provides a description of the data sample, the approaches taken to calculate option portfolio returns, the construction of the delta-hedging strategy to calculate option returns, and the measures of illiquidity used for options and stocks, Section 6.6 reports the descriptive statistics of the sample, Section 6.7 discusses the results, and finally Section 6.8 summarises and concludes.

## 6.2 Literature Review

The literature on the illiquidity premia in stock and bond markets indicates that illiquidity affects returns. Specifically, illiquid assets offer a higher expected return. Amihud and Mendelsen (1986), Brennan and Subrahmanyam (1996), Amihud (2002), Pastor and Stambaugh (2003), Acharya and Pedersen (2005), amongst others, study illiquidity and returns in stock markets, while Amihud and Mendelsen (1991), Longstaff (1994), Beber, Brandt and Kavajecz (2009) study the impact of illiquidity on expected returns in bond markets. Amihud and Mendelsen (1986) suggest that stock returns are a concave function of stock illiquidity when measured by the proportional bid-ask spread.

Relatively little research has been done on the illiquidity premia in derivatives. Studies include Brenner, Eldor and Hauser (2001) on the currency options market, Deusker et al. (2010) on the interest rate derivative market, Bongaerts et al. (2011) on the credit-default swap market, and Chou et al. (2013) and Christoferssen et al. (2015) on the equity option market. Both Chou et al. (2013) and Christoferssen et al. (2015) study the impact of the liquidity of the underlying asset and its option on option prices. Chou et al. (2013) investigate DJIA constituents. They find that options with a lower proportional spread and underlying stocks with a higher average proportional spread have a higher level of implied volatility and, hence, a higher price. Christoferssen et al. (2015) also study how the illiquidity of an option and its underlying stock affect the returns of CBOE equity options. They find a positive impact of option spreads on option expected returns, and a negative impact of stock spreads on option expected returns. The findings of both studies suggest that options become cheaper when options are more illiquid, and more expensive when their underlying stock is more illiquid. The implication is that marginal investors in the option market receive a premium for buying an illiquid option, but pay a premium for buying an option whose underlying stock is illiquid. This means higher hedging costs for buyers of options whose underlying stock is illiquid, because illiquidity is measured by the proportional bid-ask spread.

Illiquidity can also be measured by the net-demand pressure of a security. Bollen and Whaley (2004) suggest that changes in implied volatility are related to the net buying pressure from public order flows. They find that the buying pressure for index put options explains changes in the implied volatility of S&P 500 index options, whereas the buying pressure for the call options explains changes in the implied volatility of individual stock options.

Garleanu et al. (2009) suggest that net-demand patterns can explain the anomalous expensiveness of index options. End-users tend to have net-long positions in S&P 100 index options, particularly in out-the-money put options, and net-short positions in individual stock options. The conclusion is that the overall expensiveness and skew patterns in the implied volatility of index options compared to individual stock options can be explained by the demand patterns in the respective options.

When markets are imperfect, liquidity of the underlying asset will be relevant to the pricing of an option in addition to the liquidity of the option. The theoretical models of Frey (1998), Liu and Yong (2005) and Cetin et al. (2006) suggest that the liquidity of a stock (also called ‘spot liquidity’ in the literature) affects the option price. Cho and Engle’s (1999) derivative hedge theory suggests that liquidity and bid-ask spread in the option market are determined by the liquidity in the stock market.

Frey (2000) and Liu and Yong (2005) investigate option replication and super-replication (trading underlying stock in a ratio greater than the option delta) costs when the underlying asset market is illiquid. They prove that replication is cheaper than super replication when there is a price impact. Cetin, Jarrow and Protter (2004) and Cetin, Jarrow, Protter and Warachka (2006) model liquidity as a stochastic supply curve and derive a pricing formula for European call options. Cetin, Jarrow and Protter (2006) study option pricing using discrete trading strategies in an extended Black-Scholes economy in which the underlying asset is not assumed to be perfectly liquid. They present empirical evidence that the liquidity cost of the underlying asset is the main component of the option price, even under the optimal hedging strategy. The impact of the underlying stock illiquidity on the option price also depends on the moneyness of the option and is more significant for out-the-money options.

Christoffersen et al. (2015) study the effect of stock and option illiquidity on equity option returns in the CBOE market. They find that option illiquidity positively affects option expected return, consistent with the illiquidity premium hypothesis. That is, an illiquid asset will trade at a discount compared to an otherwise similar but liquid asset. They also find that illiquidity of the underlying stock of that option affects the expected option return negatively, which is consistent with the hedging cost hypothesis. The hedging cost hypothesis suggests that an option can be replicated by trading in the underlying stock and bond markets. When the stock is illiquid, the cost of hedging is high and this causes the expected option return to decline.

However, the literature is silent on the relationship between the channels of liquidity risk and expected returns in the equity option market. This is important since the growing literature on liquidity risk suggests that liquidity varies over time with market-wide variables such as market return and market liquidity. Comovement of liquidity of a stock with that of the stock market was documented for the first time by Chordia et al. (2001) in the NYSE stock market. However, another channel of liquidity risk in which the return of a stock varies over time with market-wide liquidity is documented by Amihud (2002) in the NYSE stock market. Acharya and Pedersen (2005) derive a uniform liquidity capital asset pricing model in which not only the level of the liquidity of a stock but also liquidity changes over time affect stock returns. In their model, liquidity risk has three main channels. First, the liquidity of a stock comoves with the liquidity of the stock market, which is the liquidity commonality evidence documented in the stock market by Chordia et al. (2001), and in the equity option market by Cao and Wei (2010). Second, the return of a stock comoves with the liquidity in the stock market (with evidence documented by Amihud, 2002). Third, the liquidity of a stock comoves with stock market return. Chordia et al. (2005) find evidence of liquidity risk premia for all these three channels of risk in the NYSE stock market.

Cao and Wei (2010), for the CBOE equity option market, and Deusker et al. (2011), for the interest rate options market, find that liquidity of an option comoves with option market-wide liquidity. However, they do not investigate whether the liquidity comovement is priced in the equity option market. Moreover, in light of the liquidity capital asset pricing model of Acharya and Pedersen (2005), the other two channels of liquidity risk are priced in the stock market. The stock market is a positive supply market whereas the option market is a net-zero supply market. In a net-zero supply market, market participants are classified as market-makers and end-users (Garleanu, 2009). Market-makers may be net-buyers or net-sellers. If market-makers are net-buyers, end-users will be net-sellers. In this case market-makers will charge higher prices so as to discourage building up inventory. Garleanu et al. (2009) find that index options have higher implied volatility than individual equity options because market-makers are net-long in the index option market and net-short in the equity option market. They argue that demand pressure from the end-users in the index options market is higher, and this causes index options to be more costly than individual equity options.

There is interaction not only between an option and the market where it is traded but also between an option and the underlying market where it can be hedged or replicated. Similarly, liquidity risk may be related to the comovement of the option return or option liquidity not only with liquidity in the option market but also with return and liquidity in the underlying asset market. Therefore, one can argue that the nature of options is such that the channels of liquidity risk are not confined to the comovement of liquidity or return of an option with market-wide variables of the option market but also with market-wide variables of the underlying stock market.

## 6.3 Hypotheses

The following hypotheses relate to the effects of illiquidity of an option, illiquidity of the underlying stock, and channels of liquidity risk. In this chapter these hypotheses are empirically tested in the equity options market.

### 6.3.1 Liquidity Premium Hypothesis

Hypothesis 1 (H8):

Illiuqidity of an option positively affects the option return.

It is hypothesized that the illiquidity of an option positively affects the option return. In other words, illiquid options earn higher expected returns. Buyers of an asset are concerned about the liquidity of the asset when they subsequently want to liquidate their positions, and would only be willing to buy an illiquid asset at a discounted price compared to that of an otherwise identical but liquid asset, thus earning an illiquidity premium. Therefore, the expected return on an individual option should be positively related to the illiquidity of that option.

### 6.3.2 Hedging Cost Hypothesis

Hypothesis (H9):

Illiquidity of the underlying stock negatively affects the option return.

In a complete and frictionless market, such as that in the Black-Scholes economy, an option can be replicated by trading in the underlying stock and a risk-free bond.[22] If the underlying stock is illiquid, it would be difficult to implement this replicaton. Accordingly, the illiquidity costs of trading the stock would affect the price and, consequently, the return of an option.

The illiquidity of the underlying stock negatively affects the option expected return as would be suggested by the hedging argument that higher costs of trading a stock increase the costs of replicating the option, which increases its price and, therefore, reduces its expected return. When illiquidity is defined by the bid-ask spread, a wider bid-ask spread indicates higher illiquidity. Buying delta units of an illiquid stock to replicate an option will be more costly, resulting in a higher option price and, therefore, a lower option expected return. Thus, the relationship between an option expected return and the underlying stock illiquidity is expected to be negative.

### 6.3.3 Liquidity Risk Channels and Hypotheses

Channels of liquidity risk in options can be identified by the interactions of two markets: the options market and the underlying stock market. We present below the comovements that are potential sources of liquidity risk in equity options. These are analysed in this chapter.

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[22] It is usually assumed that the riskless asset is liquid, and hence the focus is on the liquidity of the underlying risky asset.

**Comovement of option liquidity with option market liquidity**

Hypothesis (H10):

Risk premium due to liquidity comovement between an option and its market is positive.

It is documented by Cao and Wei (2010), Deusker et al. (2011), and in the first empirical chapter of this thesis (Chapter 4) that option liquidity comoves with option market liquidity.[23] A positive liquidity comovement between options and their market implies that an option will tend to be illiquid during times of low liquidity in the options market. To encourage the buying of options with such illiquidity risk, a market-maker will offer a discounted price compared to an option of lower liquidity risk. A potential buyer would purchase this option if compensated for this channel of liquidity risk. Therefore, an option with positive liquidity comovement should offer a higher expected return. Accordingly, researchers hypothesize that the risk premium for liquidity comovement between an option and its market is positive.

The results of the analysis in Chapter 4 show that liquidity comovement is positive and high for at-the-money options. If the premium for this liquidity risk channel is the same across moneyness, at-the-money options would show a higher total premium due to higher liquidity comovement for this channel of liquidity risk.

**Comovement of option liquidity with underlying stock market liquidity**

Hypothesis (H11):

Risk premium due to comovement between option liquidity and underlying stock market liquidity is positive.

The derivative hedge theory of Cho and Engle (1999) proposes that liquidity and spreads in the option market are determined by the liquidity and spreads in the underlying stock market if market-makers are able to completely hedge their option positions in the underlying stock market. This implies that option liquidity comoves with the liquidity of the underlying stock market. An option buyer would face the risk of the option being illiquid when stock market liquidity is low which would further deteriorate the option return. Therefore, option buyers expect to receive a risk premium for holding options with

[23] Cao and Wei (2010) study CBOE equity option market. Deusker et al. (2011) study OTC Floors and Caps interest rate market. This study investigates the NYSE Euronext LIFFE London equity options market. In all these options markets, liquidity comovement is found to be significant.

liquidity dependent on the liquidity of the underlying stock market. It is hypothesized that the premium for option liquidity comovement with its underlying stock market is positive.

**Comovement of option liquidity with stock market return**

Hypothesis (H12):

Risk premium due to comovement between option liquidity and underlying stock market return is negative.

A negative option liquidity comovement with the stock market return would imply that the option is more liquid when the stock market declines. An option that is liquid in a declining stock market would be more desirable, and buyers would be willing to pay a premium. Therefore, it is hypothesized that the premium for this liquidity risk channel is negative.

**Comovement of option return with option market liquidity**

Hypothesis (H13):

Risk premium due to comovement between option return and option market liquidity is negative.

Options that provide positive returns in an illiquid option market act as insurance against illiquidity in the options market. These options are desirable for hedging the underlying stock. Therefore, an option buyer would be willing to pay a premium for buying such an option. Accordingly, it is hypothesized that the premium for this comovement channel is negative.

**Comovement of option return with stock market liquidity**

Hypothesis (H14):

Risk premium due to comovement between option return and stock market liquidity is negative.

An option that provides a positive return in an illiquid stock market would act as protection against illiquid times and would be desirable for hedging the underlying stock. Therefore, an option buyer would pay a premium for this option. It is, therefore, hypothesized that the premium for this liquidity risk channel is also negative.

**Comovement of option return with stock market return**

Hypothesis (H15):

Risk premium due to comovement between option return and stock market return is positive.

The return on an asset depends on the riskiness of that asset relative to the market portfolio. An investor requires compensation for investing in risky assets. Options are leveraged securities and, therefore, are more risky than their underlying asset. The risk premium for an option is expected to be positive. When the option return is measured by delta-hedged gains, the exposure of an option to the underlying stock and, therefore, to the stock market is neutralized. Accordingly, the market risk premium for delta-hedged gains is expected to be insignificant.

**Comovement of stock liquidity with option market liquidity**

Hypothesis (H16):

Risk premium due to comovement between stock liquidity and option market liquidity is positive.

A positive comovement between the illiquidity of a stock and that of the option market would indicate that when a stock is illiquid the option market is also illiquid. Option buyers who trade the underlying stock to hedge the risks will be reluctant to buy the option on a stock whose illiquidity positively comoves with the option market illiquidity. Buyers of such an option would demand a compensation for this risk exposure. Therefore, it is hypothesized that the premium for this liquidity risk channel is positive.

**Comovement of stock liquidity with underlying stock market liquidity**

Hypothesis (H17):

Risk premium due to comovement between stock liquidity and stock market liquidity is negative.

Liquidity comovement between a stock and its market is commonly known as liquidity commonality in the asset pricing literature.[24] In the Liquidity-Capital Asset Pricing Model

[24] The evidence of liquidity commonality in the stock market was found by Chordia et al (2001), Hasbrouk and Seppi (2001), Halka and Huberman (2001). Acharya and Pedersen (2005) theoretically and empirically suggested that the investors demand a risk premium for buying a stock whose liquidity comoves with the liquidity of the stock market.

of Acharya and Pedersen (2005), an investor demands a premium to buy a stock whose liquidity may deteriorate when the liquidity in the stock market deteriorates. However, trading an option written on a stock that exhibits (the stock) positive liquidity commonality in the stock market, an option trader would earn a lower return when he keeps a delta-hedged position. A stock with a positive liquidity comovement would be trading at a lower price to compensate the stock trader for the risk. This would imply that when an option trader sells delta units of the underlying stock, she will sell it at a lower price, thus reducing the delta-hedged return on the option. Therefore, we hypothesize that liquidity commonality in the stock market would negatively affect the delta-hedged return of an option.

**Comovement of stock liquidity with stock market return**

Hypothesis (H18):

Risk premium due to comovement between stock liquidity and stock market return is negative.

A positive comovement of stock illiquidity with stock market return implies that a stock is liquid when the return in the stock market is low. Such a stock would be desirable in a declining stock market, because it helps traders unwind their positions more easily. Accordingly, traders would be willing to pay a risk premium for such a stock. Therefore, the premium for this channel of liquidity risk is expected to be negative.

## 6.4 Methodology

To test the illiquidity premium, hedging cost and liquidity risk hypotheses, standard two-pass regression analysis is used. Five portfolios of calls and puts based on moneyness are constructed. Analysis is performed separately for each moneyness category of calls and puts.

### 6.4.1 First Pass Regressions: Estimating Market and Liquidity Betas

In order to investigate the roles of the liquidity risk channels mentioned above, betas for the sources of liquidity risk are estimated. Motivated by the arbitrage pricing theory framework, several liquidity betas are estimated by the following three regressions for each stock in each moneyness category.

$$DHG_{it} = \alpha_{1i} + \beta_{(dhg,rm)i} \cdot \left(r_{mt}^{s} - r_{ft}\right) + \beta_{(dhg,smliq)i} \cdot \epsilon_{m,t}^{s} + \beta_{(dhg,omliq)i} \cdot \epsilon_{m,t}^{o} + \varepsilon_{1it} \quad (6.1)$$

$$\epsilon_{it}^{o} = \alpha_{2i} + \beta_{(oliq,rm)i} \cdot \left(r_{mt}^{s} - r_{ft}\right) + \beta_{(oliq,smliq)i} \cdot \epsilon_{m,t}^{s} + \beta_{(oliq,omliq)i} \cdot \epsilon_{m,t}^{o} + \varepsilon_{2it} \quad (6.2)$$

$$\epsilon_{it}^{s} = \alpha_{3i} + \beta_{(sliq,rm)i} \cdot \left(r_{mt}^{s} - r_{ft}\right) + \beta_{(sliq,smliq)i} \cdot \epsilon_{m,t}^{s} + \beta_{(sliq,omliq)i} \cdot \epsilon_{m,t}^{o} + \varepsilon_{3it} \quad (6.3)$$

where, $DHG_{it}$ is the delta-hedged gain (defined in Section 6.5.1) as a measure of option return averaged across all options in a moneyness portfolio on stock $i$ at time $t$, $r_{mt}^{s}$ is the stock market return (return on FTSE 100 index) at time $t$, $r_{ft}$ is the weekly data of annual risk-free rate at time $t$, $\epsilon_{m,t}^{o}$ is the AR(1) residual of the option market illiquidity at time $t$, $\epsilon_{m,t}^{s}$ is the AR(1) residual of the stock market illiquidity at time $t$, $\epsilon_{it}^{o}$ is the AR(1) residual of the illiquidity of options in the moneyness portfolio on stock $i$ at time $t$, and $\epsilon_{it}^{s}$ is the AR(1) residual of the illiquidity of stock $i$ at time $t$. To estimate illiquidity innovations (unexpected illiquidity), it is assumed that illiquidity variables as described above (illiquidity of an option market, a stock market, an option, and a stock) follow AR(1) processes since illiquidity is observed to be persistent. Most studies including Amihud (2002), Chordia et al. (2005), and Acharya and Pedersen (2005) use an AR(1) specification to estimate the innovations in liquidity of an asset.

We follow the same practice and estimate the AR(1) process:

$$illiquidity_{t} = \rho_{0} + \rho_{1} \cdot illiquidity_{t-1} + \epsilon_{t} \quad (6.4)$$

where $illiquidity_{t}$ is the illiquidity measure at time $t$, $\rho_{1}$ is the first-order auto-correlation and $\epsilon_{t}$ is the innovation in illiquidity (illiquidity shocks).

From regression (6.1) three betas are obtained for each moneyness portfolio of calls and puts. $\beta_{(dhg,rm)i}$ is the market beta of the options on stock $i$. $\beta_{(dhg,smliq)}$ is the first liquidity risk beta, which is due to the comovement between option return and shocks from stock market illiquidity. $\beta_{(dhg,omliq)}$ is the second liquidity risk beta, which is due to the comovement between option return and shocks from option market illiquidity. The last two, $\beta_{(dhg,smliq)}$ and $\beta_{(dhg,omliq)}$, are option return-liquidity sensitivity betas.

From regression (6.2) three betas are estimated for each moneyness portfolio of calls and puts. These represent the comovements of option illiquidity with stock market return, stock market illiquidity, and option market illiquidity. $\beta_{(oliq,rm)}$ is relative riskiness of a shock in option illiquidity with stock market return. $\beta_{(oliq,smliq)}$ is the relative riskiness of a shock in option illiquidity to a shock in the illiquidity of the stock market. $\beta_{(oliq,omliq)}$ is the relative riskiness of a shock in option illiquidity to a shock in the illiquidity of the option market.

From regression (6.3) three betas are obtained for each moneyness portfolio of calls and puts. These represent the comovement of stock illiquidity with stock market return, stock market illiquidity, and option market illiquidity. $\beta_{(sliq,rm)}$ is the relative riskiness of a shock in the stock illiquidity due to a shock in the stock market return. $\beta_{(sliq,smliq)}$is the relative riskiness of a shock in the stock illiquidity due to a shock in the stock market illiquidity. $\beta_{(sliq,omliq)}$is the relative riskiness of a shock in the stock illiquidity due to a shock in option market illiquidity.

Thus, $\beta_{(dhg,smliq)}$ , $\beta_{(dhg,omliq)}$ , $\beta_{(oliq,rm)}$ , $\beta_{(oliq,smliq)}$ , $\beta_{(oliq,omliq)}$ , $\beta_{(sliq,rm)}$ , $\beta_{(sliq,smliq)}$and $\beta_{(sliq,omliq)}$ represent different sources of liquidity risk. Equations (6.1), (6.2), and (6.3) are estimated by stock for each moneyness portfolio of calls and puts. The sign and significance of the betas help to identify the channels of liquidity risk that are important for each moneyness portfolio. The estimated coefficients of the time-series regressions are used in a subsequent cross-sectional analysis. Moreover, various liquidity betas could potentially be correlated. To address the issue of multicolinearity, special attention is paid to finding a suitable specification of the cross-sectional model, and to interpreting and documenting the results for each moneyness portfolio.

### 6.4.2 Second Pass Regressions: Estimating Risk Premia Using the Fama-MacBeth (1973) Approach

The Fama-MacBeth (1973) approach is used to estimate premia for stock illiquidity, option illiquidity, and liquidity risk betas. The estimation involves two steps. First, a cross-sectional regression is estimated at each time, in our case at each week '$t$'. This is done separately for each moneyness group of calls and of puts.

$$OR_{it} = \gamma_{ot} + \gamma_{1t}c_{it}^{o} + \gamma_{2t}c_{it}^{s}$$
$$+\lambda_{1t}\,\beta_{(dhg,rm)i} + \lambda_{2t}\beta_{(dhg,smliq)i} + \lambda_{3t}\,\beta_{(dhg,omliq)i}$$
$$+\lambda_{4t}\,\beta_{(oliq,rm)i} + \lambda_{5t}\,\beta_{(oliq,smliq)i} + \lambda_{6t}\,\beta_{(oliq,omliq)i} + \lambda_{7t}\,\beta_{(sliq,rm)i}$$
$$+\lambda_{8t}\,\beta_{(sliq,smliq)i} + \lambda_{9t}\beta_{(sliq,omliq)i} + e_{it} \qquad (6.5)$$

where, $OR_i$ is the option return for stock $i$ at time $t$, $\gamma_t$ is the premium at time $t$, $\lambda_t$ is the risk premia for the risk factor $\beta$, $c_{it}^{o}$ is the average illiquidity of the options on stock $i$ at time $t$, and $c_{it}^{s}$ is the illiquidity of the underlying stock $i$ at time $t$.

Second, estimates of $\gamma$ and $\lambda$ are calculated as the averages over time.

$\gamma = \frac{1}{T}\sum_{t=1}^{T}\widehat{\gamma_t}$ and $\lambda = \frac{1}{T}\sum_{t=1}^{T}\widehat{\lambda_t}$

The statistical significance of these coefficients is computed from the standard error of the weekly cross-sectional regression coefficients. The average coefficients and their significance should help to assess whether option returns include an option illiquidity premium, stock illiquidity premium, and which channels of liquidity risk command a liquidity risk premium.

## 6.5 Data

We investigate the impact of option illiquidity, stock illiquidity and liquidity risk channels on option returns. We use individual equity option data. The underlying stocks of the options are constituents of the FTSE 100 index during the period from 2008 to 2010. Stocks in the FTSE100 index are the most liquid on the London Stock Exchange. By choosing the options on these stocks, our results can be considered as highly conservative with regard to evidence of premia for option illiquidity, stock illiquidity and channels of illiquidity risk, if any. Data on options is obtained from the NYSE Euronext LIFFE database, and this includes daily closing bid and ask prices. The data on the underlying stocks and the risk-free interest rate are obtained from Datastream. The sample period is from 22 February 2008 to 31 December 2010, and the sample consists of 71 constituent stocks of the FTSE 100.

The analysis is repeated for five moneyness samples of calls and puts. For each firm, we construct five samples of calls and puts based on moneyness. Options are divided into the following moneyness categories: deep-in-the-money (DITM), in-the-money (ITM), at-the-money (ATM), out-the-money (OTM) and deep-out-the-money (DOTM) options. For calls, moneyness '$m$' is defined as the ratio of the current value of the stock price to the present value of the strike price. For puts, moneyness is defined as the ratio of the present value of the strike price to the current value of the stock price. Options are categorized as DITM if $m > 1.10$, ITM if $1.10 \geq m > 1.05$, ATM if $1.05 \geq m \geq 0.95$, OTM if $0.95 > m \geq 0.90$, and DOTM if $m < 0.90$.

Following Bakshi, Kapadia and Subrahmanyam (2003), Goyal and Saretto (2009) and Cao and Wei (2010), option observations are excluded if the following conditions are satisfied: (i) the option bid-ask midpoint violates the no-arbitrage bounds, (ii) the option ask price is lower than the option bid price, (iii) options with missing bid or ask price, (iv) options with zero bid or ask price, and (v) options whose ask or bid quotes have reporting errors (e.g., option bid is reported 0.001 when it should be 0.10).

### 6.5.1 Option Returns

To investigate uncertainty in option returns, the literature uses three main approaches. Bakshi, Kapadia and Subrahmanyam (2003a, 2003b), Carr and Wu (2009), Cao and Han (2011), and Goyal and Saretto (2009), amongst others, present empirical evidence that uncertainty in option returns is related to investors paying a premium for volatility risk. Accordingly, option returns include a negative volatility risk premium, or a variance risk premium. These studies use zero-return portfolio strategies in which the net-investment pays zero return. However, the literature finds that when these strategies are implemented on market data, they pay significant non-zero returns.[25]

The first approach used in the literature to quantify the returns on options is the delta-hedge strategy. A portfolio is constructed consisting of a long (short) call (put) and short (long) a number of the underlying shares equal to the delta of the option such that the net investment should earn a risk-free rate. The advantage of employing this strategy to calculate the delta-hedged gain and use it as a measure of option return is that it hedges

[25] Bakshi et al. (2003a, 2003b) use delta-hedged option portfolio returns and find that net-investment pay returns that are significantly less than risk-free rate. Carr and Wu (2009) synthesize the variance swap rate using option prices and find that difference between the variance swap rate and the synthesized rate is significantly negative.

risks arising from underlying asset price movements. Any return earned over the risk-free rate should then indicate the presence of a priced risk factor (or factors).

Bakshi, Kapadia and Subrahmanyam (2003a, b) compute delta-hedged gains in order to investigate the presence of the volatility risk premium in index and individual equity options. They construct a portfolio of a long call and short delta of the underlying stock. This portfolio should earn a risk-free rate. They argue that when hedging dynamically, the net gain on the delta-hedged portfolio should be zero, since the risk from the underlying asset price movements is dynamically hedged. Any finding of significant non-zero delta-hedged gains would then imply that there is some other risk that is priced. They argue that this risk is volatility risk, and options are expensive because buyers are willing to pay a premium for increased market volatility.

However, we conjecture that a significant non-zero delta-hedged gain may also indicate that traders in the option or the underlying stock market are concerned about illiquidity; more specifically, concerned about transaction costs of the option or its underlying stock, or even because illiquidity itself is risky. As discussed earlier, illiquidity risk may emanate from various sources and investors may be pricing some of these liquidity risk channels when determining option prices.

The second approach used in the literature is a variance swap. Carr and Wu (2009) employ variance swaps to investigate the variance risk premium in options. They define variance swap as an over-the-counter contract that pays the difference between a standard estimate of the realized variance and a fixed variance swap rate. The swap contract has no initial costs and, consequently, represents the risk-neutral expected value of the realized variance. Carr and Wu (2009) propose that the variance risk premium can be quantified as the difference between the ex-post realized variance and the synthetic variance, which is synthesized from a linear combination of option prices. Using this method they document a significantly negative variance risk premia.

This portfolio construction, however, is very specific to quantifying the variance risk premium, and cannot be employed to investigate whether the liquidity or liquidity risk is priced in options. However, this approach can be used to further investigate the relationship between the variance risk premium and option liquidity, underlying stock liquidity, or liquidity in the option and stock markets. We leave this for future research.

The third approach used in the literature is to estimate the option return as the percentage difference between prices over time (see Christoferssen et al., 2015).

In this chapter we adopt the delta-hedge approach and option returns are determined by using a delta-hedging strategy to calculate the net-gain from discrete hedging by buying or selling delta-shares of the underlying asset at the end of each day of the week. This is described next.

### 6.5.2 Gain of Delta-hedged Option Portfolio

The delta-hedging strategy employed by Bakshi et al. (2003) suggests that the net-investment in a delta-hedged portfolio should earn zero gain as risks arising from underlying asset price movements are dynamically hedged. A gain that is significantly different from zero would then indicate the presence of a priced risk factor(s). It may also indicate that traders in the option or the underlying stock markets are concerned about illiquidity. Therefore, following Bakshi et al. (2003), this analysis constructs delta-hedged option portfolio gains. It is argued that when an option is dynamically hedged to provide zero excess return, any non-zero delta-hedged gain indicates mispricing, which could be related to the illiquidity of options, that of the underlying stock, or the fact that illiquidity is risky over time.

In a delta-hedging strategy, option traders buy and hold the option for a period $\tau$ and hedge the option position by trading delta-shares in the underlying stock market. When stock prices move up or down, traders rebalance the hedge by trading shares accordingly to keep the portfolio hedged at all times. Therefore, delta-hedge call (put) gain is the value of the self-financing portfolio consisting of a long position in a call (put) option hedged by a short (long) position in the underlying stock such that the portfolio is locally insensitive to the underlying stock price movement. The net investment should, consequently, earn the risk-free rate.

The delta-hedged gain, $\widehat{\Pi}(t, t+\tau)$, for a call option is given by:

$$\widehat{\Pi}(t, t+\tau) = C_{t+\tau} - C_t - \int_t^{t+\tau} \Delta_u dS_u - \int_t^{t+\tau} r_u (C_u - \Delta_u S_u) du \tag{6.6}$$

and the discrete equivalent is:

$$\widehat{\Pi}(t, t+\tau) = C_{t+\tau} - C_t - \sum_{n=0}^{N-1} \Delta_{C,t_n}[S(t_{n+1}) - S(t_n)]$$
$$- \sum_{n=0}^{N-1} \frac{a_n r_{t_n}}{365}\left[C(t_n) - \Delta_{C,t_n} S(t_n)\right] \quad (6.7)$$

where $C$ is the call option price defined as the end-of-day bid-ask midpoint, $\Delta_{C,t_n}$ is the delta of a call option on date $t_n$, $r_{t_n}$ is the annualized risk-free rate on date $t_n$, $a_n$ is the number of calendar days between $t_n$ and $t_{n+1}$, $\tau$ is the number of days between the purchase and sale of a call option, $S$ is the price of the underlying stock, and $u$ is the unit of time for a differentiable function. The delta-hedged gain for a put option is calculated similarly except that the price and the delta of a put option replace the price and the delta of a call option.

In the Black-Scholes economy, a call option can be replicated by trading the underlying stock and the risk-free bond. The delta-hedged gain is, therefore, expected to be zero. When there are other risk factors that are priced, replicating an option by trading in the underlying stock would result in delta-hedged gains that would deviate from zero. One may argue that the deviation of the delta-hedged gain from zero may also be due to discrete rebalancing. However Bertsimas, Koga and Lo (2000) show that the delta-hedged gains have a symmetric distribution with zero-mean. This would mean that asymptotically, for a large sample, the delta-hedged gains on average if they deviate from zero would not be due to discrete rebalancing of the hedge.

This analysis calculates gains at a weekly frequency. To construct these gains, we need to define a trading horizon such that we consider both the initial hedge and rebalancing of the hedge and be able to construct option portfolios to study the effects of moneyness and maturity for both calls and puts separately. The trading horizon can be long, like a month or even the maturity of the option, or short such as a week. Given the data sample period from 22 February 2008 to 31 December 2010, we construct gains over a trading horizon of a week. We consider a long delta-hedge strategy, where a trader buys an option and immediately hedges it with delta units of the underlying stock. Thereafter, she rebalances her hedge positions daily. At the end of the week, she will unwind her option delta-hedged portfolio to realize any profits or losses. We choose to begin the trading week on a Wednesday and end it on the following Wednesday. In this way, we incorporate the impact of the information over the weekend in the prices, as well as avoid the beginning and end of weekeffects. The option trader buys an option at the start of the week (Wednesday) and trades the equivalent delta shares in the underlying stock to create a hedged position. At the end of each day, the trader rebalances the hedge by trading the necessary (change in delta) number of underlying stock of that option. On the next Wednesday, the option trader unwinds (closes) the position by selling the hedged portfolio at the end-of-day bid-ask midpoint.

A number of practical issues are faced in implementing this strategy. Some options have missing data during some days of certain weeks. These are classified into four categories. First, there are cases where data within a certain week is unavailable on a Wednesday but is available for the next four days. This creates a problem in calculating the delta-hedged gain for the previous week and the current week. For the previous week, the delta-hedged position cannot be closed, and for the current week it cannot be implemented (on a Wednesday). We follow the literature in handling these cases. For the previous week, the position is closed a day earlier (i.e., on a Tuesday) to calculate the delta-hedged gain. Thus, the week would start on a Wednesday and end on a Tuesday. For the delta-hedged gain in the current week, we implement the delta-hedging strategy a day later, in this case, we buy an option and trade equivalent delta-shares on a Thursday.

Second, there are cases where data is missing for certain days in the middle of a week. The data is sometimes missing for a Friday or a Monday but available for the rest of the days. In these cases we make an assumption that the delta of an option remains the same during the missing days and keep the previous day’s delta-hedged position. Accordingly, the delta-hedged gain for these days would be due solely to the movement in stock prices.

Third, there are cases in which data for some options is missing for two consecutive days at the start of a week (i.e., Wednesday and Thursday). We exclude such options in that week only.

Fourth, there are cases in which data for some options is missing for three consecutive days at the end of the week (i.e., Monday, Tuesday and Wednesday). In these cases, we also exclude such options in that weekly only.

Apart from the above missing data cases, a weekly delta-hedged gain strategy is implemented from Wednesday to Wednesday. If data is not available on a Wednesday, we implement it from Thursday to Wednesday or from Wednesday to Tuesday. If data is not available on both Tuesday and Wednesday, we implement the strategy from Wednesday to Monday. If data is not available on both Wednesday and Thursday, we exclude the option from that week. If data is not available on the three consecutive days of Monday, Tuesday and Wednesday, we exclude the option from that week. In all cases, the delta-hedged portfolio is held for at least three days in a week, and the returns adjusted to provide weekly returns.

### 6.5.3 Measures of Option and Stock Illiquidity

Stock and option illiquidity is measured by the percentage bid-ask spread. For each moneyness portfolio of calls and puts this is calculated as:

$$Option\ Illiquidity^k = \sum_{i=1}^{N} \sum_{j=1}^{M} Option\ Illiquidity_{ij}^k \qquad \text{for each } k = 1, 2, 3, 4, 5$$

where $i$ represents a stock, $j$ represents an option on stock $i$, and $k$ represents a moneyness group, where $k = 1, 2, 3, 4\ or\ 5$ standing for deep-in-the-money (DITM), in-the-money (ITM), at-the-money (ATM), out-the-money (OTM) and deep-out-the-money (DOTM) portfolios, respectively. This illiquidity measure is calculated for call and put options separately.

## 6.6 Descriptive Statistics

In the following section, descriptive statistics of delta-hedged gains, option illiquidity, stock illiquidity, and moneyness portfolios of calls and puts are reported.

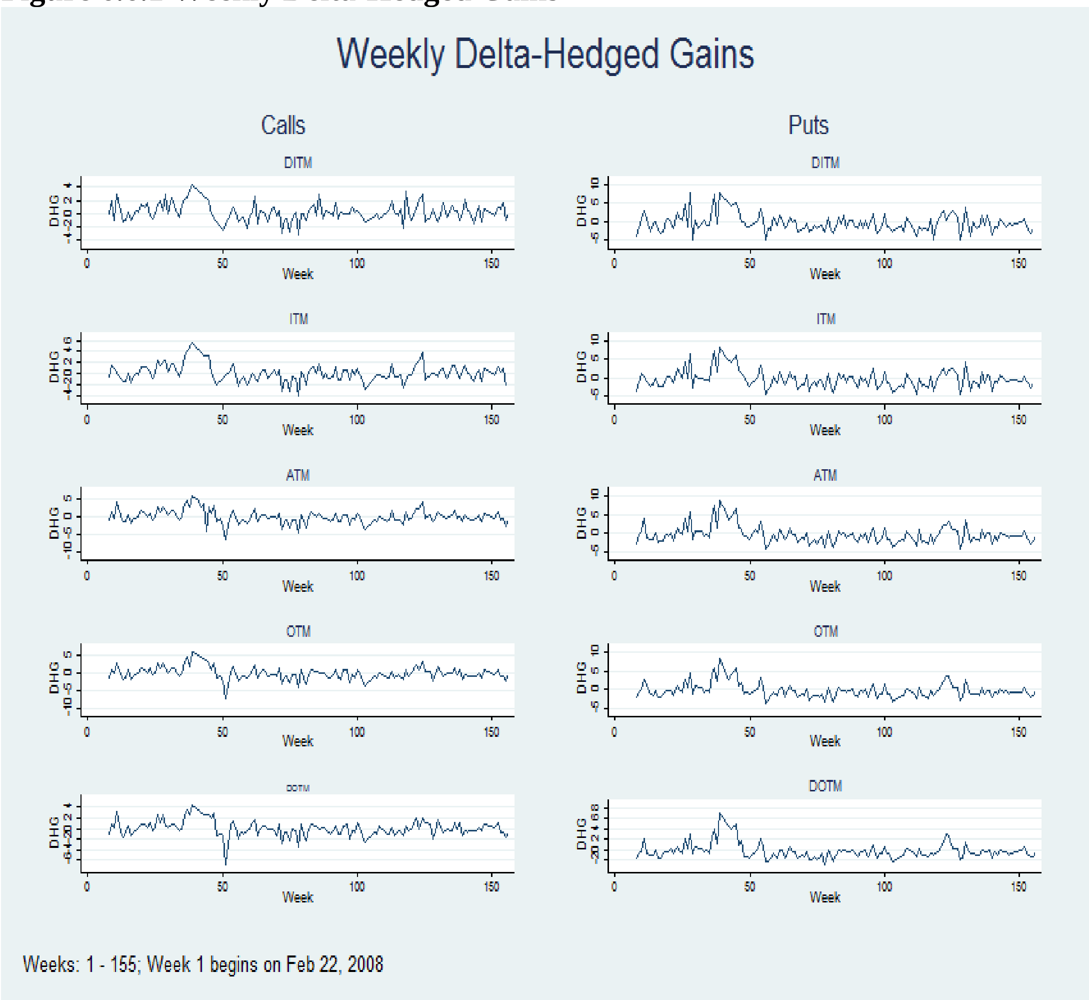
### 6.6.1 Weekly Delta-hedged Gains

Within each moneyness portfolio, and for each stock, the weekly delta-hedged call gain is calculated as the equally-weighted average across call options. The weekly delta-hedged gain of a moneyness portfolio is then a cross-sectional average across stocks. A time series plot of the weekly delta-hedged gains of calls and puts across moneyness portfolios is shown in Figure 6.1. The gains fluctuate around zero, and the patterns seem to be similar across calls and across puts. They also tend to be less volatile in later periods of the sample.

Table C1 in the Appendix presents descriptive statistics for the weekly delta-hedged gains. Puts show negative gains for all moneyness portfolios (Panel A). Gains are more negative for deeper moneyness. However, the delta-hedged gains for call options are positive for all moneyness portfolios, except DOTM calls. In Panel B, first an average of weekly delta-hedged gains is calculated for each stock and then an average across stocks is calculated and reported. The mean values for calls and puts are similar to those reported in Panel A. The percentage of stocks with negative gains (Neg dhg %) is higher for puts than for calls in all moneyness portfolios. Puts show that when delta-hedged gains are averaged over time for each stock, the percentage of stocks with significant negative gains (Neg Sig %) is small, but this percentage is higher for puts than for calls.

The dynamics of the delta-hedged gains across moneyness portfolios and types of options (calls or puts) can indicate different liquidity effects.

**Figure 6.6.1 Weekly Delta-Hedged Gains**



### 6.6.2 Liquidity of Options and their Stocks

A trader will be concerned about the illiquidity of an option and its underlying asset when hedging the option on the day of purchase. Therefore, we report the descriptive statistics of the proportional bid-ask spread of options and their underlying stocks at the beginning of the week in Table C2 in the Appendix.

In implementing the delta-hedged strategy, it is assumed that the week begins on Wednesday therefore, we report statistics for observations on Wednesday averaged over weeks. From the table it is seen that the proportional bid-ask spread of calls and puts decreases in moneyness. This implies that the bid-ask spread is not the same across options. The plausible explanation forwarded by Wei and Zheng (2010) for a similar observation is that a market maker will face high inventory risk for an option with a high leverage. Therefore, to compensate for high inventory risk, she quotes a wider bid-ask spread for high leverage options. Puts have lower average proportional spreads than calls in all moneyness portfolios. The average proportional spread for calls ranges from 9.14 for DITM to 44.51 for DOTM, with ATM calls having an average spread of 15.26 percent. The average proportional spread for puts ranges from 8.22 for DITM to 42.01 for DOTM, with ATM options having an average spread of 14.78. Verousis et al. (2015) also report that the proportional bid-ask spread is higher for calls than puts in the NYSE LIFFE for the same sample period.

## 6.7 Empirical Results

Results of the empirical analysis are reported in this section. Preliminary evidence on the relationship between illiquidity of the underlying stock and the price of the options (i.e., the proportional bid-ask spraed and the implied volatility of options) is presented in Section 6.7.1. Section 6.7.2 provides a summary of the estimated betas using Equations 6.1 to 6.3. Section 6.7.3 presents the results obtained from the Fama-MacBeth (1973) regressions. Section 6.7.4 discusses the results obtained from the analysis.

### 6.7.1 Preliminary Evidence

The implied volatility of an option indicates whether or not an option is expensive. As basic visual evidence, we check how the average price of an option moves over time considering the liquidity of the underlying stock. The liquidity of underlying stocks is lower when the proportional bid-ask spread is higher. In Figure C1, the line graphs of implied volatility of options and the proportional bid-ask spread of the underlying stocks over time indicate that the implied volatility is higher whenever the stock's proportional spread is higher. Higher transaction costs in stocks are related to a higher option price. Implied volatility and underlying illiquidity increased to a peak around Q3 2008 and by Q4 2010 receded to levels below those observed at the beginning of the sample (Q1 2008). Figure C1 also indicates a high correlation between implied volatility of the options and illiquidity of the underlying stocks. This is an early indication of pricing, in options, of underlying illiquidity and the covariance between underlying illiquidity and option returns. In the analysis that follows, when we esti mate the Fama-McBeth model for option delta-hedged gains on the liquidity of the option, the liquidity of the stock, market risk, and various liquidity risk covariances, we find that delta-hedged gains are neither due to the underlying illiquidity of the stock nor due to the sensitivity of option returns to the underlying stock market illiquidity. We provide more detail next.

### 6.7.2 Estimation of First Pass Regression: Market and Liquidity Risk Betas

The time series regressions of Equations 6.1 to 6.3, as described in Section 6.4.1, are estimated for each stock in each moneyness portfolio. In Equation 6.1, weekly delta-hedged net gains are regressed on weekly excess market (FTSE 100) return, weekly illiquidity shocks in the stock market, and weekly illiquidity shocks in the option market. In Equation 6.2, the dependent variable is the shock in the illiquidity of an option, whereas in Equation 6.3, the dependent variable is the shock in the illiquidity of the underlying stock of an option.

**Summary of Coefficient Estimates of First Pass Regression of Market and Liquidity Risk Betas**

A summary of estimates of coefficients $\beta_{(dhg,rm)}$ to $\beta_{(sliq,omliq)}$ is presented in Tables C3 and C4. Table C3 reports the percentage of stocks with significant betas in each moneyness portfolio of calls and puts. For each stock, three time-series regressions are estimated, so we obtain nine betas, and eight out of nine betas are related to liquidity measured by the proportional bid-ask spread. For calls, $\beta_{(dhg,rm)}$ and $\beta_{(dhg,smliq)}$ are significant for more than 50% of stocks in ATM, OTM and DOTM option portfolios. $\beta_{(oliq,rm)}$ is the only beta that is significant for more than 50% of stocks in all moneyness portfolios of call options, with all stocks in the ATM portfolio showing significant betas.

For puts, $\beta_{(dhg,rm)}$and $\beta_{(dhg,smliq)}$ are significant for more than 50% of stocks in all moneyness portfolios. $\beta_{(oliq,rm)}$ is significant for most stocks in ATM, OTM and DOTM portfolios. However, $\beta_{(dhg,omliq)}$and $\beta_{(oliq,smliq)}$ are also significant for some stocks in the moneyness portfolios for puts. For example, less percentage of stocks have significant $\beta_{(dhg,omliq)}$ for ITM calls (18.8%) and puts (32.4%) than ATM and OTM calls (33.3%, 33.3%) and puts (47.1%, 52.9%), respectively. Similarly, 42.4% and 44.1% of underlying stocks of OTM calls and puts have significant $\beta_{(oliq,smliq)}$ compared to 15.2% and 17.6% stocks of ITM calls and puts. $\beta_{(dhg,omliq)}$ is option return sensitivity to shocks in the options market illiquidity and $\beta_{(oliq,smliq)}$ is liquidity commonality between options and their underlying stock market. In the next paragraphs, we discuss the significance of the estimated betas and their patterns across moneyness portoflios.

$\beta_{(dhg,rm)}$ is the market beta for a delta-hedged gain portfolio. The percentage of stocks that show this beta significant is highest across all moneyness portfolios of put options when compared to other betas. Consider calls for comparison. $\beta_{(dhg,rm)}$ in calls is significant for more stocks in all moneyness portfolios except the DOTM portfolio. 89.4% of stocks in DOTM portfolios of calls have significant $\beta_{(dhg,rm)}$ when compared to 75.7% of stocks in DOTM portfolios of puts. Moreover, the percentage of stocks in call portfolios with significant $\beta_{(dhg,rm)}$ is second highest after $\beta_{(oliq,rm)}$, which is one of the liquidity risk betas. This indicates that even after calculating returns of options by constructing a portfolio which is rebalanced daily to keep it completely hedged, its non-zero delta-hedged net gain is related to excess market return, illiquidity in the stock market, and illiquidity in the options market.

Table C4 reports the mean and the standard deviation of betas across all stocks in each moneyness portfolio. The estimation results for the nine betas are first presented next and then subsequently discussed.

$\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$and $\beta_{(dhg,omliq)}$ are estimated by the regression in Equation 6.1. $\beta_{(dhg,rm)}$ is the market beta for a delta-hedged portfolio, and its estimates are negative across all moneyness portfolios for both calls and puts. A negative estimate suggests that a delta-hedged portfolio provides a positive return when the stock market declines. In the cross-section, we expect the market risk premium for delta-hedged gains to be zero, and any deviations could be explained by liquidity risk factors. Puts show more negative estimates of $\beta_{(dhg,rm)}$ than calls, and increasing negativeness with increasing moneyness. However, calls exhibit increasing negativeness with decreasing moneyness, except for the DOTM portfolio, which shows a slight decrease from the OTM portfolio.

$\beta_{(dhg,smliq)}$ can be interpreted as the relative riskiness of option return (delta-hedged net gain) to the shock in liquidity of the underlying stock market. On average, estimates of this beta are positive across stocks in each moneyness portfolio for both calls and puts. ATM option portfolios of both calls and puts have the highest estimates, whereas DITM and DOTM have the lowest. Calls have an average $\beta_{(dhg,smliq)}$ of 1.99 for DITM, increasing to 3.34 for ATM, and decreasing to 2.49 for DOTM portfolios of options. Puts have an average beta of 3.74 for DITM, increasing to 4.45 for ATM, and then decreasing to 3.39 for DOTM options. Puts generally exhibit higher sensitivity of delta-hedged gains to shocks in liquidity of the underlying stock market compared to calls.

$\beta_{(dhg,omliq)}$ can be interpreted as the relative riskiness of option return to the shock in the liquidity of the options market. On average, estimates of this beta are positive for calls and negative for puts in all moneyness portfolios. In absolute terms it is highest for ATM options for both calls and puts, and decreaes for portfolios further away in moneyness from the ATM portfolio. However, puts have higher absolute $\beta_{(dhg,omliq)}$ than calls. Calls show an average beta of 1.78 for DITM, increasing to 3.01 for ATM and decreasing to 1.79 for DOTM options. Puts show an average beta of -2.65 for DITM, decreasing to -5.04 for ATM and increasing to -3.39 for DOTM options. A delta-hedged call option reacts in an opposite way to a delta-hedged put option in respect of a shock in liquidity in the options market.

$\beta_{(oliq,rm)}$, $\beta_{(oliq,smliq)}$ and $\beta_{(oliq,omliq)}$ are estimated by the regression in Equation 6.2. $\beta_{(oliq,rm)}$ can be interpreted as the relative riskiness of a shock in the illiquidity of an option to the excess return of the underlying stock market. A negative $\beta_{(oliq,rm)}$ would suggest that an option provides better liquidity when the underlying stock market performs better. Calls have negative estimates of $\beta_{(oliq,rm)}$, whereas puts have positive estimates in all moneyness portfolios. Estimates of $\beta_{(oliq,rm)}$ are generally increasing in absolute terms with decreasing moneyness for both call and put portfolios. Compared to puts, calls have estimates with a higher magnitude in all moneyness portfolios. In general, these betas suggest that when the underlying stock market is providing positive returns, the illiquidity of calls is improving whereas the illiquidity of puts is deteriorating. This makes sense because calls are generally more traded, while puts are generally purchased as an insurance product. That is probably why puts are traded in declining markets.

$\beta_{(oliq,smliq)}$ can be interpreted as the response of a shock in the illiquidity of an option to a shock in the illiquidity of the underlying stock market. Its estimates are increasing in moneyness for both calls and puts, except the DITM and DOTM portfolios where it is slightly less than the next moneyness portfolios. Estimates have a mixed sign. However, they are negative on average across stocks in OTM and DOTM portfolios of calls and DOTM portfolios of puts. This means that ITM options have a positive correspondence between shocks in their illiquidity and that of the underlying stock market, but OTM options show a negative relationship. These patterns show that ITM options become expensive to trade when the underlying stock market becomes more expensive, while OTM options become cheaper to trade.

$\beta_{(oliq,omliq)}$ can be interepreted as liquidity commonality in the options market. Liquidity commonality is the comovement between the liquidity of an asset and that of the overall market. A shock to liquidity in the options market tends to be linked to a shock in the liquidity of an individual option. Estimates of $\beta_{(oliq,omliq)}$ for calls suggest that liquidity commonality is increasing in moneyness, except for the DITM portfolio that shows a little decline compared to the ITM portfolio. Estimates for ATM, OTM and DOTM are negative, but those for DITM and ITM portfolios have a positive liquidity commonality across stocks. This suggests that market makers when facing illiquidity shocks in the options market tend to encourage trading in out-the-money options but discourage trading in in-the-money options. However, we do not observe any particular pattern for puts.

$\beta_{(sliq,rm)}$, $\beta_{(sliq,smliq)}$and $\beta_{(sliq,omliq)}$ are estimated by the regression of Equation 6.3. Intuitively, these betas should be the same across moneyness portfolios. $\beta_{(sliq,rm)}$, $\beta_{(sliq,smliq)}$ and $\beta_{(sliq,omliq)}$ are estimated through regressing the shock in illiquidity of a stock on the excess market return, the shock in stock market illiquidity and the shock in option market illiquidity. Since, the underlying stocks in each option portfolio are the same across options, a single regression estimation would have been enough. However, as the options were bucketed into moneyness portfolios, a separate analysis for each moneyness category is performed. Differences in estimates of these betas could be observed across moneyness groups, but these differences are small mainly due to two reasons. First, weekly observations for each stock vary depending upon the option observations for each stock in each moneyness portfolio. Second, the total number of stocks differ across each moneyness portfolio, although the difference is only of two stocks. One might also argue that betas estimated by Equation 6.3 should be the same or have similar magnitude for calls and puts. However, differences in magnitude of these betas across calls and puts is due to the definition of option market illiquidity in this estimation. The 'option market' used in analysing calls is the collection of call options, and that used in analysing puts is the collection of put options. These betas are found to be small since the proportional bid-ask spread for stocks averaged around 0.1182 per cent (See Table 6.2) compared to the larger values for options, which ranged from 8.22 (DITM Puts) to 44.51 (DOTM Calls) (see Table C2).

$\beta_{(sliq,rm)}$ is interpreted as the sensitivity of a stock's illiquidity to excess return of the stock market. Estimates are found to be negative for both calls and puts. Calls have slightly higher estimates than puts. A negative $\beta_{(sliq,rm)}$ indicates that on average stocks are liquid when stock market prices increse.

$\beta_{(sliq,smliq)}$ is interpreted as liquidity commonality in the stock market. Its estimates are positive suggesting that a positive shock in stock market liquidity corresponds to a positive shock in individual underlying stock liquidity.

$\beta_{(sliq,omliq)}$ is interpreted as the response of a stock to its illiquidity when the option market faces unexpected illiquidity. Estimates are positive and generally increasing in decreasing moneyness for calls. DITM calls have a beta of 0.1117, compared to 0.1924 for ATM and 0.1878 for DOTM when averaged across stocks in their respective portfolios. For puts, estimates of $\beta_{(sliq,omliq)}$ are negative across all portfolios. The magnitude of this beta generally increases when moneyness decreases, with the only exception being the DITM portfolio. Across stocks, estimates of $\beta_{(sliq,omliq)}$ averaged -0.0379 for the ITM options, lower at -0.0396 for the ATM options and even lower at -0.0686 for DOTM options.

**Summary of Correlations among Variables in Second Pass Regression**

From the above results, it is clear that the cross-sectional correlations between some of the betas will be high. This could potentially lead to biased estimates of premia coefficients in the subsequent cross-sectional regression analysis. Therefore, it is important to identify the betas with high cross-sectional correlations so that multi-collinearity can be dealt with. With this in mind, the correlations of the independent variables for each moneyness portfolio of calls and puts are calculated. We report correlations between the natural logarithm of the options proportional bid-ask spread, the natural logarithm of the stocks proportional bid-ask spread, and the betas estimated by Equations 6.1, 6.2 and 6.3 for only ITM, ATM and OTM portfolios of both calls and puts. Tables C5(a), C5(b) and C5(c) report the correlations for these portfolios, respectively. In each table, the upper half triangle represents correlations for puts and the lower half triangle represents correlations for calls. These correlations play an important role in deciding which cross-sectional specification to estimate, since it is not clear which liquidity beta could explain the variation in option returns. We observe that some of the estimated betas show relatively high correlations between each other and with the log of the options proportional spread (option illiquidity) and with the log of the proportional spread of the underlying stocks (stock illiquidity). Therefore, dropping one of these illiquidity variables becomes a possible collinearity mitigating solution. Option illiquidity shows high positive correlations of 0.685 and 0.684 with underlying stock illiquidity across stocks for both put and call moneyness portfolios. Option illiquidity is highly correlated with $\beta_{(dhg,rm)}$ and $\beta_{(oliq,rm)}$, $\beta_{(dhg,rm)}$ is correlated with $\beta_{(dhg,smliq)}$ and $\beta_{(dhg,omliq)}$, and $\beta_{(dhg,smliq)}$ is also highly correlated with $\beta_{(dhg,omliq)}$ across stocks for both put and call portfolios. Moreover, for ATM option portfolios, option illiquidity also shows high negative correlation across stocks for both calls and puts. These high correlations are considered when conducting the cross-sectional analysis in the next section.

### 6.7.3 Estimation of Fama-MacBeth (1973) Regressions

The cross-sectional regression analysis is performed using the Fama-MacBeth (1973) procedure. At each week '$t$', the cross-sectional regressions are estimated. As discussed in the previous section, nine specifications are estimated for each moneyness portfolio of calls and puts. Average estimates, their significance, number of total weekly observations

(Obs), average R-square (R Square) and total weeks (Weeks) are reported in Tables C6 to C15 in the Appendix.

Specification (1) is a benchmark full model as in Equation 6.5 with all independent variables included. In specification (2), $\beta_{(dhg,rm)}$ is dropped and the model is re-estimated. In specification (3), $\beta_{(dhg,rm)}$ and $\beta_{(sliq,rm)}$ are dropped. In specification (4), $\beta_{(dhg,rm)}$, $\beta_{(dhg,omliq)}$, and $\beta_{(sliq,rm)}$ are dropped. In specification (5), $\beta_{(dhg,omliq)i}$, $\beta_{(oliq,rm)i}$ and $\beta_{(sliq,rm)}$ are dropped. In specification (6), $\beta_{(dhg,rm)}$, $\beta_{(dhg,omliq)}$ and $\beta_{(oliq,omliq)}$ are dropped. Next, we investigate the impact of dropping the liquidity variable for the underlying stock, since it is not significant in most cases and is also highly correlated with some of the variables in different moneyness portfolios. In specification (7), *lnssperc*, $\beta_{(dhg,rm)}$, $\beta_{(dhg,omliq)}$, and $\beta_{(sliq,rm)}$ are dropped. In specification (8), $\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$and $\beta_{(sliq,rm)}$ are dropped. In specification (9), we re-estimate the previous specification (8) by dropping the stock liquidity variable *lnssperc*. Specification (9) includes the option liquidity variable (*lnosprop*), $\beta_{(oliq,rm)}$, $\beta_{(oliq,smliq)}$, $\beta_{(oliq,omliq)}$, $\beta_{(sliq,smliq)}$and $\beta_{(sliq,omliq)}$.

## Calls

This section reports the results of the call option regressions for each moneyness portfolio for the hypotheses discussed in Section 6.3.

***Deep-in-the-Money Calls (DITM)***

The results for DITM calls are reported in Table C6. Those of the full specification (1) show that none of the variables is significant. This is most probably due to the high correlations between the independent variables. The sign of the variables for option illiquidity and stock illiquidity is not as expected. When $\beta_{(dhg,rm)i}$ is removed in specification (2), the coefficient on $\beta_{(sliq,omliq)}$, which is related to the covariance between stock illiquidity and option market illiquidity, becomes significantly negative. Since the average $\beta_{(sliq,omliq)}$ across stocks for calls is positive (see Table C4), an option investor would not wish to hold options on a stock whose liquidity is moving positively with liquidity in the options market. Therefore, the investor would require a premium. However, our finding is contrary to this argument for DITM options. A negative premium would suggest that the option investor would pay a premium for holding DITM call options when the options market faces illiquidity shocks and the option's underlying stock is also illiquid. Although counter-intuitive, an investor will be willing to pay a premium for buying that option if he is either risk-loving or if the investor (end-user rather than the market maker) is net-short in the options market. Considering the demand-based option pricing theory of Garleanu et al. (2010), end-users are net-short in the equity options market. In this case, the end-users who need to hedge the options would be willing to pay a premium to buy an option for hedging purposes although illiquidity of the underlying stock is covarying with illiquidity of the options market. In orther words, if the market-makers are generally net-long in DITM options and do not want to hold a positive inventory of such options, they will demand a premium as these options can be attractive when both the option market and the underlying stocks of DITM calls are highly liquid (less costly to trade underlying stocks for hedging purposes).

In specification (8), we drop $\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$ and $\beta_{(sliq,rm)}$ and re-estimate the results. We find that, the variable for option illiquidity, *lnosprop*, becomes significant at the 10% significance level. Even after dropping *lnssprop*, the variable for stock illiquidity, *lnosprop* and $\beta_{(sliq,omliq)}$ are still significant. However, we find the signs of both these significant variables are contrary to what would be expected from our hypotheses.

***In-the-Money Calls (ITM)***

The results for ITM Calls are reported in Table C7. The full specification (1) shows that the option illiquidity variable, *lnosprop*, and $\beta_{(sliq,omliq)}$, one of the liquidity risk channels, are significant. The option illiquidity variable, *lnosprop*, is positive throughout all specifications but is only significant in the full specification and its magnitude reduces considerably from 0.3301 in the full specification to 0.0283 in specification (8) and 0.0309 in specification (9). This effect is mainly due to dropping variable $\beta_{(dhg,smliq)}$, which is correlated with $\beta_{(dhg,rm)}$, *lnosprop* as well as *lnssprop.* Dropping the other variables *lnssprop*, $\beta_{(dhg,rm)}$, $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$ or $\beta_{(sliq,omliq)}$ does not cause any considerable decrease in the magnitude of the coefficient of *lnosprop* in other specifications. Moreover, $\beta_{(sliq,omliq)}$ remains significant and has a negative sign in all the nine reported specifications. This finding is similar to the finding for DITM calls. This implies that a marginal investor (end-user) in ITM and DITM (in the money call options) are generally net-short and therefore are willing to pay a risk premium for using these options to hedge the underlying stocks.

The most parsimonious specification (9) suggests that only one variable has a consistent and significant explanatory power on the cross-section of delta-hedged portfolio net-gains. This variable is one of the liquidity risk factors. This source of liquidity risk is due to the shock in the illiquidity of a stock comoving with the shock in the illiquidity of the option market. Although insignificant, the signs of the option illiquidity measure, *lnosprop*, $\beta_{(oliq,rm)}$ and $\beta_{(oliq,smliq)}$ are in accordance with our hypotheses. However, $\beta_{(sliq,smliq)}$and $\beta_{(sliq,omliq)}$ have opposite signs from what we hypothesized.

The significant and negative premium for the source of liquidity risk measured by $\beta_{(sliq,omliq)}$ for in-the-money call option portfolios, DITM and ITM, could suggest that market makers are probably net-long in these options and do not want to accumulate any extra inventory of these options and, hence, demand a premium from investors who would like to buy these options for various purposes.

***At-the-Money Calls (ATM)***

The results for ATM Calls are reported in Table C8. They indicate that the option illiquidity variable, *lnosprop*, $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$ are significant in most of the specifications. *Lnosprop* is significantly positive in specifications (1) to (7). It ranges from 0.3705 in specification (2) to 0.5030 in specification (5). The significance is lost in specifications (8) and (9) once $\beta_{(dhg,smliq)}$ is dropped from specification (4) and *lnssprop* is dropped from specification (8), respectively. This shows that correlations among different liquidity risk channels play an important role in determining the sign, magnitude and significance of coefficients. The premium for liquidity risk due to the comovement between the shock in the illiquidity of an option and the return in the underlying stock market, $\beta_{(oliq,rm)}$, is negative and significant. However, liquidity risk due to the comovement between option portfolio returns and the shock in options market illiquidity, $\beta_{(dhg,omliq)}$, is significant and positive in specifications (1), (2) and (3). The sign of the coefficient $\beta_{(dhg,omliq)}$ is opposite to what was hypothesized. It suggests that investors are receiving instead of paying a risk premium for holding a hedged portfolio of options on a stock which has a positive comovement between its delta-hedged net-gain and the shock in the illiquidity of the options market. Once again, there could be two plausible explanations for this. First, the end-user is net-short in at-the-money call options and the market maker is net-long as discussed previously for DITM and ITM options

(Garleanu et al. (2010). Due to net-demand pressure, a net-long options market maker will like to sell the options at lower price compared to the decrease the inventory risk, thus a net-short end-user would earn a positive net-gain on his delta-hedged portfolio. Bongaert et al. (2011) suggest that the sign of the premia on liquidity risk can be positive or negative depending upon the aggressiveness of the trader (determined by either his risk apetite or by his trading horizon). Second, a less aggressive investor, or one who has a longer trading horizon than that of other the traders in the options market, would receive the premium.

***Out-the-Money Calls (OTM)***

The results for OTM calls are reported in Table C9. The results of the full specification (1) suggest that the coefficients of three variables have a significant explanatory power on delta-hedged portfolio net-gains. These three variables are: the illiquidity of an option, the comovement between option illiquidity and the stock market return, and the comovement between option illiquidity and option market illiquidity. The net-gains increase with the illiquidity of options, and decrease with two channels of liquidity risk: the comovement between option illiquidity shock and the return in the underlying stock market, and the comovement between the option illiquidity shock and the shock in option market illiquidity, as represented by $\beta_{(oliq,rm)}$ and $\beta_{(oliq,omliq)}$. The coefficients on *lnosprop* and $\beta_{(oliq,omliq)}$ become insignificant while retaining the same sign when the $\beta_{(dhg,smliq)}$ variable is dropped. The magnitudes of the coefficients of *lnosprop* and $\beta_{(oliq,rm)}$ are lower in absolute terms than those for ATM calls.

***Deep-Out-the-Money Calls (DOTM)***

The results for DOTM calls are reported in Table C10. The option illiquidity variable, *lnosprop*, and one channel of liquidity risk, the comovement between the option illiquidity shock and the stock market excess return ($\beta_{(oliq,rm)}$), are significant in all the specifications. However, $\beta_{(sliq,smliq)}$, which represents the liquidity commonality in the underlying stock market, is for the first time significant for DOTM options in specifications (5), (6) and (8) only.

***Summary and Discussion***

The results for calls indicate that delta-hedged portfolio gains increase in moneyness (see Table C1 and summarized Table 6.1). With the exception of DOTM calls, portfolios have positive mean weekly delta-hedged gains. A non-zero delta-hedge gain would imply that there is some factor which is priced by the option traders. When we investigate whether it is the liquidity of the option, liquidity of the underlying stock, and/or the sources (channels) of liquidity risk which help explain the variation in the weekly delta-hedged gains, we find that the extreme moneyness portfolios of DITM and DOTM behave differently from ITM, ATM and OTM calls. This suggests that the leverage of the options plays a role in explaining the non-zero delta-hedge gain.

We find that option illiquidity is only negatively significant in two specifications for DITM calls. This finding is surprising and contrary to what we hypothesized. The illiquidity premium hypothesis suggests that option returns will be higher for illiquid options. The option illiquidity premium is positive across moneyness portfolios and is mainly significant for ATM, OTM and DOTM calls. Moreover, the option illiquidity premium decreases in moneyness for calls. The plausible explanation that could explain this behaviour is the leverage of the option and the rebalancing costs. A rebalancing cost is related to the rebalancing of the delta such that the portfolio remains delta-hedged. A delta-hedged call option would require less rebalancing when the option is deep-in-the-money. Higher rebalancing costs could arise due to two reasons (Wu et al., 2013). First, changes in delta imply higher rebalancing costs. Second, market makers widen the bid-ask spread when their inventories deviate from their optimal levels, and the greater these deviations are, the higher the rebalancing costs. DITM options are less sensitive to the rebalancing costs, and therefore, the illiquidity premium required by the option trader on a delta-hedged portfolio decreases with moneyness. According to the demand-based option pricing theory of Garleanu et al. (2010), the expensiveness of an option can be explained by the net-demand pressure. When the market is not in zero net-supply, the illiquidity premium can be positive, negative or even zero depending upon who is faced with the illiquidity of the asset. A negative illiquidity premium for DITM and ITM options suggest that probably the end-users in these two option categories are net-short. Therefore, they incur more costs for selling option and, thus, pay an illiquidity premium.

The coefficient on stock illiquidity is not significant in any specification for any portfolio. This suggests that illiquidity of the underlying stock does not affect the option portfolio, which is rebalanced daily by trading its own underlying shares to hedge the risks. It seems the illiquidity of the underlying stock does not play a role in explaining the non-zero gains of a delta-hedged portfolio.

The sources of liquidity risk that are priced in calls differ across moneyness portfolios. For DITM and ITM call portfolios, only $\beta_{(sliq,omliq)}$ is priced. The risk premium is significant and negative. However, we observe that the hedged gains of ATM calls are explained by three sources of liquidity risk: $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$. These repres the comovement between delta-hedged net-gains and the shocks in options market illiquidity, the comovement between the shocks in option illiquidity and the shocks in option market illiquidity, and the comovement between the shocks in stock illiquidity and the shocks in the stock market illiquidity, respectively. For OTM and DOTM option portfolios, $\beta_{(sliq,omliq)}$ is not priced. However, liquidity risk related to liquidity commonality in the option market is found to be priced. The risk premium associated with this variable is negative, which is again contrary to what was hypothesized.

To summarize, options tend to behave more like stocks as moneyness increases. We find that the liquidity risk channel that is related to the liquidity commonality in the options market is no more significant for ITM and DITM options. Moreover, the finding that the illiquidity premium is negative is counterintuitive, because we assume the markets to be in net-positive supply. However, it seems that markets are not in net-positive supply, but either net-zero or net-short. When options are not in net-positive supply, or the trader of a particular option portfolio is more aggressive than an average option trader due to risk aversion or a shorter trading horizon, the signs of the liquidity premia and liquidity risk premia can be opposite to the ones hypothesized under the assumption of positive net-supply. Since the sign of the illiquidity premium for ITM and DITM is negative, and the sign of liquidity commonality in the options market for OTM and DOTM is negative, which are contrary to what we would expect, we suspect that either these options are quite sensitive to rebalancing, or end-users in these options are net-short which would be in line with the arguments of Garleanu et al. (2010).

Since three risk-factors are significant for ATM options, we show how these factors impact the weekly delta-hedged gains:

The estimated specification (7) in Table C8 (also in Table 6.1) is:

$$DHG = -1.6038^{**} + 0.4199^{**}\, lnosprop + 0.0484\, \beta_{(dhg,smliq)} - 11.2303^{***}\, \beta_{(oliq,rm)} + 0.1338\, \beta_{(oliq,smliq)} - 0.1342\, \beta_{(oliq,omliq)} + 0.0979\, \beta_{(sliq,smliq)} - 0.2037^{**}\, \beta_{(sliq,omliq)}$$

In this specification, $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$ are significant for ATM calls. In Table C4 (also Table 6.1), average $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$ across stocks in ATM calls are -0.0494 and 0.1924, respectively. Moreover, we also know that the average weekly delta-hedged gain for ATM calls is 0.154. A percentage increase in each significant beta would affect the weekly delta-hedged gains by 0.1123 and -0.002 pence, all else equal. Based on average liquidity risk betas, the liquidity risk premia for $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$ are 0.554 and -.039 pence, respectively. In this case, the sum of these liquidity risk premia is 0.515 pence. Accordingly, to hold a delta-hedged call portfolio, an investor would demand a liquidity risk premium of 0.515 pence.

**Table 6.1 Fama-MacBeth (1973) Results for Call Option Moneyness Portfolios**
This table reports the results obtained from the Fama-MacBeth (1973) regression estimation of specification (7) for call moneyness portfolios. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | DITM | ITM | ATM | OTM | DOTM |
|---|---|---|---|---|---|
| *lnosprop* | -0.294 | 0.261 | 0.419** | 0.345** | 0.3064** |
| | *0.203* | *0.208* | *0.172* | *0.136* | *0.128* |
| *lnssprop* | | | | | |
| $\beta_{(dhg,rm)}$ | | | | | |
| $\beta_{(dhg,smliq)}$ | 0.048 | 0.051 | 0.0484 | 0.0128 | 0.0104 |
| | *0.034* | *0.032* | *0.040* | *0.038* | *0.032* |
| $\beta_{(dhg,omliq)}$ | | | | | |
| $\beta_{(oliq,rm)}$ | -1.852 | -2.924 | -11.23*** | -6.676*** | -7.214*** |
| | *4.957* | *4.269* | *4.066* | *2.481* | *2.138* |
| $\beta_{(oliq,smliq)}$ | 0.532 | 0.123 | 0.1338 | 0.2344 | 0.0757 |
| | *0.325* | *0.288* | *0.321* | *0.202* | *0.173* |
| $\beta_{(oliq,omliq)}$ | 0.030 | -0.047 | -0.1342 | -0.165* | -0.1412 |
| | *0.166* | *0.167* | *0.127* | *0.095* | *0.106* |
| $\beta_{(sliq,rm)}$ | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.272 | 0.021 | 0.0979 | 0.1252 | 0.1024 |
| | *0.194* | *0.173* | *0.132* | *0.109* | *0.074* |
| $\beta_{(sliq,omliq)}$ | -0.192** | -0.15** | -0.203** | -0.0251 | -0.0176 |
| | *0.097* | *0.077* | *0.080* | *0.078* | *0.070* |
| *Constant* | 0.702 | -0.706 | -1.60*** | -1.381*** | -1.581*** |
| | *0.536* | *0.642* | *0.538* | *0.497* | *0.527* |
| $N$ | 7,742 | 7,081 | 8,886 | 8,103 | 8,475 |
| $R^2$ | 0.169 | 0.175 | 0.209 | 0.226 | 0.240 |
| $N_{wk}$ | 129 | 123 | 140 | 135 | 135 |

## Puts

This section reports the results of put options for each moneyness portfolio separately and then presents a discussion of the results in light of the hypotheses presented in Section 6.3.

***Deep-in-the-Money Puts (DITM)***

The results for DITM puts are reported in Table C11 (also in Table 6.2 for moneyness portfolios for specification (7)). Compared to call portfolios, we generally find more liquidity risk channels that have an explanatory power on delta-hedged gains of put portfolios. In the full specification (1), we find that four channels of liquidity risk, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$ and $\beta_{(oliq,omliq)}$ are significant.

$\beta_{(dhg,smliq)}$ is the channel of liquidity risk that links the relative riskiness of delta-hedged portfolio gains to shocks in stock market illiquidity. The coefficient is significantly negative, which suggests that an option trader who keeps the portfolio hedged with the underlying stock is paying a premium to invest in a portfolio that pays a positive return when there is a shock in stock market illiquidity.

$\beta_{(dhg,omliq)}$ is the risk channel that represents the relative riskiness of delta-hedged portfolio gains to a shock in option market illiquidity. The coefficient is negative, significant only at the 10% level in the full specification, and becomes insignificant when $\beta_{(dhg,rm)}$ is dropped (in specifications (2) to (9)).

$\beta_{(oliq,rm)}$ is the channel of liquidity risk about the comovement between option illiquidity shocks and stock market excess return. This coefficient is positive and significant. This is in contrast with the negative estimates of this coefficient for call portfolios of all moneyness groups. The significance level of this coefficient drops from 5% to 10% in specifications (7) and (8) and is no longer significant when the stock illiquidity variable is dropped.

$\beta_{(oliq,smliq)}$ is the channel of liquidity risk which relates to the comovement between shocks in option illiquidity and shocks in stock market illiquidity. The risk premium associated with this liquidity risk channel is negative and significant at the 10% significance level in specifications (3), (4), (7), (8) and (9). These specifications do not include the liquidity risk channel represented by $\beta_{(sliq,rm)}$ which relates to the comovement between shocks in stock illiquidity and excess stock market return because including it the coefficients to change substantially indicating effects of multicollinearity.

$\beta_{(oliq,omliq)}$ is another channel of liquidity risk that is clearly negative and significant. This channel is related to liquidity commonality in the option market, which is the comovement between shocks in option illiquidity and shocks in option market illiquidity.

*Lnosprop*, the variable for option illiquidity, is significantly positive only in specifications (6), (8) and (9). This variable becomes significant when $\beta_{(oliq,omliq)}$, which is significant, is dropped in specification (6), and when $\beta_{(dhg,smliq)}$, which is significant, is dropped in specifications (7) and (8). this seems to be due to a correlation of -0.236 (unreported) between *lnosprop* and $\beta_{(oliq,omliq)}$, and a correlation of -0.538 (unreported) between *lnosprop* and $\beta_{(dhg,smliq)}$. The positive and significant coefficient for option illiquidity suggests that the delta-hedged portfolio gain is higher for illiquid options, confirming the illiquidity premium hypothesis.

***In-the-Money Puts (ITM)***

The results for ITM puts are reported in Table C12. They show that *lnosprop*, $\beta_{(oliq,rm)}$ and $\beta_{(oliq,omliq)}$, help explain delta-hedged portfolio gains.

The illiquidity premium, which is the coefficient on *lnosprop*, for ITM puts is positive and significant in all specifications. Although the coefficient of stock illiquidity, *lnssprop*, is insignificant, it has a negative sign, which is consistent with the hedging cost hypothesis.

The coefficient on $\beta_{(oliq,rm)}$, which is the channel of liquidity risk that results from the comovement between shocks in option illiquidity and excess returns in the stock market, is positive and significant. This liquidity risk premium is higher for ITM than DITM and is contrary to what was hypothesized. For example, the risk premium is 5.470 for DITM (though insignificant; see Table C11) compared to a significant 11.933 for ITM in specification (9).

$\beta_{(oliq,omliq)}$ is negative and significant at the 1% level in all specifications. The coefficient for ITM puts is less negative than what was estimated for DITM puts. The coefficient is found to be -0.8462 for DITM compared to -0.6275 for ITM. All other liquidity risk variables are insignificant across all the specifications.

***At-the-Money Puts (ATM)***

The results for ATM puts are reported in Table C13. They show that option illiquidity and the three channels of liquidity risk, $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$and $\beta_{(sliq,smliq)}$, have a significant explanatory power on the variation in delta-hedged portfolio gains of ATM puts.

The liquidity risk premium related to the comovement between shocks in option illiquidity and excess returns in the stock market, $\beta_{(oliq,rm)}$, is significantly positive across all specifications. Significance decreases from the 1% level in the full specification to the 10% level in the most parsimonious specification (9). This liquidity risk premium is also smaller for ATM puts than for ITM puts. The figure for ITM puts is 11.933 (Table C12) compared to 6.90 for ATM puts in specification (9).

For ATM puts, liquidity commonality in the option market, $\beta_{(oliq,omliq)}$, and liquidity commonality in the stock market, $\beta_{(sliq,smliq)}$, are significant. The liquidity risk premium related to comovement between shocks in option illiquidity and shocks in option market illiquidity, $\beta_{(oliq,omliq)}$, is negative and significant across all specifications. On the other hand, the liquidity risk premium related to comovement between shocks in stock illiquidity and shocks in stock market illiquidity, $\beta_{(sliq,smliq)}$, is positive and significant across all specifications.

***Out-the-Money Puts (OTM)***

The results for OTM puts are reported in Table C14. The results for OTM puts are similar to those of ATM puts in Table C13. Option illiquidity and three liquidity betas have explanatory power on variations in delta-hedged gains. The liquidity risks that are priced in OTM puts is related to $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$ and $\beta_{(sliq,smliq)}$.

The option illiquidity premium is significantly positive and is higher for OTM than ATM puts. The liquidity risk premium related to $\beta_{(oliq,rm)}$ is positive and significant but is smaller than for ITM and ATM puts. The results indicate that the liquidity risk premium related to $\beta_{(oliq,rm)}$ decreases in the moneyness. The liquidity risk premium related to $\beta_{(oliq,omliq)}$ is negative and significant. This liquidity risk premium for OTM puts is smaller in absolute terms than for ATM puts. Moreover, the liquidity risk premium related to $\beta_8$ is positive and significant. Apart from the premium for option illiquidity, the sign for liquidity risk premia related to $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$and $\beta_{(sliq,smliq)}$ are contrary to what was hypothesized.

***Deep-Out-the-Money Puts (DOTM)***

The results for DOTM puts are reported in Table C15. The results are slightly different than those for ITM, ATM and OTM puts. The coefficient of option illiquidity, *lnosprop*, is positive but is significant in specifications (1) to (7). However, it becomes insignificant when $\beta_{(dhg,smliq)}$ is dropped in specifications (8) and (9). The option illiquidity premium is positive as hypothesized. We also observe that the coefficient of stock illiquidity, *lnssprop*, is significant and positive, while we should expect a negative sign according to the hedging cost hypothesis.

The coefficient of $\beta_{(oliq,rm)}$ is positive and significant across all specifications. However, it is only $\beta_{(oliq,smliq)}$ which is significant in DOTM and DITM puts across all specifications. Moreover, $\beta_{(oliq,omliq)}$ is only significant and positive in specifications (1), (2), (3) and (5). Significance is at the 10% level, which is lower than the significance level of 1% for ATM and OTM portfolios.

***Summary and Discussion***

Weekly delta-hedged portfolio gains for puts are negative and decrease in moneyness. DITM puts have more negative average weekly delta-hedged portfolio gains compared to ITM puts (See Table C1). This is opposite to what is observed for calls.

Unlike call moneyness portfolios, various liquidity and liquidity risk variables explain variations in weekly delta-hedged gains in puts. We find that option illiquidity is priced in most specifications across all moneyness portfolios and is found to be positive and significant. This suggests that investors demand an option illiquidity premium to hold an illiquid option. This finding is in line with the liquidity premium hypothesis. ATM puts have a lower option illiquidity premium than ITM and OTM puts. Moreover, DITM and DOTM puts do not follow the trend observed in middle moneyness portfolios (ITM, ATM and OTM), in the magnitude and significance of option illiquidity and significance of some betas. This positive premium for put option illiquidity suggest that option buyers demand a compensation for illiquidity of the option. However, we do not find this to be the case for call options. Only ITM and DITM call portfolios show significant but negative coefficient on option illiquidity. We argued that this could be because of rebalancing costs or that the options are in net-short supply. By a similar argument the positive illiquidity premium in puts suggests that these put options are, generally, in net-positive supply.

With the exception of DOTM puts, the stock illiquidity variable is insignificant across all moneyness portfolios of puts. This suggests that, like calls, the hedging cost premium is not part of the delta-hedged portfolio net-gains of options. This could be because the measure of option return used in this analysis is the delta-hedged net gain. By delta-hedging, we already take into account the price, and implicitly the illiquidity, of the underlying asset when buying a call or a put option.

There are generally more channels of liquidity risk priced in puts compared to calls. These are: the comovement between gains and the shock in the liquidity in the option market ($\beta_{(dhg,smliq)}$), the comovement between the shock in the liquidity of an option and the stock market excess return ($\beta_{(oliq,rm)}$), the comovement between the shock in the liquidity of an option and the stock market illiquidity ($\beta_{(oliq,omliq)}$), and the comovement between the shock in the liquidity of a stock and the shock in the liquidity of the stock market($\beta_{(sliq,smliq)}$). DITM puts show that $\beta_{(dhg,smliq)}$, $\beta_{(oliq,rm)}$ $\beta_{(oliq,omliq)}$ are priced. For ITM puts, only $\beta_{(oliq,rm)}$ and $\beta_{(oliq,omliq)}$ are priced. For ATM and OTM puts, liquidity commonality in the option ($\beta_{(oliq,omliq)}$) and in the stock market ($\beta_{(sliq,smliq)}$), as well as ($\beta_{(oliq,rm)}$), which is related to the comovement between shocks in option illiquidity and excess stock market returns, are priced. For DOTM puts, the liquidity risk premium is related to $\beta_{(oliq,rm)}$, $\beta_{(oliq,smliq)}$ and $\beta_{(sliq,smliq)}$. However, $\beta_{(sliq,smliq)}$is not significant in all specifications.

Since ATM options show a higher number of significant explanatory factors, we reproduce below the estimated specification (7) reported in Table C13 (also in Table 6.2).

$$\begin{aligned} DHG = & -1.4399^{**} + 0.3945^{**}\, lnosprop - 0.0252\, \beta_{(dhg,smliq)} \\ & - 10.2365^{***}\, \beta_{(oliq,rm)} + 0.1317\, \beta_{(oliq,smliq)} - 0.458^{***} \beta_{(oliq,omliq)} \\ & + 0.5102^{***}\, \beta_{(sliq,smliq)} - 0.0951\, \beta_{(sliq,omliq)} \end{aligned}$$

**Table 6.2 Fama-MacBeth (1973) Results for Put Option Moneyness Portfolios**
This table reports the results obtained from the Fama-MacBeth (1973) regression estimation of specification (7) for put moneyness portfolios. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | DITM | ITM | ATM | OTM | DOTM |
|---|---|---|---|---|---|
| *lnosprop* | 0.2793 | 0.432** | 0.3945** | 0.507*** | 0.321** |
| | *0.177* | *0.170* | *0.174* | *0.154* | *0.135* |
| *lnssprop* | | | | | |
| $\beta_{(dhg,rm)}$ | | | | | |
| $\beta_{(dhg,smliq)}$ | -0.113*** | -0.0427 | -0.0252 | -0.0453 | -0.0033 |
| | *0.039* | *0.039* | *0.042* | *0.038* | *0.038* |
| $\beta_{(dhg,omliq)}$ | | | | | |
| $\beta_{(oliq,rm)}$ | 6.690* | 9.857** | 10.2366*** | 8.650*** | 5.805** |
| | *3.774* | *4.085* | *3.753* | *2.723* | *2.659* |
| $\beta_{(oliq,smliq)}$ | -0.5687* | 0.032 | 0.1317 | 0.2342 | 0.337** |
| | *0.318* | *0.236* | *0.216* | *0.145* | *0.133* |
| $\beta_{(oliq,omliq)}$ | -0.61*** | -0.409*** | -0.458*** | -0.327*** | -0.0281 |
| | *0.202* | *0.152* | *0.125* | *0.104* | *0.084* |
| $\beta_{(sliq,rm)}$ | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.1107 | 0.235* | 0.5102*** | 0.371*** | 0.1696 |
| | *0.156* | *0.142* | *0.139* | *0.118* | *0.106* |
| $\beta_{(sliq,omliq)}$ | -0.0366 | -0.1286 | -0.0951 | -0.0902 | -0.0128 |
| | *0.131* | *0.122* | *0.132* | *0.100* | *0.074* |
| *Constant* | -0.6110 | -1.38*** | -1.4399** | -1.934*** | -1.589*** |
| | *0.444* | *0.465* | *0.561* | *0.563* | *0.511* |
| $N$ | 8,419 | 7,899 | 9,150 | 8,513 | 8,790 |
| $R^2$ | 0.231 | 0.253 | 0.250 | 0.257 | 0.261 |
| $N_{wk}$ | 133 | 132 | 140 | 137 | 136 |

In this specification we find that for ATM puts, $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$ and $\beta_{(sliq,smliq)}$ are significant. Compared to ATM calls, two different sources of liquidity risk are priced, and both of these relate to liquidity commonality in option and stock markets. In Table C4, average $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$ and $\beta_{(sliq,smliq)}$ across stocks in ATM puts are 0.0299, 0.0173, and 0.0393, respectively. Moreover, we also know that the average weekly delta-hedged gain for ATM puts is -0.308. Accordingly, all else equal, a percentage increase in each significant beta would affect the weekly delta-hedged gains by 10.23%, -0.458% and 0.51%, respectively. Based on average liquidity risk betas, the liquidity risk premia for $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$and $\beta_{(sliq,smliq)}$ are 0.306, -0.0078 and 0.02, respectively. The total liquidity risk premium is approximately 0.3181. This positive value for the liquidity risk premium suggests that an investor demands liquidity risk premium to hold a delta-hedged put portfolio, as this portfolio is not completely riskless and shows that there are some systematic liquidity risk factors that are priced in the options.

## 6.8 Conclusion

In this chapter, we investigate three main research questions on NYSE Euronext LIFFE London equity options. The first is whether the price of an option includes a premium for the illiquidity of an option. This is referred to as the liquidity premium hypothesis, which suggests that the return of an illiquid asset includes a premium for its illiquidity compared to an otherwise liquid asset. Therefore, the return on an illiquid option compared to an otherwise identical but liquid option should be higher.

The second research question is whether the price of an option includes a premium for the liquidity of an option. This is referred to as the hedging cost hypothesis, which purports that higher transaction costs in trading a stock increase the costs of replicating an option and, consequently, the price of the option. This in turn reduces the option's return.

The third research question is which sources of liquidity risk are important for pricing options? From the asset pricing literature, we know that liquidity risk emanates from three main comovements (Acharya and Pedersen, 2005) specific to one market. However, since options are replicative securities whose payoff depends on the payoffs of the underlying stocks, the sources of liquidity risk emanate from both the underlying stock market and the option market. We identify nine different sources of comovements that are related to liquidity risk. Option return, option liquidity, and stock liquidity are important factors that comove with stock market excess return, stock market liquidity and option market liquidity. We then investigate which of these nine sources of liquidity risk are priced in equity options by using the Fama-MacBeth (1973) procedure in which we first estimate the liquidity betas using Equations 5.1, 5.2 and 5.3 and then estimate the risk premia associated with these liquidity betas using cross-sectional regressions. The analysis is carried out for different moneyness groups and separately for calls and puts, so that the sources of liquidity risk priced in different moneyness portfolios can be identified.

In complete markets, an option is a replicative security. However, when a delta-hedged portfolio of options is constructed, net delta-hedged gain is found to be non-zero (see Table C1). In interest rate options, Deusker et al. (2001) suggest that this non-zero delta-hedged gain is because option investors are willing to pay a premium for volatility risk as the options provide a hedge against market declines, and higher volatility is associated with declining markets. However, we argue that delta-hedged gains are non-zero because illiquidity is priced, since illiquidity is also associated with declining markets.

To investigate these research questions we construct delta-hedged portfolios and calculate weekly delta-hedged net-gains for these portfolios. The net gain is calculated by buying an option at the beginning of a week and hedging it with delta underlying shares to keep the portfolio completely hedged such that it provides a risk-free return. We assume the week starts on Wednesday. We rebalance the delta-hedge strategy by purchasing more or less delta shares depending on the movement in the underlying stock and the type of option, whether a call or a put. We wind up the delta-hedged portfolio position by selling the option and trading the delta-shares. The net-gain from this strategy is termed as the weekly delta-hedged portfolio gain, and is the portfolio's return that we seek to explain.

We find that average weekly delta-hedged net-gains for calls and puts behave differently across moneyness portfolios. The weekly gains for calls increase in moneyness whereas for puts they decrease in moneyness.

We estimate betas in time-series regressions as given in Equations 5.1, 5.2 and 5.3 for each stock in each moneyness portfolio of calls and puts. Betas that are significant for most stocks in a portfolio are $\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$ and $\beta_{(oliq,rm)}$ for calls and $\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$, $\beta_{(oliq,smliq)}$ and $\beta_{(oliq,omliq)}$ for puts.

We then estimate Fama-MacBeth (1973) cross-sectional regressions to investigate the role of liquidity variables and channels of liquidity risk in explaining the variation in weekly delta-hedged portfolio net-gains. We find that option illiquidity, as measured by the natural logarithm of the option's proportional bid-ask spread, is positive for call moneyness portfolios except DITM. For puts, it is positive and mostly significant across moneyness portfolios.

However, there is no evidence of a hedging cost premium as the coefficient on the underlying stock illiquidity is insignificant and has mixed sign in various specifications estimated across moneyness portfolios of calls and puts. This finding is contrary to Cetin et al (2006) who suggest that when the underlying asset is not assumed to be perfectly liquid, the liquidity cost of the underlying asset is a significant component of the option price, and the impact on the option price depends on the moneyness of the option.

We find evidence of liquidity risk premia in both calls and puts, with these risk premia being related to different sources of liquidity risk across moneyness for puts and calls.

For calls, the comovement between gains and the shock in the liquidty of the option market ($\beta_{(dhg,omliq)}$), the comovement between the shock in liquidity of an option and the stock market excess return ($\beta_{(oliq,rm)}$), and the comovement between the shock in liquidity of a stock and the shock in the liquidity in the option market ($\beta_{(sliq,omliq)}$) are priced sources of liquidity risk for ATM portfolios. For DITM and ITM portfolios we find $\beta_{(sliq,omliq)}$ the only priced source of liquidity risk. Further, this source of liquidity risk, $\beta_{(sliq,omliq)}$, is not priced in OTM and DOTM calls. Rather, another source of liquidity risk, liquidity commonality in the option market, represented by $\beta_{(oliq,omliq)}$, is priced.

Liquidity risk premia related to liquidity commonality in the option market, $\beta_{(oliq,omliq)i}$, as well as the stock market is found to be more important for puts than for calls. $\beta_{(oliq,omliq)}$ is priced in DITM, ITM, ATM and OTM puts. $\beta_{(sliq,smliq)}$, which is liquidity commonality in the stock market, is priced in ATM, OTM and DOTM puts. $\beta_{(oliq,rm)}$, which is the source of liquidity risk related to the comomvement between option illuiqidity shocks and stock market excess return, is significant in all portfolios. $\beta_{(oliq,smliq)}$, which is the source of liquidity risk related to the comovement between option illiquidity shocks and stock market illiquidity shocks, is priced only in DOTM options.

We also calculate the liquidity risk premia for ATM calls and puts using the significant sources of liquidity risk as in specification (7). We find that there are two sources of liquidity risk which are priced in ATM calls, namely $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$, whereas, the sources of liquidity risk priced in ATM puts are $\beta_{(oliq,rm)}$ , $\beta_{(oliq,omliq)}$ and $\beta_{(sliq,smliq)}$. Interestingly, three sources of liquidity risk are significant in ATM puts compared to two sources for ATM calls. However, using average beta values from Table C4, we find that the total liquidity risk premia for ATM calls is 0.515 compared to 0.3181 for ATM puts. Although more sources of liquidity risk are priced in ATM puts, liquidity risk premia demanded by investors in calls is higher than that in puts. This suggests that calls are more liquidity-risky than puts.

# CHAPTER 7
# SUMMARY AND CONCLUSION

## 7.1 Introduction

This chapter summarises the main findings relating to the objectives of each of the empirical chapters, highlights the contributions, draws overall conclusions of the thesis and presents suggestions for future research.

In this thesis, we perform empirical analysis for options by stocks but separately for call and put options. We do it mainly because liquidity of calls and puts behave asymmetrically with respect to increase or decrease in the market. For example, Chordia et al. (2001) provide the evidence that liquidity in the stock market decreases in a declining market and increases only slightly up. Moreover, calls are more liquid in up markets and puts are more liquid in down markets (Cao and Wei, 2010). Given option is used as a hedging instrument, its hedging argument motivates us to perform a separate analysis for calls and puts.

An outline of the main findings of the empirical analyses of Chapters 4, 5 and 6 are presented in Sections 7.2, 7.3, and 7.4 respectively. Section 7.5 summarizes the overall findings, Section 7.6 reports the main contributions of this thesis, and Section 7.7 highlights the limitations and suggests the recommendations for future research.

## 7.2 Main Findings of Empirical Analysis of Chapter 4

Evidence of liquidity comovement between assets and their markets is very well documented in the literature. This evidence is important for understanding the variation in asset returns, since liquidity comovement is one of the potential sources of liquidity risk according to the Liquidity-adjusted Asset Pricing Model of Acharya and Pedersen (2005). Likewise, liquidity risk is important for option markets. Since options are securities whose payoff depend on the price of the underlying asset, the sources of liquidity risk would be related to both the options market and the underlying asset market. In Chapter 4, we argue that in the equity options market, there are two main sources of liquidity comovement: variations in the liquidity of an option with those of the option market, and with those of the underlying stock market. The second source is motivated by the argument that hedging is the primary reason for trading in the derivatives market (Cho and Engle, 1999). The main findings of this chapter are reported next.

### 7.2.1 Liquidity Comovement between Options and their Market

Liquidity comovement between options and their market is found to be positive and significant across all moneyness and maturity portfolios for calls, puts, and all options (calls and puts combined). In the time-series market model of liquidity commonality, where option illiquidity is regressed on option market illiquidity, lagged option market illiquidity and control variables, we find that, in general, the coefficient on option market illiquidity is positive and significant but the coefficient on the lagged option market liquidity shows mixed sign and significance for only some stocks in most portfolios. ATM options have higher liquidity comovement than OTM and ITM options. One possible explanation is that ATM options are most actively traded and are more sensitive to changes in the stock price and volatility. We do not observe any particular pattern in the liquidity comovement across maturities, which suggests that it is leverage which is important for liquidity commonality.

Regardless of the type of option, liquidity comovement in the options market is found to be significant. When calls and puts are combined in portfolios, liquidity comovement is higher than when they are analysed separately. The coefficient of option market liquidity when estimating the time-series market model for liquidity commonality, liquidity comovement has the same sign regardless of whether liquidity is measured by the proportional bid-ask spread (option spread as a percentage of option bid-ask midpoint) or the percentage bid-ask spread (option spread as a percentage of the stock price). However, the percentage spread shows a positive and higher liquidity comovement. These patterns are robust across moneyness and maturities.

Inventory risk and information asymmetry are higher for small firms. When stratifying option portfolios further into four quartiles according to the size of the underlying stocks, most portfolios of calls and puts show a small firm effect in the liquidity comovement between options and their market. However, when calls and puts are combined, only the portfolios with maturity greater than 91 days show a small firm effect. We also observe for calls within the 30-day maturity group that liquidity comovement for the underlying firms within the first size quartile increases with moneyness. A similar effect is observed for portfolios of put options, and across all options with maturity greater than 91 days.

We also analyse these effects while controlling for volatility. When volatility is higher, market-makers widen the bid-ask spread. Consequently, as they increase the bid-ask spread for volatile stocks, these stocks may also exhibit high liquidity comovement. When options are stratified into four quartiles of stocks based on their average implied volatility of the options we find mixed results for implied-volatility (IV) effects in call, put and all option portfolios. Liquidity comomvement is high for calls and puts whose underlying stocks have high implied volatility. When liquidity comovement is estimated across all options, rather than separately for calls and puts, ITM, ATM and OTM options with a maturity of 30 days show higher liquidity comovement for stocks with high IV options. This effect may be due to the fact that options close to maturity are more volatile compared to options with longer maturities.

### 7.2.2 Liquidity between Options and their Underlying Stock Market

ATM options show higher liquidity comovement with their underlying market than ITM and OTM options. This comovement is found to be positive for all portfolios of call options. However, it is found to be negative, but insignificant, for some portfolios of put options.

Liquidity comovement for all options combined is higher than the liquidity comovement for calls and puts when considered separately. It ranges from 0.0014 to 0.1142 for calls, and is much lower than the liquidity comovement between options and their options market, which ranges from -0.0003 to 0.6496 for calls. This evidence supports the hedging argument of the derivative hedge theory (Cho and Engle, 1999).

These findings show that option liquidity comoves with the liquidity of both the options market and the underlying stock market, but the comovement with the options market is higher.

The above results for liquidity comovement are robust for calls, puts and all options to the choice of illiquidity measures. Similar results are found when illiquidity is measured by the percentage spread and when it is measured by the proportional bid-ask spread. Specifically, liquidity comovement between options and the stock market is higher for

ATM option portfolios than for ITM and OTM portfolios. Across call, put and all options portfolios, put options exhibit the highest liquidity comovement and call options the lowest.

Liquidity comovement between options and the underlying stock market shows mixed results across size quartile option portfolios. As observed for the liquidity comovement between options and their market, the liquidity comovement between options and their underlying stock market does not show any pattern across moneyness and maturity in any size quartile.

The volatility effect for liquidity comovment with the underlying stock market is also not consistent across all portfolios of calls, puts and all options. Generally, declining stock markets show higher volatility and relatively lower liquidity. Consequently, the cost of hedging is expected to be higher. Therefore, the liquidity comovement of volatile stocks should be higher. However, the results do not show such evidence. Further, a larger number of put portfolios show volatility effects than call portfolios.

### 7.2.3 Spread Variations in the NYSE Euronext LIFFE London Equity Option Market

Derivative hedge theory does not help explain the observed option spreads for most portfolios, whereas we find that information asymmetry theory helps explain the spreads of ATM and OTM options with maturity greater than 60 days. Since OTM options provide high leverage, the impact of information asymmetry is found to be higher in these options. This also suggests that investors may be hiding their information by trading in options with high leverage to exploit information asymmetries. OTM options show a higher and positive relation between the percentage change in option spreads and the percentage change in open interest (proxy for inventory risk). However, some of the ITM portfolios show a negative relationship. We conclude that inventory risk is higher for OTM options. From inventory-risk perspective, we expect volume to be negatively related to option spreads, but our findings suggest that this is not the case for all portfolios. For all options portfolios, this relationship is positive and significant for most OTM, ATM, and ITM portfolios. Call portfolios show an insignificant relationship, and most put portfolios show an insignificant positive relationship. This finding is contrary to what inventory theory suggests, since we find a positive (though mostly insignificant) relationship. Black (1975), Easley and O'Hara (1998), and Pan and Poteshman (2006), however, suggest that traders with private information may trade options because of their inherent leverage. Pan and Poteshman (2006) show that option volume can predict stock prices. With our finding of a positive and significant relationship for option portfolios that are ITM, ATM, and OTM, it seems that information asymmetry theory would be an acceptable explanation for the spreads in the options market, as the higher option volume may be an indication of the arrival of new information.

## 7.3 Main Findings of Empirical Analysis of Chapter 5

In Chapter 5, the sensitivity of option return to the illiquidity in the options market and in the stock market is investigated across moneyness and maturity portfolios of calls and puts. Several papers have investigated the effect of the spot (stock) and option illiquidity levels on option prices (Brenner et al., 2001; Chou et al., 2013; Feng et al., 2013). Although illiquidity in cross-sectional analysis is an important determinant of asset prices, the comovement of liquidity with market-wide factors is found to be an important determinant of returns in the stock market (Amihud, 2002; Acharya and Pedersen, 2005), and in the option market (Frey, 2000; Cetin et al., 2004 and 2006).

The persistence in illiquidity in the options and stock markets can have time-series effects on option returns. This persistence allows for the decomposition of illiquidity into expected and unexpected components. We develop and investigate two hypotheses for both option market illiquidity and stock market illiquidity. The first hypothesis is expected illiquidity in the option market has a positive effect on option expected returns. The second hypothesis is unexpected illiquidity in the option market has a negative effect on contemporaneous option returns.

Intuitively, persistence in stock market illiquidity implies that if the market is illiquid today, it is likely to also be illiquid the next day. This would be reflected in a lower current asset price as investors would demand a higher return. Lower prices in stocks will result in lower prices for call options and higher prices for put options on these stocks. This suggests that higher illiquidity in the stock market leads to higher returns on call options (the first hypothesis). When there is a positive shock in stock market illiquidity (unexpected illiquidity) current stock prices will decrease, thereby reducing contemporaneous option returns (the second hypothesis). We find that illiquidity in the stock market, as measured by the proportional bid-ask spread, is less persistent (0.736) than illiquidity in the option market (0.847), given an AR(1) specification. However, we use an AR(p) specification with lag structure determined by the AIC and BIC criteria to separate illiquidity, as measured by proportional bid-ask spread, into expected and unexpected parts for each of calls, puts, all options, and the stock market. The sensitivity of option returns to illiquidity in the options market is analysed by regressing the unexpected and expected illiquidity on option returns for each moneyness and maturity portfolio. The results are summarised next.

### 7.3.1 Option Return Sensitivity to Option Market Illiquidity

The results of the regression of expected and unexpected illiquidity in the option market on option returns suggest that the coefficient of expected illiquidity in the options market is positive and significant for most moneyness and maturity call portfolios. The effect is smaller for calls with longer maturity than shorter maturity. This may be because traders consider expected illiquidity more important in the short term. Returns of put portfolios, however, do not exhibit significant sensitivities to expected illiquidity in the option market.

Unexpected illiquidity in the option market has a negative impact on contemporaneous option excess returns. Returns of call portfolios show a decreasing sensitivity as unexpected illiquidity decreases, in both moneyness and maturity. The coefficient on expected illiquidity is generally smaller than that on unexpected illiquidity for call portfolios. Returns of put portfolios do not show any particular pattern with respect to unexpected illiquidity across moneyness. However, they show higher sensitivity to unexpected illiquidity at higher maturities. ATM put portfolios show a decreasing absolute coefficient of unexpected illiquidity in the option market over longer maturities.

### 7.3.2 Option Return Sensitivity to Stock Market Illiquidity

The results also suggest that option portfolio returns are generally not sensitive to stock market illiquidity for most call and put portfolios. We find that option return sensitivity is significantly affected by expected illiquidity in the stock market for eleven out of thirty call portfolios and three out of thirty put portfolios. Only DITM call portfolios (five) with maturity greater than 30 days are sensitive to expected illiquidity in the stock market. This may be due to the delta effect, which is that DITM calls act more like stocks as they have delta close to one. Moreover, returns of call portfolios with long maturities show significant sensitivity to unexpected illiquidity in the stock market. However, returns of put portfolios do not depict any sensitivity to unexpected illiquidity in the stock market.

One possible explanation could be an asymmetric response to stock market illiquidity shocks based on the upward or downward movement of the stock market.

Fixed effects regressions are estimated to take into account the individual moneynes and maturity characteristics of the option portfolios. The results show that returns of call portfolios have a positive sensitivity to expected illiquidity in the option and stock markets. However, the coefficient of unexpected illiquidity, though significant, changes sign when controlling for log volatility. Moreover, returns of put portfolios have a positive sensitivity to expected illiquidity in the option market as well as in the stock market, as expected. However, returns of put portfolios have a negative sensitivity to unexpected illiquidity in the option market and a positive sensitivity to unexpected illiquidity in the stock market. This may be due to the short supply in the underlying stock market during that period.

These findings are robust to the measure of illiquidity, the sample period, and the expiry cycles of options. As a first robustness check, the regressions are re-estimated using the natural log of the proportional bid-ask spread as a measure of illiquidity. A second robustness check was to choose a sub-sample period from January 2009 to December 2010 to avoid the thin data on a few options and the volatility in option spreads during the last quarter of 2008. A third robustness check was to choose a sub-sample of stocks with options that expire in each quarter of the year and monthly maturities for the next three months. The results of each robustness check provide qualitatively similar findings.

## 7.4 Main Findings of Empirical Analysis of Chapter 6

Chapter 6 investigates three main research questions. The first relates to the illiquidity premium hypothesis that the return of an illiquid asset includes an illiquidity premium. The second research question relates to the hedging cost hypothesis, which states that high transaction costs increase the costs of replicating an option, which in turn increase the price of that option. Replicating an option by buying delta shares of an illiquid stock will be more costly when the transaction costs are higher and this increases the option price and lowers its return. The third research question focuses on the importance of sources of liquidity to option pricing. From the asset pricing literature we know that liquidity risk emanates from three main comovements (Acharya and Pedersen, 2005). However, since options are replicative securities whose payoff depends on the payoffs of the underlying stock, the sources of liquidity risk emanate from both the underlying stock market as well as the option market. We identify nine different sources of comovements that are related to liquidity risk. Option return, option liquidity and stock liquidity are important factors that comove with stock market excess returns, stock market liquidity and option market liquidity. We then investigate which of these sources of liquidity risk are priced in equity options by first estimating liquidity betas and then the risk premia associated with these betas using the Fama-MacBeth (1973) methodology. The analysis is performed on call and put moneyness portfolios.

To investigate these research questions, we construct delta-hedged portfolios and calculate the weekly delta-hedged net-gains on these portfolios. The net gain of a delta-hedged portfolio is calculated by buying options at the beginning of a week and hedging each with delta underlying shares such that the strategy should theoretically provide a risk-free return. We assume the week starts on Wednesday. We rebalance the delta-hedged portfolio by trading delta shares depending on the movement in the underlying stocks and the type of option, whether a call or a put. We unwind the delta-hedged portfolio position by selling the options and trading the delta-shares. The net-gain from this strategy is the weekly delta-hedged portfolio gain. We find that average weekly delta-hedged net-gains for call and put portfolios behave differently across moneyness. The gains for calls increase in moneyness whereas for puts they decrease in moneyness.

We use time-series regressions to test for significant sources of liquidity risk such a source of risk is defined as a covariation between two variables. We have identified eight different sources of liquidity risk. $\beta_{(dhg,smliq)}$ and $\beta_{(dhg,omliq)}$ are option return sensitivities to stock market illiquidity and options market illiquidity, respectively. $\beta_{(oliq,rm)}$ is the covariation between option illiquidity and stock market return; $\beta_{(oliq,smliq)}$ is the covariation between option illiquidity and stock market illiquidity; $\beta_{(oliq,omliq)}$ is the covariation between option illiquidity and option market illiquidity; $\beta_{(sliq,rm)}$ is the covariation of stock illiquidity and stock market return; $\beta_{(sliq,smliq)}$ is the covariation between stock illiquidity and stock market illiquidity; and, $\beta_{(sliq,omliq)}$ is the covariation between stock illiquidity and option market illiquidity. Betas that are significant for most stocks in a portfolio are $\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$ and $\beta_{(oliq,rm)}$ for calls and $\beta_{(dhg,rm)}$, $\beta_{(dhg,smliq)}$, $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$, $\beta_{(oliq,smliq)}$ and $\beta_{(oliq,omliq)}$ for puts.

We estimate Fama-MacBeth (1973) cross-sectional regressions to investigate the role of the liquidity variables and channels of liquidity risk in explaining the variation in weekly delta-hedged portfolio net-gains. We find that the coefficient on option illiquidity, as measured by the natural logarithm of options proportional bid-ask spread, is positive for call moneyness portfolios except DITM. For puts, it is positive and mostly significant across moneyness portfolios. Although positive illiquidity premium makes more intuition, a negative illiquidity premium is counterintuitive but can be explained by by leverage of options and rebalancing costs as in Wu et al. (2013), the demand-based option pricing theory of Garleanu et al. (2010), and by the relative aggressiveness of a trader in Bongaerts et al. (2010). The first explanation is due to the leverage and rebalancing costs. A rebalancing cost is related to the delta such that the portfolio remains delta-hedged. A delta-hedged call option would require less rebalancing when the option is deep-in-the-money. Higher rebalancing costs could arise due to two reasons (Wu et al., 2013). First, when delta-changes the rebalancing costs will increase. Second, when the market maker moves away from the optimal level of the inventory, she widens the bid-ask spreads and thus the rebalancing costs will increase. When options are deep-in-the-money, the options are less sensitive to the rebalancing costs and therefore, the illiquidity premium required by the option trader on a delta-hedged portfolio decreases with the moneyness. The second explanation is according to the demand-based option pricing theory of Garleanu et al. (2010). The net-demand pressure can explain the expensiveness of an option. When the market is not in zero net-supply, the illiquidity premium can be positive, negative or even zero depending upon who is faced with the illiquidity of the asset. A negative illiquidity premium for DITM and ITM options suggest that probably the end-users in these two option categories are net-short. Therefore, they incur more costs for selling option and thus pay an illiquidity premium. The third explanation depends on the aggressiveness of option traders. If the option trader of in-the-money options are more aggressive than option traders of other options, they will be willing to pay a premium for holding these options.

We do not find any evidence of the hedging cost premium, since the coefficient of the underlying stock illiquidity is insignificant and has mixed sign in various specifications estimated across moneyness portfolios of calls and puts. This finding is contrary to Cetin et al. (2006) who suggest that when the underlying asset is not perfectly liquid, the liquidity cost of the underlying asset is a significant part of the option price, and the effect on the option price depends on the moneyness of the option. This may be because we construct a portfolio of options that is delta-hedged. Since, the portfolio is always delta-hedged, it is possible that the rebalancing of the portfolio already takes into account the implicit costs of illiquidity in the underlying stock which results into an insignificant coefficient for stock illiquidity.

We find evidence of liquidity risk premia in both calls and puts, with the risk premia related to different sources of liquidity risk across moneyness for both puts and calls. For calls, $\beta_{(dhg,omliq)}$, $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$ are priced sources of liquidity risk for ATM portfolios, whereas only one source of liquidity risk, $\beta_{(sliq,omliq)}$, is priced in DITM and ITM portfolios and has a negative coefficient. Moreover, this latter source of liquidity risk, $\beta_{(sliq,omliq)}$, is not priced in OTM or DOTM calls. Rather, another source of liquidity risk, the commonality in the option market, represented by $\beta_{(oliq,omliq)}$, is priced and has a negative coefficient. As explained before, Bongaerts et al. (2010) suggest that the sign of the liquidity risk premia depends on the aggressiveness of a trader. The aggressiveness of a trader could depend on his risk aversion, trading horizon and wealth. This possibly suggests that investors' preferences differ with respect to which options they are trading. Liquidity risk can be due to any of the above-mentioned sources and could have different signs for different portfolios.

Liquidity risk premia related to liquidity commonality in the option market as well as the stock market are found to be more important for puts than for calls. $\beta_{(oliq,omliq)}$, which is the liquidity commonality in the option market, is priced in DITM, ITM, ATM and OTM puts. $\beta_{(sliq,smliq)}$, which is the liquidity commonality in the stock market, is priced in ATM, OTM and DOTM puts. $\beta_{(oliq,rm)}$, which is liquidity risk related to the comomvement between option illiquidity shocks and stock market excess returns, is significant in all portfolios. $\beta_{(oliq,smliq)}$, which is liquidity risk related to the comovement between option illiquidity shocks and stock market illiquidity shocks, is significant only in DOTM options.

We also calculate the liquidity risk premia for ATM calls and puts using the significant sources of liquidity risk as in specification (7). We find that $\beta_{(oliq,rm)}$ and $\beta_{(sliq,omliq)}$ are priced in ATM calls, whereas $\beta_{(oliq,rm)}$, $\beta_{(oliq,omliq)}$ and $\beta_{(sliq,smliq)}$ are priced in ATM puts. Interestingly, three sources of liquidity risk are significant in ATM puts compared to two sources for ATM calls. However, using average beta values from Table C4, we find that the total liquidity risk premia for ATM calls is 0.515 compared to 0.318 for ATM puts. Although more sources of liquidity risk are priced in ATM puts, liquidity risk premia demanded by investors for calls is higher than that for puts. This suggests that, as far as liquidity is concerned, calls are riskier than puts.

## 7.5 Overall Conclusions

This section outlines the overall conclusions of the thesis. The thesis investigates the sources of liquidity risk and their pricing in the NYSE Euronext LIFFE equity options. It provides new evidence of liquidity comovement between options and their underlying stock market, evidence of option return sensitivity towards expected and unexpected illiquidity in the option market as well as in the stock market, and evidence of different sources of liquidity risk being priced in the London equity options during the sample period from 22 February 2008 to 31 December 2010.

In general, puts show higher liquidity comovement. This comovement also depends on the degree of moneyness of the options. Generally, ATM options show stronger/higher liquidity comovement than ITM and OTM options. Moreover, daily liquidity is found to comove with contemporaneous daily liquidity in the market rather than with lagged liquidity.

On the main, the literature provides three theories to explain option spreads. Derivative hedge theory explains the spreads in the options market by the spreads or trading activity in the underlying stock market when market makers are able to hedge their options positions in the underlying market. We find no evidence that this theory explains the spreads in LIFFE equity options during our sample period when we use the change in trading volume in the underlying stock market as a proxy to trading activity in the derivative hedging argument. Instead, we find the information asymmetry theory better able to explain some changes in spreads, especially for OTM options.

Although the change in the trading volume in the stock market does not explain the change in the option spreads, the liquidity comovement between options and their underlying stock market, when liquidity is measured by the proportional bid-ask spread, is found to be significant for most call and put option portfolios. This is evidence that has not been clearly documented in the literature. This is important because option traders, especially market makers, hedge their option positions by trading underlying stocks to hedge delta or gamma risk.

We also suggest in this thesis that when liquidity is persistent, one can investigate option return sensitivities to shocks in illiquidity. Due to the persistence in liquidity, we separate expected from unexpected (shocks) illiquidity in the market. We find that option returns are indeed sensitive to shocks in the illiquidity of both the options market and the stock market. This evidence is checked for robustness to different measures of liquidity, sample period and the expiration cycles of the options. The findings suggest that not only liquidity comovement between options and their market or the underlying stock market are sources of liquidity risk, but option return sensitivity to the liquidity in the options market and the stock market are additional sources of liquidity risk.

These liquidity comovements and option return sensitivities have their implications as potential sources of liquidity risk that are priced in equity options. To investigate these sources we use the Fama-McBeth (1973) methodology to test whether these sources are priced in options. We test three main hypotheses: the illiquidity premium hypothesis, the hedging cost hypothesis, and the liquidity risk premia hypothesis. The illiquidity premium hypothesis relates to the possibility that option illiquidity explains variations in option returns. The hedging cost hypothesis relates to whether the underlying stock illiquidity explains variations in option returns. The liquidity risk hypothesis relates to the identification of liquidity risk factors that are important in explaining variations in option returns. We find that option return variations are partially explained by the illiquidity premium hypothesis. We also find that not only calls and puts but moneyness of calls and puts is important for liquidity risk. Across these portfolios, different sources of liquidity risk are priced. We conclude that liquidity risk premia demanded by investors for calls is higher than for puts.

The summarize findings in accordance with the hypotheses tested in the whole thesis are presented in the following table.

**Table 7.1 Summary of the Findings**

This table lists the hypotheses and the main findings for each empirical chapter.

| Hypothesis | Description | Main Findings |
|---|---|---|
| **Chapter 4** | **Liquidity Comovement** | |
| H1 | Liquidity comovement in the options market is positive. | For all moneyness and maturity portfolios, it is positive and significant. Contamporaneous liquidity comovement is significant for most stocks. Generally, it is higher for ATM compared to OTM and ITM options. Across maturity of options, we do not find any discernible patterns. Liquidity comovement is robust to percentage bid-ask spreads (option spread divided by stock mid point). |
| H1a | Liquidity comovement in the options market is positive for both calls and puts. | Puts on average show higher liquidity comovement. Although calls are more actively traded than puts, but possibly due to the nature of puts as an insurance product, puts show relatively stronger liquidity comovement than calls. |
| H1b | The options on small firms show higher liquidity comovement. | This effect is related to the maturity of options. Consistent with inventory and information asymmetry explanations for small firms, liquidity comovement is higher for small firms for options greater than 3months maturity. Short-maturity options generally have higher liquidity comovement for ITM and OTM options. |
| H1c | The options on low volatility stocks show higher liquidity comovement. | Low volatility stocks generally show higher liquidity comovement for options with maturity greater than 3 months. High volatility stocks show high liquidity comovement for short-maturity options. |
| H2 | Liquidity comovement between options and their underlying stock market is positive. | Liquidity comovement with stock market is positive for calls and insignificant for puts in general. ATM show higher liquidity comovement than ITM and OTM options. |
| H2a | Liquidity comovement in the options market is positive for both calls and puts. | Liquidity comovement in stock market is positive for calls across moneyness and maturity portfolios. However, it has mixed sign and mostly insignificant for put options. |

| Hypothesis | Description | Main Findings |
|---|---|---|
| **Chapter 4** | **Liquidity Comovement** | |
| H2b | The options on small firms show higher liquidity comovement. | The results are mixed across calls and puts for different moneyness and maturity portfolios. |
| H2c | The options on low volatility stocks show higher liquidity comovement. | We do not find a robust evidence of low volatility stocks having high liquidity comovement in the stock market. However, puts compared to calls, on average show the volatility effect. |
| H3 | Does inventory, information asymmetry or derivative hedge theory or the combination of these help explain liquidity comovement in the options? | Information asymmetry and inventory risk (as proxied by open interest of an option) help explain the liquidity comovement for OTM options with maturity greater than 60 days (2Months). Information asymmetry also explains the liquidity comovement for ATM options. Moreover, volume shows positive impact on option spreads, opposite to the negative relation based on inventory theory. Volume measure can also be used as information asymmetry proxy as option traders with information may trade options due to their inherent leverage. |
| **Chapter 5** | **Option Return Sensitivity** | |
| H4 | Options market expected illiquidity positively affects option ex-ante excess returns. | The effect is positive and significant for most moneyness and maturity options. Long maturity calls (greater than 90 days) show lower effect than short maturity options. |
| H5 | Options market unexpected illiquidity has a negative impact on contemporaneous option excess return. | For both calls and puts, the effect is negative and significant across all portfolios. Calls show decreasing effect in both moneyness and maturity. Puts only show that the effect is higher for long maturity options. |
| H6 | Expected stock market illiquidity positively affects option ex-ante excess returns. | The effect is not robust across all portfolios of calls and puts. Deep in the money calls (more act like stocks) do show the effect of expected stock market illiquidity on option returns. |
| H7 | Unexpected stock market illiquidity has a negative impact on contemporaneous option excess return. | The effect is mainly significant for calls. |

| Hypothesis | Description | Main Findings |
|---|---|---|
| **Chapter 6** | **Pricing Liquidity** | |
| H8 | Illiquidity of an option positively affects the option return also called Liquidity Premium Hypothesis | It is positive for most portfolios and mainly significant for put options. |
| H9 | Illiquidity of the underlying stock negatively affects the option return also called Hedging Cost Hypothesis | In a multivariate Fama-McBeth setting, we do not find any moneyness portfolio of calls and puts to have significant effect of stock liquidity on the option returns. |
| H10 | Risk premium due to liquidity comovment between and option and its market is positive. | Not priced. |
| H11 | Risk premium due to comovement between option liquidity and underlying stock market liquidity is positive | Not priced. |
| H12 | Risk premium due to comovement between option liquidity and underlying stock market return is negative | Negative and signficant for ATM Calls, |
| H13 | Risk premium due to comovement between option return and option market liquidity is negative | Negative and signficant for OTM and DOTM Calls and DITM, ITM, ATM and OTM puts. |
| H14 | Risk premium due to comovement between option return and stock market liquidity is negative | Negative and signficant for DOTM puts. |

| Hypothesis | Description | Main Findings |
|---|---|---|
| **Chapter 6** | **Pricing Liquidity** | |
| H15 | Risk premium due to comovement between option return and stock market return is positive | Positive and signficant for all put portfolios. |
| H16 | Risk premium due to comovement between stock liquidity and option market liquidity is positive | Positive and signficant for ATM, ITM and DITM calls |
| H17 | Risk premium due to comovement between stock liquidity and stock market liquidity is negative | Negative and signficant for ATM, OTM and DOTM puts. |
| H18 | Risk premium due to comovement between stock liquidity and stock market return is negative | Not priced. |

## 7.6 Contribution of the Study

The contributions are as follows:

- The analysis is performed on equity options of the most actively traded stocks trading on the NYSE Euronext LIFFE London Equity options market. There are mainly two benefits of this data set. First, data on options of such active stocks to study the liquidity effects on prices are rarely used. We know of only two studies, recently emerged, Verousis et al. (2015) and Verousis et al. (2016) who investigate liquidity commonality and the intra-day patterns in the NYSE LIFFE equity options. Second, this is the first study to investigate liquidity of options, underlying stock and sources of liquidity risk using daily data on UK equity options market.

- We extend the work of Amihud (2002) to investigate the effect of expected and unexpected illiquidity in options and stock markets on option returns. In time-series, we find that option returns are sensitive to both the expected and unexpected illiquidity in the options market, but option returns are only sensitive to the unexpected (not the expected) illiquidity in the underlying stock market. This finding has implications for option traders. When options are sensitive to the unexpected illiquidity in the stock market, which we find across different portfolios of calls and puts, it implies that prices of all options vary with unexpected illiquidity. Thus, traders that ignore unexpected illiquidity in the underlying asset market might be conducting inefficient strategies.

- This study is the first to investigate sources of liquidity risk other than liquidity commonality in the options market. We document that not all identified sources of liquidity risk are priced in all options. Rather, ATM options generally have more priced liquidity risk factors compared to OTM and ITM. Further, the sign of liquidity and liquidity risk premia is not consistent across portfolios. In addition, it seems that in options, liquidity risk is related to their moneyness.

- This study documents that delta-hedge gains are non-zero. They are positive for calls and negative for puts. We document evidence that these non-zero delta-hedged gains are related to the option illiquidity premium and to premia related to different sources of liquidity risk. The significant sources of liquidity risk identified are: the liquidity comovement between options and their market, the liquidity comovement between options and their underlying stock market, the option return sensitivity to option market liquidity, the option return sensitivity to stock market liquidity, and the comovement of option liquidity with the excess return of the stock market. The thesis documents that for calls the priced sources of liquidity risk are: the option return sensitivity to stock market liquidity, the option liquidity comovement with the stock market excess return, and the liquidity comovement between stocks and the options market. For puts, the sources of liquidity risk that have a significant premium are: the liquidity comovement between options and their market, the liquidity comovement between options and the stock market, the option liquidity comovement with the stock excess return, and the option liquidity comovement with stock market liquidity.

## 7.7 Limitations and Recommendations for the Future Research

- The options data is daily end-of-day data of bid price, ask price, volume and open interest for the period from 22 February 2008 to 31 December 2010. The data is restrictive in sample size as well as in the number of liquidity measures that can be computed. Since most of the volume and open-interest data is missing, we have to rely only on the bid and ask spreads for liquidity measures. This creates further opportunities to verify the results obtained on a larger size and longer sample period.

- The results in Chapter 4, 5 and 6 are dependent on the definition of liquidity. We measured liquidity of an option by the bid-ask spread, the spread as a percentage of the bid-ask midpoint, and as a percentage of the underlying stock price. Other liquidity proxies have not been, or could not be, analysed. The results obtained in the analysis, therefore, may or may not generalise to other liquidity proxies. For example, Garleanu et al. (2010) propose that it is the net-demand pressure which determines who commands the liquidity premium. We forwarded this rationale in explaining some of our findings, but we cannot verify this unless data that differentiates between market-maker prices and end users is made available.

- Although there are studies that propose theoretical option pricing models with transaction costs or that incorporate stock market illiquidity (Liu and Young, 2005), there is no theoretical framework that considers the various sources of liquidity risk in the equity options market that could be used to compare our results with. One direction of future research is to derive an equilibrium model that takes into account the liquidity of options, underlying stock and various sources of liquidity risk. Bongaerts et al. (2010) have derived a pricing model with liquidity risk for Credit Default Swap market. Developments along these lines might prove beneficial.

- The other limitation of the study is that we rely on the delta-hedged option gains strategy as a measurement of option returns. In the literature, return on an option is calculated using different option strategies. For example, to study whether variance risk is a priced factor in options, Carr and Wu (2009) quantify option returns by employing a variance swap strategy. Similarly, Christoffersen et al. (2015) calculates the expected returns. Such strategies can be employed to quantify the option returns and see if there are any interactions between volatility and liquidity and whether they are also priced in the options.

- A further future research area is to study the sources of liquidity risk in the index options market for different maturity and moneyness options. The cross-sectional variance of maturity and moneyness options can be studied in the index options more effectively as the cross-sectional variance across the stocks would not be a complicating issue in the analysis.

The overall results in this thesis for the UK equity options market, as well as the findings in the literature on the equity options market, indicate that option traders consider liquidity to be an important determinant of the option price. Liquidity of an option, liquidity of the underlying stock, and the channels of liquidity risk related to the comovements of liquidity and return of an option with the liquidity and return in the options and stock markets affect option returns.

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# APPENDICES

# A. APPENDIX TO CHAPTER 4

**Figure A1 Call and Put Options Markets' Liquidity (Percentage Bid-Ask Spread)**

This figure shows liquidity measured by the percentage bid-ask spread (option spread divided by stock price) for call and put options. Options market liquidity is calculated as a cross-sectional average of liquidity of options. Liquidity in call and put options markets moves together. However, we see that the London LIFFE market documented a dramatic decrease in liquidity in September-October-November 2008. It took some time to revert to its previous level. This is the same period in which the short-selling ban was imposed in financial markets (Verousis et al., 2015). Verousis and Gwilym also report the same finding in terms of a dramatic drop in depth.

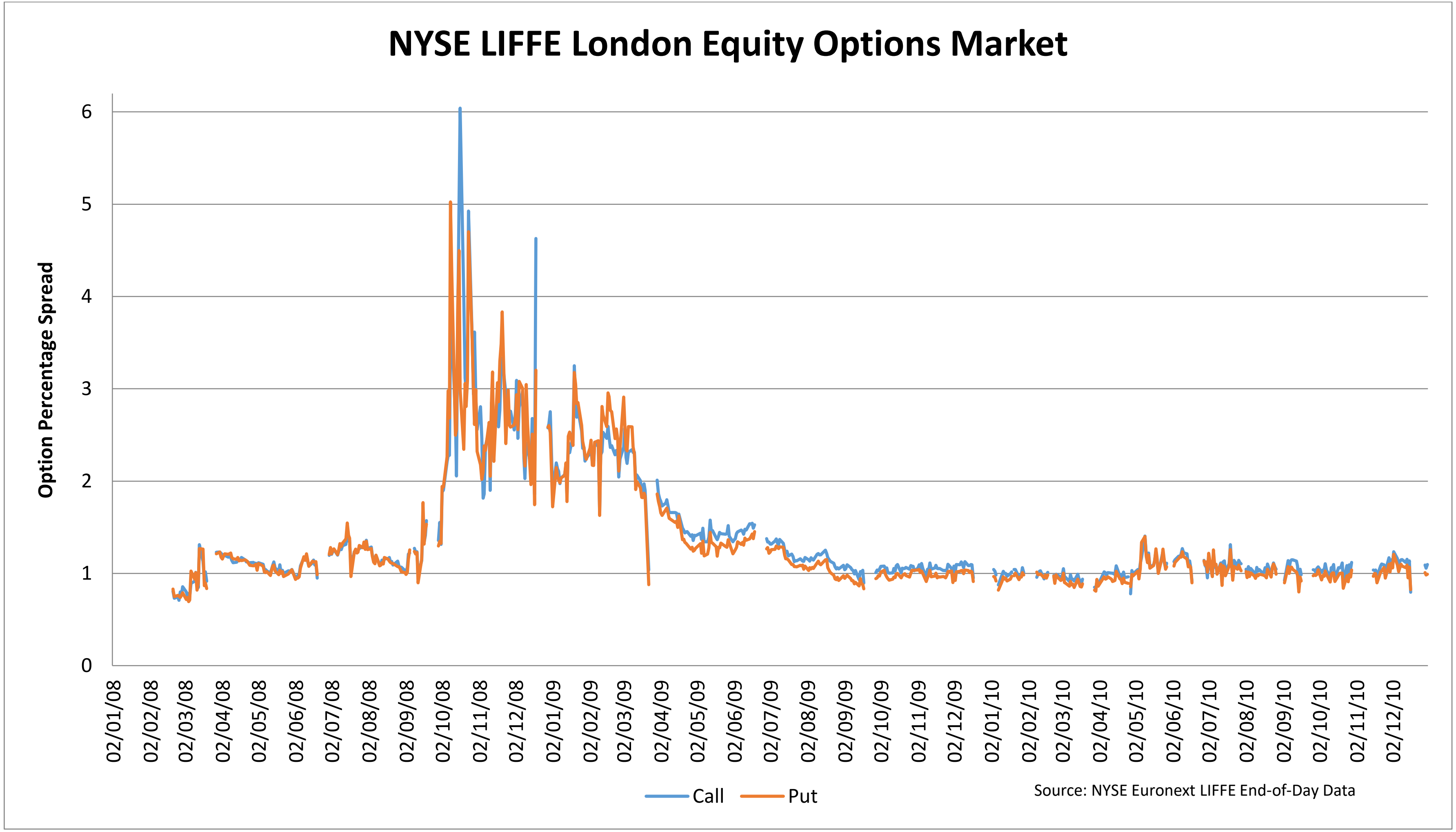


**Figure A2 All (Combined Call and Put) Options Market Liquidity**

This figure shows the percentage bid-ask spread (option spread divided by stock price) for the options market. Options market liquidity is calculated as a cross-sectional average of liquidity of options.

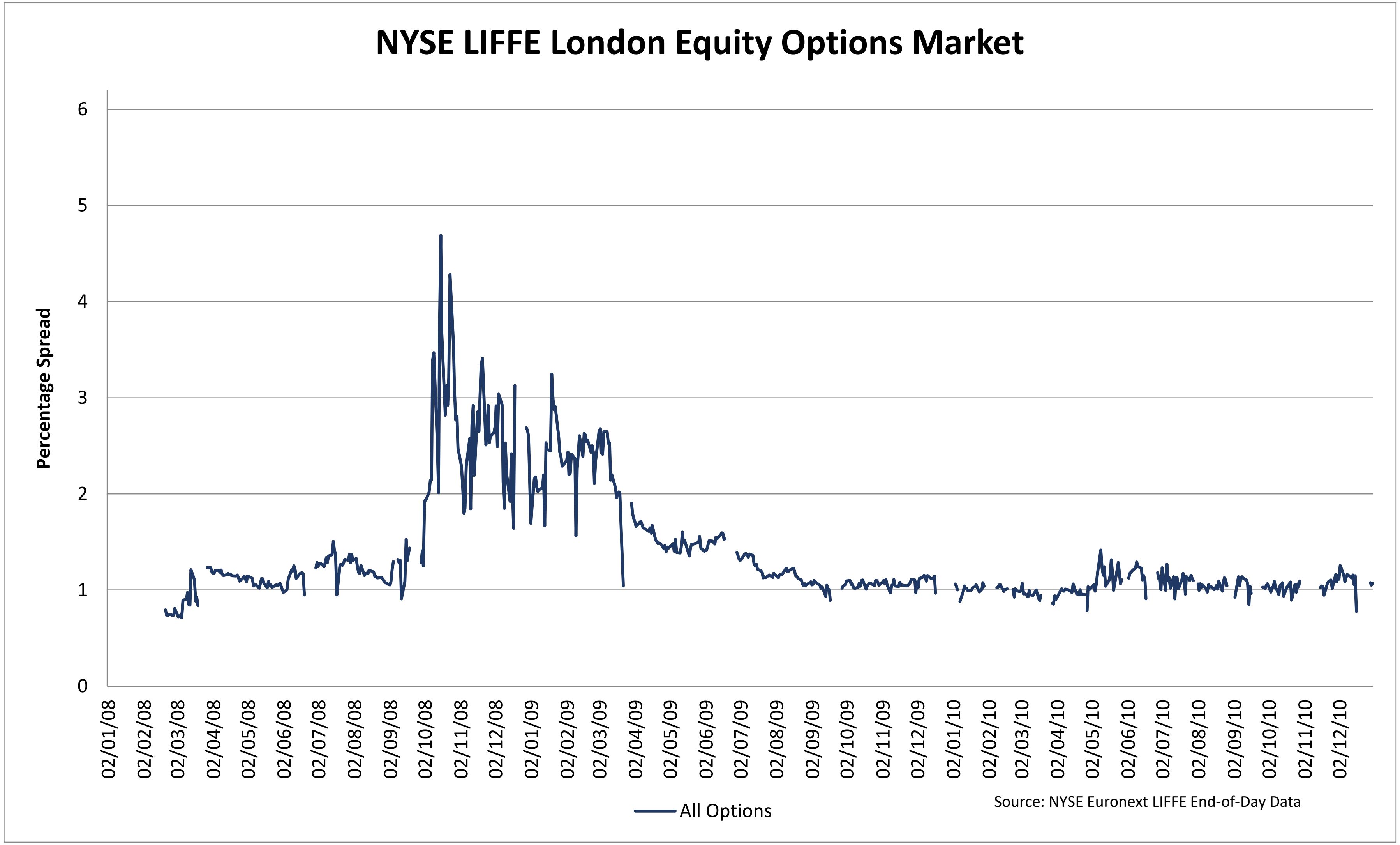
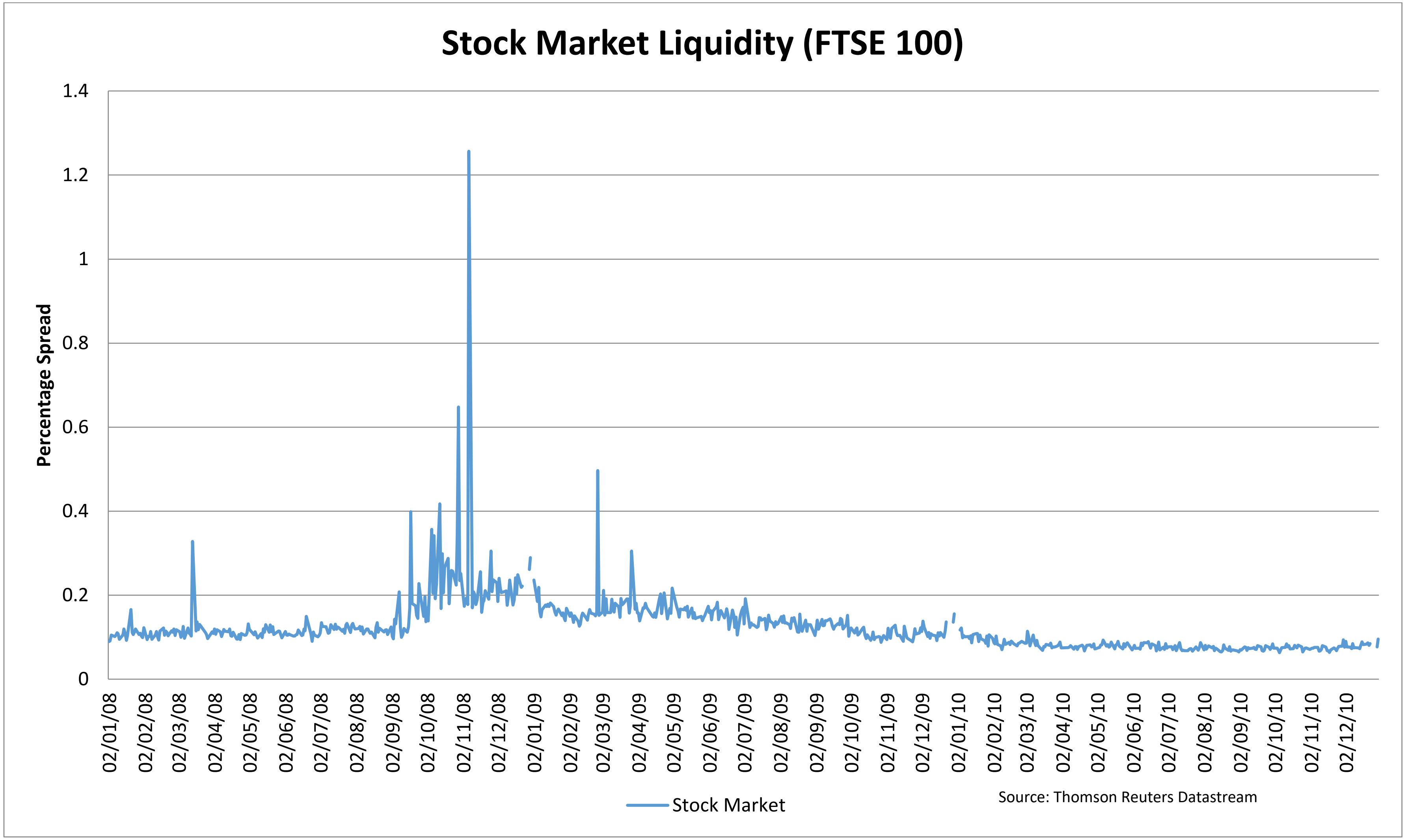


**Figure A3 Stock Market Liquidity**

This figure shows the bid-ask spread and the percentage bid-ask spread (stock bid-ask spread divided by stock price) for the stock market. Stock market liquidity is calculated as a cross-sectional average of liquidity of all FTSE 100 stocks. Both dollar and percentage bid-ask spreads show a similar pattern. The stock market also experienced a decrease in liquidity in September-October-November 2008 and it took some time to revert to its previous level.



## Table A1

## Liquidity Comovement between Call Options and Call Options Market (Proportional Spread)

This table presents the results of liquidity comovement between call options and their options market. For each stock in its maturity and moneyness portfolio, all options are averaged at time t, and at stock level, we run following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of call options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have +ve coeficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.012 | 0.000 | 0.003 | 0.0068 | 0.005 | 0.003 | 0.004 | -0.001 | 0.003 | -0.002 |
| | 1.53 | 0.06 | 1.10 | 1.32 | 0.51 | 0.81 | 1.25 | -0.42 | 0.86 | -0.48 |
| | 58.90 | 48.00 | 52.00 | 53.42 | 39.44 | 45.21 | 49.32 | 46.58 | 50.68 | 47.22 |
| $\beta_2$ | $0.247^{3}$ | 0.031 | $0.481^{1}$ | $0.3581^{1}$ | 0.296 | $0.489^{1}$ | $0.573^{1}$ | $0.539^{1}$ | $0.460^{1}$ | $0.128^{2}$ |
| | 1.97 | 0.32 | 5.54 | 3.54 | 1.72 | 6.48 | 6.29 | 8.28 | 6.60 | 2.52 |
| | 50.68 | 54.67 | 72.00 | 68.49 | 64.79 | 78.08 | 83.56 | 90.41 | 82.19 | 68.06 |
| $\beta_{2lag}$ | 0.003 | -0.064 | -0.049 | 0.0234 | 0.127 | $0.063^{3}$ | $0.076^{1}$ | $0.063^{1}$ | $0.067^{1}$ | 0.018 |
| | 0.03 | -0.84 | -1.17 | 0.38 | 0.82 | 1.94 | 4.11 | 4.16 | 3.69 | 0.77 |
| | 56.16 | 52.00 | 49.33 | 57.53 | 53.52 | 65.75 | 75.34 | 69.86 | 69.86 | 61.11 |
| $\beta_2 + \beta_{2lag}$ | 0.250 | -0.033 | $0.432^{1}$ | $0.3815^{1}$ | $0.422^{3}$ | $0.552^{1}$ | $0.649^{1}$ | $0.602^{1}$ | $0.527^{1}$ | $0.146^{2}$ |
| | 1.59 | -0.24 | 3.83 | 2.69 | 1.76 | 6.34 | 7.14 | 8.98 | 7.06 | 2.21 |
| | 57.53 | 50.00 | 50.67 | 55.48 | 46.48 | 55.48 | 62.33 | 58.22 | 60.27 | 54.17 |
| $\beta_3$ | 0.044 | $0.053^{2}$ | $0.061^{1}$ | -0.024 | 0.045 | -0.014 | 0.026 | $0.053^{1}$ | $0.052^{3}$ | 0.006 |
| | 1.00 | 2.59 | 3.50 | -1.12 | 0.79 | -0.63 | 1.09 | 2.82 | 1.79 | 0.21 |
| | 50.68 | 56.00 | 60.00 | 43.84 | 46.48 | 52.05 | 56.16 | 60.27 | 57.53 | 50.00 |
| $\beta_{3lag}$ | 0.010 | -0.007 | -0.001 | $-0.061^{2}$ | 0.006 | -0.016 | $0.067^{1}$ | $0.102^{1}$ | $0.108^{1}$ | $0.105^{1}$ |
| | 0.23 | -0.27 | -0.04 | -2.26 | 0.15 | -0.57 | 2.90 | 4.69 | 3.74 | 3.19 |
| | 47.95 | 40.00 | 40.00 | 36.99 | 46.48 | 47.95 | 57.53 | 67.12 | 67.12 | 69.44 |
| $\beta_3 + \beta_{3lag}$ | 0.054 | 0.046 | $0.061^{2}$ | $-0.085^{2}$ | 0.051 | -0.030 | $0.093^{2}$ | $0.156^{1}$ | $0.160^{1}$ | $0.111^{2}$ |
| | 0.76 | 1.22 | 2.20 | -2.26 | 0.59 | -0.73 | 2.40 | 4.29 | 3.24 | 2.05 |
| | 49.32 | 48.00 | 50.00 | 40.41 | 46.48 | 50.00 | 56.85 | 63.70 | 62.33 | 59.72 |
| $\beta_4$ | $-2.684^{1}$ | $-4.624^{1}$ | $-10.724^{1}$ | $-16.039^{1}$ | $-12.166^{1}$ | $-2.054^{1}$ | $-3.142^{1}$ | $-7.105^{1}$ | $-11.549^{1}$ | $-11.756^{1}$ |
| | -6.49 | -15.94 | -19.40 | -20.74 | -14.12 | -7.88 | -13.01 | -20.62 | -19.69 | -20.50 |
| | 13.70 | 1.33 | 0.00 | 0.00 | 4.23 | 15.07 | 4.11 | 0.00 | 1.37 | 0.00 |
| $\beta_5$ | $0.191^{2}$ | 0.079 | 0.152 | $0.574^{1}$ | $0.455^{1}$ | $0.190^{2}$ | $-0.118^{2}$ | $0.096^{2}$ | $0.378^{1}$ | $0.481^{1}$ |
| | 2.75 | 1.14 | 1.15 | 2.97 | 3.03 | 2.31 | -2.61 | 2.00 | 4.16 | 3.38 |
| | 61.64 | 46.67 | 54.67 | 57.53 | 69.01 | 68.49 | 36.99 | 58.90 | 69.86 | 83.33 |
| $\beta_6$ | -0.810 | 0.278 | -0.322 | 1.919 | $4.157^{3}$ | $-1.912^{2}$ | -0.922 | $-1.089^{1}$ | $-1.364^{2}$ | -0.409 |
| | -0.57 | 0.32 | -0.40 | 1.55 | 1.78 | -2.49 | -1.49 | -2.70 | -2.36 | -0.43 |
| | 41.10 | 45.33 | 49.33 | 64.38 | 54.93 | 47.95 | 31.51 | 42.47 | 39.73 | 54.17 |
| $\beta_7$ | 2.962 | $3.429^{1}$ | $1.886^{2}$ | $5.090^{1}$ | 3.174 | -0.134 | 0.893 | 0.692 | 0.192 | 0.277 |
| | 1.24 | 2.92 | 2.07 | 3.27 | 0.78 | -0.11 | 1.01 | 1.32 | 0.26 | 0.18 |
| | 41.10 | 48.00 | 57.33 | 61.64 | 35.21 | 47.95 | 49.32 | 53.42 | 58.90 | 48.61 |
| $intercept$ | $5.149^{1}$ | $3.772^{1}$ | $6.798^{1}$ | $12.494^{1}$ | $15.094^{1}$ | $5.255^{1}$ | $4.447^{1}$ | $5.734^{1}$ | $8.539^{1}$ | $11.440^{1}$ |
| | 3.67 | 5.43 | 8.87 | 11.42 | 8.65 | 6.88 | 9.94 | 14.90 | 14.62 | 12.55 |
| | 68.49 | 77.33 | 88.00 | 94.52 | 77.46 | 79.45 | 91.78 | 97.26 | 98.63 | 95.83 |
| $adj\ R^2$ | 6.91 | 11.14 | 35.84 | 39.36 | 45.62 | 7.53 | 8.5 | 25.66 | 35.07 | 43.07 |
| $N$ | 24 | 62 | 70 | 63 | 20 | 67 | 70 | 70 | 70 | 64 |

## Table A1 (Continued)
## Liquidity Comovement between Call Options and Call Options Market (Proportional Spread)

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.002 | -0.002 | -0.000 | 0.004 | 0.006 | 0.002 | -0.001 | 0.000 | 0.004[3] | -0.000 |
| | -0.55 | -0.71 | -0.11 | 0.92 | 1.14 | 0.95 | -0.33 | 0.20 | 1.71 | -0.20 |
| | 53.42 | 43.84 | 36.99 | 52.70 | 47.22 | 51.32 | 40.79 | 52.63 | 52.63 | 43.24 |
| $\beta_2$ | 0.312[1] | 0.370[1] | 0.543[1] | 0.372[1] | 0.154[1] | 0.430[1] | 0.432[1] | 0.499[1] | 0.410[1] | 0.222[1] |
| | 5.08 | 4.76 | 5.30 | 6.39 | 5.29 | 8.36 | 6.64 | 9.16 | 7.95 | 8.80 |
| | 75.34 | 67.12 | 82.19 | 77.03 | 77.78 | 82.89 | 73.68 | 84.21 | 86.84 | 89.19 |
| $\beta_{2lag}$ | 0.078[2] | 0.004 | 0.028 | -0.006 | -0.001 | 0.039[2] | 0.049[2] | -0.005 | 0.022 | -0.002 |
| | 2.60 | 0.12 | 1.27 | -0.25 | -0.06 | 2.25 | 2.61 | -0.39 | 1.05 | -0.22 |
| | 64.38 | 61.64 | 54.79 | 47.30 | 56.94 | 68.42 | 67.11 | 50.00 | 51.32 | 54.05 |
| $\beta_2 + \beta_{2lag}$ | 0.390[1] | 0.374[1] | 0.571[1] | 0.366[1] | 0.152[1] | 0.469[1] | 0.481[1] | 0.494[1] | 0.433[1] | 0.220[1] |
| | 6.19 | 4.72 | 4.96 | 5.21 | 3.79 | 9.31 | 7.34 | 9.13 | 7.81 | 7.79 |
| | 58.90 | 52.74 | 45.89 | 50.00 | 52.08 | 59.87 | 53.95 | 51.32 | 51.97 | 48.65 |
| $\beta_3$ | 0.083[2] | 0.030 | 0.017 | 0.070[2] | -0.030 | 0.021[3] | 0.057[1] | 0.048[1] | 0.037[2] | 0.006 |
| | 2.18 | 0.95 | 0.84 | 2.47 | -0.90 | 1.89 | 3.82 | 4.17 | 2.14 | 0.55 |
| | 58.90 | 60.27 | 56.16 | 59.46 | 52.78 | 55.26 | 61.84 | 64.47 | 60.53 | 60.81 |
| $\beta_{3lag}$ | -0.024 | -0.095[3] | -0.078[1] | -0.053[3] | -0.034 | -0.001 | 0.038[2] | 0.026[2] | 0.014 | 0.012 |
| | -0.62 | -1.84 | -3.30 | -1.70 | -0.94 | -0.05 | 2.38 | 2.21 | 0.88 | 1.42 |
| | 43.84 | 38.36 | 36.99 | 41.89 | 45.83 | 53.95 | 60.53 | 57.89 | 67.11 | 52.70 |
| $\beta_3 + \beta_{3lag}$ | 0.059 | -0.065 | -0.061 | 0.017 | -0.064 | 0.021 | 0.095[1] | 0.074[1] | 0.052[3] | 0.018 |
| | 0.89 | -0.97 | -1.65 | 0.34 | -1.06 | 1.08 | 3.95 | 3.64 | 1.72 | 1.18 |
| | 51.37 | 49.32 | 46.58 | 50.68 | 49.31 | 54.61 | 61.18 | 61.18 | 63.82 | 56.76 |
| $\beta_4$ | -0.918[1] | -2.453[1] | -5.949[1] | -9.001[1] | -10.479[1] | -1.612[1] | -3.129[1] | -4.379[1] | -5.855[1] | -7.669[1] |
| | -2.90 | -8.64 | -20.85 | -20.29 | -21.75 | -11.19 | -16.19 | -21.15 | -22.59 | -24.44 |
| | 28.77 | 10.96 | 0.00 | 1.35 | 0.00 | 9.21 | 1.32 | 3.95 | 0.00 | 0.00 |
| $\beta_5$ | 0.189[2] | -0.061 | 0.094[2] | 0.028 | 0.536[1] | 0.128[1] | 0.054 | 0.084[2] | 0.042 | 0.231[1] |
| | 2.24 | -0.76 | 2.52 | 0.34 | 5.82 | 3.82 | 1.39 | 2.14 | 1.39 | 5.26 |
| | 60.27 | 52.05 | 63.01 | 48.65 | 88.89 | 69.74 | 53.95 | 63.16 | 60.53 | 79.73 |
| $\beta_6$ | 1.016 | -0.340 | -0.264 | 0.617 | -0.990 | 0.138 | -0.623 | -0.123 | -0.916[2] | -1.205[1] |
| | 0.89 | -0.33 | -0.47 | 0.78 | -1.09 | 0.38 | -1.13 | -0.44 | -2.35 | -3.15 |
| | 56.16 | 47.95 | 50.68 | 50.00 | 50.00 | 57.89 | 36.84 | 44.74 | 35.53 | 33.78 |
| $\beta_7$ | 3.596[1] | 3.872[1] | 1.679[2] | 2.180[1] | -0.235 | 2.389[1] | 3.947[1] | 2.180[1] | 1.394[1] | -0.558 |
| | 2.78 | 3.54 | 2.36 | 2.73 | -0.19 | 4.02 | 4.50 | 4.67 | 2.66 | -1.13 |
| | 63.01 | 65.75 | 61.64 | 58.11 | 58.33 | 60.53 | 65.79 | 67.11 | 53.95 | 37.84 |
| $intercept$ | 2.471[2] | 2.761[1] | 3.399[1] | 5.131[1] | 7.653[1] | 2.849[1] | 3.165[1] | 3.217[1] | 4.268[1] | 6.272[1] |
| | 2.36 | 3.27 | 6.36 | 7.32 | 8.64 | 7.43 | 5.74 | 12.11 | 12.81 | 17.04 |
| | 68.49 | 75.34 | 75.34 | 78.38 | 81.94 | 84.21 | 82.89 | 94.74 | 93.42 | 95.95 |
| $adj\ R^2$ | 3.21 | 7.06 | 20.21 | 23.26 | 39.01 | 4.27 | 6.56 | 10.94 | 13.71 | 28.96 |
| $N$ | 65 | 68 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A1 (Continued)
## Liquidity Comovement between Call Options and Call Options Market (Proportional Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.000 | 0.004 | -0.003 | -0.002 | -0.002 | 0.002 | 0.001 | -0.001 | -0.001 | -0.001 |
| | 0.19 | 1.17 | -1.59 | -1.04 | -0.94 | 0.59 | 0.34 | -0.37 | -0.38 | -0.78 |
| | 48.68 | 52.63 | 47.37 | 46.05 | 45.33 | 42.86 | 45.45 | 54.55 | 36.36 | 50.00 |
| $\beta_2$ | 0.429[1] | 0.458[1] | 0.504[1] | 0.407[1] | 0.251[1] | 0.005 | 0.031 | 0.002 | -0.015 | 0.062[3] |
| | 7.17 | 6.47 | 9.70 | 8.22 | 5.77 | 0.08 | 0.54 | 0.04 | -0.27 | 1.80 |
| | 78.95 | 80.26 | 86.84 | 76.32 | 78.67 | 47.62 | 68.18 | 40.91 | 40.91 | 63.64 |
| $\beta_{2lag}$ | 0.023 | 0.018 | 0.010 | -0.041 | -0.002 | -0.014 | 0.096[1] | 0.069[2] | 0.028 | 0.052[1] |
| | 1.07 | 0.65 | 0.50 | -1.66 | -0.15 | -0.36 | 3.02 | 2.11 | 0.68 | 3.14 |
| | 55.26 | 60.53 | 46.05 | 43.42 | 44.00 | 52.38 | 77.27 | 68.18 | 59.09 | 63.64 |
| $\beta_2 + \beta_{2lag}$ | 0.445[1] | 0.477[1] | 0.514[1] | 0.365[1] | 0.248[1] | -0.008 | 0.126[2] | 0.0713 | 0.013 | 0.114[1] |
| | 7.64 | 6.12 | 9.65 | 6.42 | 5.34 | -0.11 | 2.10 | 1.13 | 0.16 | 3.25 |
| | 51.97 | 56.58 | 46.71 | 44.74 | 44.67 | 47.62 | 61.36 | 61.36 | 47.73 | 56.82 |
| $\beta_3$ | 0.017 | 0.051[1] | 0.021[3] | 0.030[3] | 0.001 | 0.022 | 0.049[3] | 0.033[2] | 0.049 | 0.018 |
| | 1.19 | 3.00 | 1.78 | 1.78 | 0.09 | 1.36 | 2.01 | 2.39 | 1.71 | 1.19 |
| | 51.32 | 55.26 | 59.21 | 51.32 | 50.67 | 57.14 | 63.64 | 72.73 | 68.18 | 59.09 |
| $\beta_{3lag}$ | 0.012 | 0.021 | 0.013 | 0.010 | -0.005 | 0.031[3] | 0.061[2] | 0.016 | 0.079[1] | 0.051[1] |
| | 0.78 | 1.18 | 1.17 | 0.51 | -0.44 | 1.83 | 2.20 | 0.89 | 3.67 | 3.42 |
| | 46.05 | 53.95 | 46.05 | 48.68 | 52.00 | 61.90 | 59.09 | 59.09 | 81.82 | 63.64 |
| $\beta_3 + \beta_{3lag}$ | 0.029 | 0.072[2] | 0.034[3] | 0.040 | -0.004 | 0.053[2] | 0.109[2] | 0.049[3] | 0.127[1] | 0.069[2] |
| | 1.19 | 2.43 | 1.76 | 1.23 | -0.19 | 2.19 | 2.43 | 1.98 | 2.92 | 2.73 |
| | 48.68 | 54.61 | 52.63 | 50.00 | 51.33 | 59.52 | 61.36 | 65.91 | 75.00 | 61.36 |
| $\beta_4$ | -1.377[1] | -3.103[1] | -3.540[1] | -4.623[1] | -6.234[1] | -0.809[3] | -1.885[1] | -2.453[1] | -3.157[1] | -4.555[1] |
| | -6.52 | -12.16 | -17.39 | -18.99 | -23.57 | -1.78 | -3.38 | -9.97 | -9.84 | -10.82 |
| | 19.74 | 6.58 | 1.32 | 0.00 | 0.00 | 9.52 | 9.09 | 0.00 | 4.55 | 0.00 |
| $\beta_5$ | 0.066[2] | 0.070 | 0.006 | 0.009 | 0.126[1] | 0.064 | -0.001 | -0.029 | 0.019 | 0.077[2] |
| | 2.48 | 1.52 | 0.24 | 0.24 | 4.20 | 1.51 | -0.02 | -1.23 | 0.26 | 2.28 |
| | 59.21 | 52.63 | 47.37 | 51.32 | 73.33 | 47.62 | 63.64 | 54.55 | 54.55 | 77.27 |
| $\beta_6$ | 0.904[2] | 0.252 | 0.248 | -0.818[3] | -0.525 | 0.731 | -0.065 | -0.092 | 0.158 | 0.231 |
| | 2.54 | 0.39 | 0.62 | -1.80 | -1.21 | 1.54 | -0.08 | -0.24 | 0.17 | 0.49 |
| | 61.84 | 56.58 | 53.95 | 42.11 | 40.00 | 57.14 | 50.00 | 54.55 | 54.55 | 68.18 |
| $\beta_7$ | 4.224[1] | 4.041[1] | 3.115[1] | 1.777[1] | 0.570 | 4.938[1] | 2.921[2] | 2.051[1] | 1.943 | 1.384[3] |
| | 7.39 | 5.25 | 7.04 | 2.88 | 1.24 | 6.50 | 2.24 | 3.75 | 1.70 | 1.87 |
| | 73.68 | 65.79 | 77.63 | 60.53 | 53.33 | 90.48 | 68.18 | 68.18 | 59.09 | 68.18 |
| $intercept$ | 2.056[1] | 2.591[1] | 3.036[1] | 3.657[1] | 4.444[1] | 1.282[1] | 2.058[2] | 2.672[1] | 2.710[1] | 3.344[1] |
| | 5.81 | 5.03 | 8.95 | 7.45 | 11.28 | 3.02 | 2.45 | 7.34 | 3.02 | 5.70 |
| | 80.26 | 78.95 | 86.84 | 88.16 | 92.00 | 71.43 | 81.82 | 90.91 | 86.36 | 95.45 |
| $adj\ R^2$ | 2.91 | 6.57 | 7.23 | 9.37 | 19.96 | 2.69 | 4.67 | 5.62 | 7.28 | 17.98 |
| $N$ | 68 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A2
## Liquidity Comovement between Put Options and Put Options Market (Proportional Spread)

This table presents the results of liquidity comovement between put options and their options market. For each stock in its maturity and moneyness portfolio, all options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$ . $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of put options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0108 | -0.0061 | -0.0003 | -0.0047 | 0.0022 | -0.0035 | -0.0029 | -0.0004 | -0.0014 | 0.0004 |
| | 0.92 | -1.08 | -0.10 | -0.92 | 0.19 | -0.75 | -1.14 | -0.16 | -0.54 | 0.10 |
| | 44.44 | 34.25 | 45.33 | 42.67 | 51.39 | 47.95 | 47.95 | 42.47 | 46.58 | 51.39 |
| $\beta_2$ | 0.7631$^{1}$ | 0.4307$^{1}$ | 0.6701$^{1}$ | 0.4874$^{1}$ | 0.4463$^{1}$ | 0.3397$^{1}$ | 0.5684$^{1}$ | 0.6077$^{1}$ | 0.5375$^{1}$ | 0.2667$^{1}$ |
| | 3.34 | 5.43 | 7.85 | 4.60 | 3.74 | 3.99 | 8.68 | 7.80 | 7.43 | 4.15 |
| | 66.67 | 76.71 | 80.00 | 65.33 | 72.22 | 71.23 | 89.04 | 91.78 | 89.04 | 72.22 |
| $\beta_{2lag}$ | -0.1022 | -0.0321 | 0.0730 | 0.1068 | 0.0421 | -0.0464 | -0.0377$^{3}$ | 0.0142 | 0.0662$^{1}$ | 0.0352$^{3}$ |
| | -0.97 | -0.52 | 1.31 | 1.56 | 0.41 | -0.96 | -1.69 | 0.67 | 3.10 | 1.68 |
| | 37.50 | 46.58 | 56.00 | 46.67 | 51.39 | 36.99 | 45.21 | 60.27 | 67.12 | 59.72 |
| $\beta_2 + \beta_{2lag}$ | 0.6608$^{2}$ | 0.3986$^{1}$ | 0.7431$^{1}$ | 0.5942$^{1}$ | 0.4884$^{2}$ | 0.2933$^{1}$ | 0.5307$^{1}$ | 0.6220$^{1}$ | 0.6038$^{1}$ | 0.3018$^{1}$ |
| | 2.54 | 3.90 | 6.23 | 3.96 | 2.39 | 2.94 | 7.33 | 7.54 | 7.46 | 4.11 |
| | 52.08 | 61.64 | 68.00 | 56.00 | 61.81 | 54.11 | 67.12 | 76.03 | 78.08 | 65.97 |
| $\beta_3$ | -0.0185 | -0.0183 | -0.0063 | -0.0427 | -0.0313 | 0.0624$^{2}$ | 0.0475$^{3}$ | 0.0536$^{1}$ | 0.0373 | -0.0396 |
| | -0.21 | -0.68 | -0.33 | -1.33 | -0.65 | 2.02 | 1.81 | 2.79 | 1.56 | -1.63 |
| | 45.83 | 47.95 | 50.67 | 48.00 | 36.11 | 58.90 | 60.27 | 60.27 | 63.01 | 36.11 |
| $\beta_{3lag}$ | -0.1134 | -0.0397$^{3}$ | -0.0393$^{2}$ | -0.0493$^{3}$ | -0.0047 | 0.0284 | 0.0607$^{2}$ | 0.0825$^{1}$ | 0.0825$^{1}$ | 0.0664$^{1}$ |
| | -1.31 | -1.84 | -2.26 | -1.75 | -0.15 | 0.84 | 2.55 | 3.10 | 3.24 | 3.14 |
| | 44.44 | 32.88 | 40.00 | 44.00 | 40.28 | 52.05 | 61.64 | 69.86 | 61.64 | 58.33 |
| $\beta_3 + \beta_{3lag}$ | -0.1319 | -0.0580 | -0.0456 | -0.0920$^{3}$ | -0.0360 | 0.0908 | 0.1082$^{2}$ | 0.1361$^{1}$ | 0.1197$^{1}$ | 0.0269 |
| | -0.81 | -1.47 | -1.40 | -1.77 | -0.56 | 1.65 | 2.46 | 3.71 | 2.70 | 0.71 |
| | 45.14 | 40.41 | 45.33 | 46.00 | 38.19 | 55.48 | 60.96 | 65.07 | 62.33 | 47.22 |
| $\beta_4$ | -0.2194 | 2.3059$^{1}$ | 9.1308$^{1}$ | 14.4388$^{1}$ | 13.0265$^{1}$ | 0.5967$^{2}$ | 2.4261$^{1}$ | 6.1306$^{1}$ | 9.8749$^{1}$ | 10.8045$^{1}$ |
| | -0.30 | 8.42 | 19.35 | 20.55 | 18.50 | 2.27 | 10.18 | 19.12 | 19.80 | 23.35 |
| | 52.78 | 89.04 | 97.33 | 96.00 | 98.61 | 63.01 | 90.41 | 100.00 | 100.00 | 100.00 |
| $\beta_5$ | 0.1509 | 0.0123 | 0.4727$^{1}$ | 0.7254$^{1}$ | 0.9654$^{1}$ | 0.1904$^{2}$ | 0.0151 | 0.2406$^{1}$ | 0.2928$^{1}$ | 0.6585$^{1}$ |
| | 1.40 | 0.13 | 5.21 | 5.92 | 3.38 | 2.30 | 0.24 | 3.51 | 4.74 | 5.02 |
| | 50.00 | 49.32 | 72.00 | 72.00 | 70.83 | 49.32 | 31.51 | 63.01 | 72.60 | 81.94 |
| $\beta_6$ | 0.9745 | 1.5710 | 2.1287$^{1}$ | 3.8445$^{1}$ | 4.2068$^{1}$ | -0.3530 | -0.7817 | -0.5423 | -0.7447 | -0.5315 |
| | 0.55 | 1.31 | 3.55 | 3.07 | 2.97 | -0.32 | -1.42 | -1.07 | -1.18 | -0.64 |
| | 50.00 | 61.64 | 58.67 | 61.33 | 72.22 | 53.42 | 43.84 | 50.68 | 45.21 | 54.17 |
| $\beta_7$ | -0.2271 | 1.8943 | 4.9903$^{1}$ | 6.7935$^{1}$ | 7.2334$^{1}$ | 0.1006 | 1.4104 | 1.6123$^{2}$ | 2.0940$^{2}$ | 1.1534 |
| | -0.06 | 1.34 | 6.34 | 4.86 | 4.01 | 0.07 | 1.55 | 2.27 | 2.63 | 1.04 |
| | 23.61 | 47.95 | 74.67 | 72.00 | 61.11 | 52.05 | 60.27 | 64.38 | 67.12 | 56.94 |
| $intercept$ | 3.4397$^{3}$ | 2.3282$^{2}$ | 4.6887$^{1}$ | 10.0165$^{1}$ | 11.5117$^{1}$ | 5.2034$^{1}$ | 3.7827$^{1}$ | 5.1091$^{1}$ | 7.2205$^{1}$ | 9.0270$^{1}$ |
| | 2.14 | 2.40 | 7.32 | 10.55 | 9.92 | 5.62 | 6.80 | 10.93 | 10.91 | 12.05 |
| | 61.11 | 67.12 | 86.67 | 90.67 | 88.89 | 76.71 | 78.08 | 94.52 | 93.15 | 90.28 |
| $adj\ R^2$ | 8.74 | 6.96 | 36.82 | 41.05 | 45.79 | 6.88 | 8.85 | 25.37 | 33.27 | 40.7 |
| $N$ | 15 | 43 | 70 | 68 | 35 | 59 | 70 | 70 | 70 | 70 |

## Table A2 (Continued)
## Liquidity Comovement between Put Options and Put Options Market (Proportional Spread)

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0029 | -0.0009 | -0.0051[2] | -0.0058 | -0.0038 | -0.0002 | -0.0018 | 0.0006 | -0.0032[3] | -0.0002 |
| | -1.01 | -0.24 | -2.16 | -1.39 | -1.00 | -0.12 | -0.71 | 0.33 | -1.69 | -0.13 |
| | 43.84 | 43.84 | 47.95 | 39.73 | 31.94 | 46.67 | 46.67 | 50.00 | 40.79 | 48.68 |
| $\beta_2$ | 0.4299[1] | 0.4877[1] | 0.7106[1] | 0.4803[1] | 0.2190[1] | 0.5016[1] | 0.6414[1] | 0.6019[1] | 0.5266[1] | 0.2593[1] |
| | 3.99 | 7.63 | 6.73 | 6.24 | 7.53 | 9.24 | 10.78 | 7.51 | 8.80 | 7.29 |
| | 71.23 | 82.19 | 83.56 | 83.56 | 81.94 | 89.33 | 89.33 | 88.16 | 86.84 | 89.47 |
| $\beta_{2lag}$ | -0.0198 | -0.0054 | 0.0629[1] | 0.0663[1] | 0.0641[1] | -0.0122 | -0.0073 | 0.0035 | 0.0171 | 0.0374[2] |
| | -0.66 | -0.18 | 2.72 | 2.90 | 2.76 | -0.74 | -0.41 | 0.24 | 0.93 | 2.61 |
| | 57.53 | 54.79 | 69.86 | 68.49 | 69.44 | 49.33 | 54.67 | 53.95 | 59.21 | 56.58 |
| $\beta_2 + \beta_{2lag}$ | 0.4101[1] | 0.4822[1] | 0.7734[1] | 0.5466[1] | 0.2831[1] | 0.4894[1] | 0.6342[1] | 0.6054[1] | 0.5436[1] | 0.2968[1] |
| | 3.54 | 6.70 | 6.53 | 6.24 | 6.91 | 8.68 | 11.09 | 7.17 | 9.05 | 7.56 |
| | 64.38 | 68.49 | 76.71 | 76.03 | 75.69 | 69.33 | 72.00 | 71.05 | 73.03 | 73.03 |
| $\beta_3$ | 0.0858[2] | 0.0193 | 0.0583[2] | 0.0852[2] | 0.0536[2] | 0.0317[2] | 0.0490[2] | 0.0404[1] | 0.0453[1] | 0.0389[1] |
| | 2.12 | 0.62 | 2.24 | 2.51 | 2.16 | 2.43 | 2.53 | 2.78 | 3.00 | 3.08 |
| | 56.16 | 52.05 | 61.64 | 65.75 | 58.33 | 56.00 | 58.67 | 65.79 | 60.53 | 52.63 |
| $\beta_{3lag}$ | -0.0501 | -0.0703[3] | -0.0152 | 0.0564[2] | 0.0223 | 0.0068 | 0.0535[1] | 0.0215[2] | 0.0048 | 0.0272[2] |
| | -1.21 | -1.91 | -0.62 | 2.12 | 0.82 | 0.49 | 2.86 | 2.00 | 0.37 | 2.50 |
| | 41.10 | 46.58 | 52.05 | 60.27 | 54.17 | 49.33 | 61.33 | 60.53 | 46.05 | 51.32 |
| $\beta_3 + \beta_{3lag}$ | 0.0357 | -0.0510 | 0.0431 | 0.1416[1] | 0.0759[3] | 0.0386[3] | 0.1025[1] | 0.0619[1] | 0.0502[2] | 0.0661[1] |
| | 0.51 | -0.87 | 1.04 | 3.00 | 1.70 | 1.71 | 3.26 | 3.17 | 2.30 | 3.28 |
| | 48.63 | 49.32 | 56.85 | 63.01 | 56.25 | 52.67 | 60.00 | 63.16 | 53.29 | 51.97 |
| $\beta_4$ | 0.5640[3] | 1.9816[1] | 4.3715[1] | 7.2785[1] | 9.0883[1] | 0.5961[1] | 1.8086[1] | 3.0468[1] | 4.5516[1] | 5.9735[1] |
| | 1.73 | 7.42 | 16.32 | 18.74 | 21.54 | 3.62 | 10.91 | 17.57 | 19.05 | 22.26 |
| | 64.38 | 84.93 | 97.26 | 100.00 | 100.00 | 64.00 | 90.67 | 97.37 | 98.68 | 98.68 |
| $\beta_5$ | 0.2962[1] | -0.1822[1] | -0.0179 | 0.1599[2] | 0.2602[1] | 0.1012[2] | 0.0301 | 0.1237[1] | 0.1692[1] | 0.2309[1] |
| | 3.00 | -2.74 | -0.34 | 2.05 | 3.62 | 2.65 | 0.93 | 3.97 | 4.06 | 4.93 |
| | 57.53 | 31.51 | 38.36 | 54.79 | 72.22 | 56.00 | 48.00 | 67.11 | 61.84 | 73.68 |
| $\beta_6$ | -0.3712 | -0.0633 | 0.4812 | 1.7840[3] | 1.6811[3] | -0.9209[2] | 1.1588[2] | 0.7570[2] | 0.0892 | 0.8122[3] |
| | -0.41 | -0.09 | 0.95 | 1.83 | 1.68 | -2.05 | 2.53 | 2.28 | 0.20 | 1.96 |
| | 50.68 | 47.95 | 54.79 | 57.53 | 63.89 | 36.00 | 65.33 | 61.84 | 50.00 | 57.89 |
| $\beta_7$ | 2.3368 | 2.0626[2] | 2.4734[1] | 2.9900[1] | 1.7633 | 2.1621[1] | 4.1533[1] | 3.2481[1] | 2.3174[1] | 1.9934[1] |
| | 1.65 | 2.43 | 3.76 | 3.29 | 1.55 | 3.23 | 6.14 | 6.48 | 4.04 | 4.40 |
| | 56.16 | 57.53 | 68.49 | 61.64 | 61.11 | 62.67 | 73.33 | 73.68 | 61.84 | 71.05 |
| $intercept$ | 4.1646[1] | 4.2073[1] | 4.2065[1] | 4.2814[1] | 6.4772[1] | 4.1080[1] | 2.9251[1] | 3.2505[1] | 3.9399[1] | 4.6458[1] |
| | 4.66 | 6.32 | 7.90 | 5.21 | 6.01 | 10.19 | 7.48 | 10.78 | 11.14 | 12.86 |
| | 71.23 | 76.71 | 87.67 | 82.19 | 88.89 | 92.00 | 78.67 | 90.79 | 93.42 | 93.42 |
| $adj\ R^2$ | 4.18 | 5.82 | 20.67 | 24.24 | 35.38 | 3.8 | 5.8 | 10.24 | 13.74 | 23.41 |
| $N$ | 58 | 68 | 70 | 69 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A2 (Continued)
## Liquidity Comovement between Put Options and Put Options Market (Proportional Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0017 | -0.0037 | -0.0021 | 0.0004 | -0.0006 | -0.0027 | 0.0050 | -0.0004 | 0.0004 | 0.0021 |
| | -0.52 | -1.46 | -1.21 | 0.11 | -0.26 | -1.47 | 1.56 | -0.24 | 0.24 | 0.91 |
| | 41.33 | 43.42 | 44.74 | 50.00 | 40.79 | 45.45 | 68.18 | 54.55 | 40.91 | 47.62 |
| $\beta_2$ | 0.5328[1] | 0.6053[1] | 0.5970[1] | 0.5139[1] | 0.4283[1] | 0.1447[2] | 0.0355 | 0.1492[1] | 0.0676 | 0.0174 |
| | 9.12 | 8.51 | 9.21 | 7.27 | 8.13 | 2.38 | 0.73 | 2.90 | 0.94 | 0.45 |
| | 84.00 | 88.16 | 89.47 | 81.58 | 85.53 | 68.18 | 54.55 | 72.73 | 59.09 | 52.38 |
| $\beta_{2lag}$ | -0.0487[3] | -0.0401 | -0.0197 | -0.0334 | 0.0224 | 0.0065 | 0.0447 | 0.0433 | 0.0343 | 0.0414[2] |
| | -1.81 | -1.47 | -0.79 | -1.13 | 1.05 | 0.20 | 1.17 | 1.58 | 1.14 | 1.49 |
| | 45.33 | 48.68 | 51.32 | 48.68 | 55.26 | 50.00 | 68.18 | 68.18 | 50.00 | 76.19 |
| $\beta_2 + \beta_{2lag}$ | 0.4841[1] | 0.5651[1] | 0.5773[1] | 0.4805[1] | 0.4507[1] | 0.1512[3] | 0.0802 | 0.1925[1] | 0.1019 | 0.0588 |
| | 9.29 | 8.92 | 9.08 | 6.44 | 8.22 | 2.04 | 1.31 | 3.32 | 1.21 | 1.43 |
| | 64.67 | 68.42 | 70.39 | 65.13 | 70.39 | 59.09 | 61.36 | 70.45 | 54.55 | 64.29 |
| $\beta_3$ | -0.0099 | 0.0128 | 0.0212[3] | 0.0213 | -0.0037 | 0.0201 | -0.0044 | 0.0071 | 0.0146 | 0.0153 |
| | -0.68 | 0.65 | 1.89 | 1.15 | -0.28 | 1.09 | -0.18 | 0.35 | 0.70 | 0.72 |
| | 48.00 | 53.95 | 57.89 | 44.74 | 42.11 | 63.64 | 45.45 | 50.00 | 59.09 | 47.62 |
| $\beta_{3lag}$ | -0.0099 | 0.0260 | 0.0006 | 0.0067 | 0.0017 | 0.0759[1] | 0.0903[1] | 0.0095 | 0.0894[1] | 0.0407[2] |
| | -0.45 | 0.92 | 0.04 | 0.30 | 0.12 | 4.79 | 4.29 | 0.41 | 3.21 | 2.49 |
| | 48.00 | 52.63 | 43.42 | 48.68 | 50.00 | 86.36 | 86.36 | 50.00 | 72.73 | 71.43 |
| $\beta_3 + \beta_{3lag}$ | -0.0199 | 0.0388 | 0.0218 | 0.0280 | -0.0020 | 0.0960[1] | 0.0858[2] | 0.0166 | 0.1040[1] | 0.0560[3] |
| | -0.61 | 0.97 | 1.08 | 0.89 | -0.08 | 3.36 | 2.43 | 0.46 | 2.88 | 1.94 |
| | 48.00 | 53.29 | 50.66 | 46.71 | 46.05 | 75.00 | 65.91 | 50.00 | 65.91 | 59.52 |
| $\beta_4$ | 0.3467[2] | 1.3930[1] | 2.1227[1] | 3.2629[1] | 4.2903[1] | 0.4516[3] | 1.1665[1] | 1.7004[1] | 2.1892[1] | 2.7914[1] |
| | 2.26 | 7.23 | 11.74 | 14.25 | 21.29 | 1.93 | 3.85 | 6.34 | 9.33 | 9.32 |
| | 66.67 | 88.16 | 92.11 | 97.37 | 100.00 | 63.64 | 81.82 | 90.91 | 90.91 | 100.00 |
| $\beta_5$ | 0.1247[1] | 0.0590[3] | 0.1151[1] | 0.1154[2] | 0.1057[1] | 0.0116 | -0.0252 | -0.0028 | 0.0629 | 0.0099 |
| | 3.13 | 1.84 | 3.71 | 2.46 | 2.89 | 0.26 | -0.67 | -0.08 | 1.55 | 0.38 |
| | 64.00 | 63.16 | 53.95 | 53.95 | 61.84 | 68.18 | 54.55 | 54.55 | 63.64 | 52.38 |
| $\beta_6$ | -0.0013 | 1.3151[2] | 0.4947 | 0.3755 | 1.0744[1] | -0.4005 | 0.1830 | 0.5750 | -0.1177 | 2.2465[1] |
| | 0.00 | 2.42 | 1.09 | 0.68 | 2.88 | -0.65 | 0.17 | 0.96 | -0.13 | 3.22 |
| | 52.00 | 59.21 | 55.26 | 51.32 | 61.84 | 63.64 | 59.09 | 63.64 | 54.55 | 71.43 |
| $\beta_7$ | 3.9767[1] | 5.0136[1] | 4.0715[1] | 3.1590[1] | 3.1961[1] | 5.0253[1] | 2.6999[1] | 3.1107[1] | 1.9504[2] | 4.5498[1] |
| | 6.37 | 6.35 | 7.35 | 5.09 | 7.08 | 5.31 | 1.70 | 3.81 | 2.52 | 6.52 |
| | 72.00 | 75.00 | 72.37 | 65.79 | 68.42 | 81.82 | 68.18 | 68.18 | 63.64 | 85.71 |
| $intercept$ | 3.0484[1] | 2.5245[1] | 2.8711[1] | 3.0021[1] | 3.3029[1] | 2.2500[1] | 2.1605[2] | 1.8400[1] | 2.6125[1] | 1.7893[1] |
| | 6.59 | 6.07 | 7.45 | 7.74 | 9.50 | 3.86 | 2.20 | 3.08 | 3.39 | 4.88 |
| | 77.33 | 75.00 | 82.89 | 82.89 | 84.21 | 86.36 | 59.09 | 77.27 | 72.73 | 90.48 |
| $adj\ R^2$ | 3.17 | 4.44 | 6.67 | 8.35 | 13.16 | 1.82 | 1.71 | 3.54 | 4.15 | 5.83 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A3

## Liquidity Comovement between All Options and their Options Market (Proportional Spread)

This table presents the results of liquidity comovement between all options (both call and put options combined) and their options market. For each stock in its maturity and moneyness portfolio, all options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL_{m,t}^{res} + \beta_{3lag,i}DOSL_{m,t-1}^{res} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 respectively, $DOSL_{m,t}^{res}$ and $DOSL_{m,t-1}^{res}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0037 | 0.0001 | 0.0013 | 0.0060 | -0.0051 | 0.0013 | -0.0001 | -0.0004 | 0.0018 | 0.0001 |
| | 0.66 | 0.03 | 0.53 | 1.60 | -0.63 | 0.56 | -0.04 | -0.19 | 0.67 | 0.03 |
| | 59.46 | 50.67 | 56.00 | 57.33 | 41.67 | 47.95 | 49.32 | 46.58 | 47.95 | 54.17 |
| $\beta_2$ | 0.3434 | 0.6648$^{1}$ | 0.8253$^{1}$ | 0.6098$^{1}$ | 0.4309$^{2}$ | 0.7088$^{1}$ | 1.0131$^{1}$ | 0.8639$^{1}$ | 0.6704$^{1}$ | 0.2628$^{1}$ |
| | 1.08 | 6.90 | 9.97 | 5.30 | 2.39 | 7.87 | 10.59 | 8.09 | 6.48 | 3.69 |
| | 68.92 | 78.67 | 88.00 | 68.00 | 62.50 | 83.56 | 95.89 | 93.15 | 94.52 | 65.28 |
| $\beta_{2lag}$ | 0.1394 | -0.0562 | 0.0098 | 0.0038 | -0.0662 | -0.0211 | 0.0101 | 0.0289 | 0.0424$^{2}$ | 0.0060 |
| | 0.52 | -0.68 | 0.19 | 0.06 | -0.68 | -0.72 | 0.52 | 1.55 | 2.11 | 0.33 |
| | 54.05 | 49.33 | 48.00 | 42.67 | 43.06 | 52.05 | 50.68 | 63.01 | 50.68 | 47.22 |
| $\beta_2 + \beta_{2lag}$ | 0.4828 | 0.6086$^{1}$ | 0.8351$^{1}$ | 0.6136$^{1}$ | 0.3647 | 0.6877$^{1}$ | 1.0232$^{1}$ | 0.8928$^{1}$ | 0.7128$^{1}$ | 0.2688 |
| | 1.12 | 4.48 | 8.47 | 3.83 | 1.51 | 7.30 | 10.75 | 7.87 | 6.23 | 3.36 |
| | 61.49 | 64.00 | 68.00 | 55.33 | 52.78 | 67.81 | 73.29 | 78.08 | 72.60 | 56.25 |
| $\beta_3$ | 0.0672 | 0.0344$^{2}$ | 0.0351$^{2}$ | -0.0121 | 0.0415 | 0.0164 | 0.0525$^{1}$ | 0.0558$^{1}$ | 0.0424$^{2}$ | -0.0068 |
| | 1.00 | 2.37 | 2.22 | -0.49 | 0.85 | 0.75 | 2.76 | 3.50 | 2.03 | -0.30 |
| | 52.70 | 52.00 | 56.00 | 46.67 | 51.39 | 56.16 | 63.01 | 64.38 | 58.90 | 43.06 |
| $\beta_{3lag}$ | -0.0723$^{2}$ | -0.0175 | -0.0073 | -0.0501$^{2}$ | -0.0195 | 0.0025 | 0.0636$^{1}$ | 0.0796$^{1}$ | 0.0957$^{1}$ | 0.1055$^{1}$ |
| | -2.04 | -1.12 | -0.51 | -2.64 | -0.78 | 0.11 | 3.42 | 3.21 | 4.08 | 3.87 |
| | 31.08 | 41.33 | 45.33 | 34.67 | 43.06 | 46.58 | 61.64 | 71.23 | 65.75 | 61.11 |
| $\beta_3 + \beta_{3lag}$ | -0.0051 | 0.0169 | 0.0279 | -0.0622$^{3}$ | 0.0220 | 0.0189 | 0.1161$^{1}$ | 0.1354$^{1}$ | 0.1381$^{1}$ | 0.0986$^{2}$ |
| | -0.06 | 0.73 | 1.10 | -1.68 | 0.34 | 0.50 | 3.50 | 4.01 | 3.66 | 2.28 |
| | 41.89 | 46.67 | 50.67 | 40.67 | 47.22 | 51.37 | 62.33 | 67.81 | 62.33 | 52.08 |
| $\beta_4$ | -1.2597$^{1}$ | -1.4651$^{1}$ | -0.2130 | 1.4126$^{1}$ | 3.8452$^{1}$ | -0.6009 | -0.2926$^{2}$ | -0.0216 | 0.1156 | 2.5462$^{1}$ |
| | -3.32 | -6.84 | -1.09 | 3.59 | 5.25 | -3.11 | -2.01 | -0.16 | 0.46 | 6.44 |
| | 31.08 | 22.67 | 41.33 | 57.33 | 76.39 | 32.88 | 35.62 | 45.21 | 47.95 | 76.39 |
| $\beta_5$ | -0.0520 | -0.3488$^{1}$ | 0.2149$^{2}$ | 1.7151$^{1}$ | 1.9281$^{1}$ | 0.1030$^{3}$ | -0.1998$^{1}$ | 0.1414$^{2}$ | 0.8780$^{1}$ | 1.3685$^{1}$ |
| | -0.66 | -5.70 | 2.48 | 7.76 | 6.93 | 1.67 | -6.06 | 2.64 | 7.51 | 9.65 |
| | 25.68 | 16.00 | 58.67 | 92.00 | 98.61 | 56.16 | 13.70 | 47.95 | 93.15 | 97.22 |
| $\beta_6$ | 0.1596 | 0.3474 | 1.2617$^{2}$ | 3.0963$^{2}$ | 4.4505$^{2}$ | -1.0467 | -0.5066 | -0.5824 | -0.5359 | -2.4708$^{2}$ |
| | 0.13 | 0.46 | 2.10 | 2.21 | 2.67 | -1.48 | -1.08 | -1.37 | -0.78 | -2.60 |
| | 50.00 | 54.67 | 56.00 | 58.67 | 56.94 | 46.58 | 45.21 | 49.32 | 52.05 | 41.67 |
| $\beta_7$ | 0.4663 | 1.8826 | 4.1119$^{1}$ | 9.9353$^{1}$ | 7.2101$^{1}$ | 0.1344 | 1.4845$^{3}$ | 1.1597$^{3}$ | 4.1330$^{1}$ | 1.8586 |
| | 0.23 | 1.63 | 6.28 | 6.53 | 3.11 | 0.13 | 1.93 | 1.99 | 4.77 | 1.44 |
| | 47.30 | 54.67 | 74.67 | 72.00 | 50.00 | 45.21 | 57.53 | 63.01 | 75.34 | 56.94 |
| $intercept$ | 4.6481$^{1}$ | 3.2161$^{1}$ | 5.5400$^{1}$ | 11.7372$^{1}$ | 14.3063$^{1}$ | 4.7964$^{1}$ | 3.7488$^{1}$ | 5.4041$^{1}$ | 7.1543$^{1}$ | 12.4111$^{1}$ |
| | 4.08 | 5.09 | 9.02 | 11.24 | 9.91 | 7.37 | 9.43 | 13.89 | 10.94 | 14.37 |
| | 56.76 | 72.00 | 86.67 | 90.67 | 88.89 | 86.30 | 90.41 | 100.00 | 91.78 | 98.61 |
| $adj\ R^2$ | 5.75 | 7.51 | 7.56 | 13.17 | 30.58 | 4.4 | 6.51 | 9.55 | 11.85 | 20.98 |
| $N$ | 34 | 70 | 70 | 70 | 40 | 70 | 70 | 70 | 70 | 70 |

**Table A3 (Continued)**
**Liquidity Comovement between All Options and their Options Market**
**(Proportional Spread)**

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0027 | -0.0029 | -0.0028 | 0.0018 | -0.0002 | 0.0012 | -0.0007 | 0.0009 | 0.0018 | 0.0006 |
| | -0.90 | -1.14 | -1.49 | 0.52 | -0.04 | 0.87 | -0.36 | 0.60 | 1.02 | 0.38 |
| | 45.21 | 42.47 | 41.10 | 43.24 | 36.11 | 42.11 | 53.95 | 57.89 | 52.63 | 52.63 |
| $\beta_2$ | $0.6961^{1}$ | $0.8257^{1}$ | $0.9918^{1}$ | $0.6511^{1}$ | $0.1832^{1}$ | $0.7826^{1}$ | $0.9435^{1}$ | $0.8905^{1}$ | $0.7074^{1}$ | $0.2382^{1}$ |
| | 6.30 | 8.88 | 6.43 | 7.33 | 6.12 | 10.50 | 11.11 | 8.42 | 9.87 | 9.25 |
| | 79.45 | 86.30 | 91.78 | 93.24 | 83.33 | 89.47 | 92.11 | 94.74 | 90.79 | 89.47 |
| $\beta_{2lag}$ | 0.0378 | 0.0143 | 0.0186 | 0.0305 | -0.0106 | 0.0121 | $0.0386^{2}$ | 0.0049 | 0.0215 | -0.0018 |
| | 1.24 | 0.54 | 0.74 | 1.08 | -0.36 | 0.79 | 2.18 | 0.34 | 1.36 | -0.15 |
| | 52.05 | 57.53 | 56.16 | 63.51 | 58.33 | 67.11 | 57.89 | 52.63 | 51.32 | 59.21 |
| $\beta_2 + \beta_{2lag}$ | $0.7340^{1}$ | $0.8400^{1}$ | $1.0104^{1}$ | $0.6816^{1}$ | $0.1726^{1}$ | $0.7947^{1}$ | $0.9820^{1}$ | $0.8954^{1}$ | $0.7289^{1}$ | $0.2364^{1}$ |
| | 6.93 | 9.10 | 6.08 | 6.68 | 4.49 | 10.77 | 11.74 | 8.15 | 10.10 | 8.79 |
| | 65.75 | 71.92 | 73.97 | 78.38 | 70.83 | 78.29 | 75.00 | 73.68 | 71.05 | 74.34 |
| $\beta_3$ | $0.0969^{1}$ | 0.0377 | $0.0620^{1}$ | $0.0864^{1}$ | 0.0373 | $0.0309^{1}$ | $0.0563^{1}$ | $0.0504^{1}$ | $0.0399^{1}$ | $0.0220^{2}$ |
| | 3.14 | 1.37 | 2.66 | 3.22 | 1.25 | 2.76 | 4.04 | 4.67 | 3.16 | 2.14 |
| | 63.01 | 58.90 | 57.53 | 66.22 | 66.67 | 60.53 | 65.79 | 69.74 | 61.84 | 56.58 |
| $\beta_{3lag}$ | -0.0352 | $-0.0795^{2}$ | -0.0234 | 0.0345 | 0.0071 | 0.0054 | $0.0452^{1}$ | $0.0256^{2}$ | 0.0071 | $0.0277^{1}$ |
| | -1.30 | -2.63 | -1.08 | 1.34 | 0.25 | 0.45 | 3.23 | 2.54 | 0.60 | 3.21 |
| | 42.47 | 35.62 | 46.58 | 63.51 | 58.33 | 50.00 | 65.79 | 59.21 | 55.26 | 56.58 |
| $\beta_3 + \beta_{3lag}$ | 0.0617 | -0.0418 | 0.0386 | $0.1209^{1}$ | 0.0444 | $0.0363^{3}$ | $0.1015^{1}$ | $0.0760^{1}$ | $0.0470^{2}$ | $0.0497^{1}$ |
| | 1.26 | -0.85 | 0.99 | 2.77 | 0.83 | 1.88 | 4.59 | 4.52 | 2.20 | 3.13 |
| | 52.74 | 47.26 | 52.05 | 64.86 | 62.50 | 55.26 | 65.79 | 64.47 | 58.55 | 56.58 |
| $\beta_4$ | 0.2040 | 0.2305 | 0.0806 | $-0.4212^{3}$ | $0.5518^{2}$ | -0.0793 | -0.0522 | -0.0657 | $-0.2437^{3}$ | -0.2088 |
| | 0.93 | 1.36 | 0.54 | -1.93 | 2.20 | -0.82 | -0.42 | -0.67 | -1.71 | -1.32 |
| | 41.10 | 50.68 | 45.21 | 47.30 | 55.56 | 35.53 | 47.37 | 48.68 | 40.79 | 42.11 |
| $\beta_5$ | $0.1482^{2}$ | $-0.2902^{1}$ | 0.0009 | $0.3771^{1}$ | $0.9417^{1}$ | $0.0529^{3}$ | 0.0226 | $0.0935^{1}$ | $0.1877^{1}$ | $0.5132^{1}$ |
| | 2.07 | -5.51 | 0.02 | 4.80 | 10.89 | 1.84 | 0.75 | 3.02 | 5.68 | 9.18 |
| | 57.53 | 19.18 | 46.58 | 79.73 | 98.61 | 53.95 | 48.68 | 57.89 | 78.95 | 97.37 |
| $\beta_6$ | -0.3175 | -0.8417 | -0.4636 | -0.4240 | $-2.7469^{1}$ | $-0.6768^{3}$ | 0.0451 | -0.0116 | $-0.6790^{3}$ | $-1.1074^{1}$ |
| | -0.50 | -1.16 | -0.85 | -0.48 | -2.91 | -1.92 | 0.12 | -0.04 | -1.82 | -2.66 |
| | 52.05 | 45.21 | 50.68 | 43.24 | 43.06 | 35.53 | 47.37 | 48.68 | 39.47 | 34.21 |
| $\beta_7$ | $2.4442^{2}$ | $2.0478^{2}$ | $1.4908^{2}$ | $1.5802^{3}$ | -0.3323 | $1.9105^{1}$ | $4.3010^{1}$ | $2.4670^{1}$ | $1.7818^{1}$ | $0.8804^{3}$ |
| | 2.54 | 2.45 | 2.15 | 1.95 | -0.32 | 3.29 | 5.74 | 5.43 | 3.78 | 1.87 |
| | 57.53 | 60.27 | 63.01 | 59.46 | 50.00 | 61.84 | 72.37 | 69.74 | 61.84 | 57.89 |
| $intercept$ | $3.9940^{1}$ | $4.2901^{1}$ | $4.7417^{1}$ | $6.7530^{1}$ | $10.9236^{1}$ | $3.7909^{1}$ | $3.1780^{1}$ | $3.6452^{1}$ | $4.2535^{1}$ | $6.4372^{1}$ |
| | 6.14 | 7.16 | 8.57 | 9.92 | 12.42 | 10.27 | 8.45 | 13.77 | 14.52 | 16.17 |
| | 75.34 | 83.56 | 86.30 | 90.54 | 97.22 | 93.42 | 80.26 | 96.05 | 97.37 | 96.05 |
| $adj\ R^2$ | 3.67 | 4.25 | 13.44 | 9.59 | 14.73 | 4.08 | 3.58 | 6.27 | 5.04 | 9.95 |
| $N$ | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A3 (Continued)
## Liquidity Comovement between All Options and their Options Market (Proportional Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0010 | -0.0002 | -0.0022 | 0.0003 | -0.0002 | 0.0001 | 0.0026 | -0.0001 | 0.0004 | -0.0004 |
| | 0.35 | -0.07 | -1.32 | 0.11 | -0.13 | 0.03 | 0.90 | -0.09 | 0.21 | -0.23 |
| | 48.68 | 48.68 | 48.68 | 46.05 | 44.74 | 40.91 | 68.18 | 54.55 | 50.00 | 50.00 |
| $\beta_2$ | 0.8199$^{1}$ | 0.8785$^{1}$ | 0.8778$^{1}$ | 0.7216$^{1}$ | 0.4604$^{1}$ | 0.2917$^{1}$ | 0.2415$^{1}$ | 0.2249$^{1}$ | 0.1346$^{1}$ | 0.0284 |
| | 9.69 | 9.19 | 10.71 | 9.12 | 7.16 | 3.97 | 4.14 | 4.82 | 3.27 | 0.83 |
| | 86.84 | 88.16 | 90.79 | 85.53 | 88.16 | 77.27 | 81.82 | 77.27 | 68.18 | 59.09 |
| $\beta_{2lag}$ | -0.0357 | -0.0209 | -0.0275 | -0.0562$^{2}$ | 0.0005 | 0.0140 | 0.0400 | 0.0351 | 0.0107 | 0.0438$^{2}$ |
| | -1.29 | -0.73 | -1.07 | -2.02 | 0.03 | 0.58 | 1.26 | 1.17 | 0.33 | 2.42 |
| | 48.68 | 53.95 | 44.74 | 42.11 | 39.47 | 68.18 | 63.64 | 72.73 | 63.64 | 63.64 |
| $\beta_2 + \beta_{2lag}$ | 0.7843$^{1}$ | 0.8576$^{1}$ | 0.8503$^{1}$ | 0.6654$^{1}$ | 0.4608$^{1}$ | 0.3057$^{1}$ | 0.2815$^{1}$ | 0.2599$^{1}$ | 0.1454$^{2}$ | 0.0722 |
| | 9.61 | 9.39 | 10.58 | 7.97 | 6.74 | 3.87 | 4.45 | 4.18 | 2.37 | 1.73 |
| | 67.76 | 71.05 | 67.76 | 63.82 | 63.82 | 72.73 | 72.73 | 75.00 | 65.91 | 61.36 |
| $\beta_3$ | 0.0074 | 0.0369$^{2}$ | 0.0298$^{1}$ | 0.0308$^{3}$ | -0.0014 | 0.0155 | 0.0263$^{3}$ | 0.0256$^{3}$ | 0.0537$^{2}$ | 0.0066 |
| | 0.53 | 2.57 | 3.05 | 1.90 | -0.13 | 1.14 | 1.75 | 1.95 | 2.42 | 0.51 |
| | 52.63 | 63.16 | 64.47 | 60.53 | 47.37 | 72.73 | 68.18 | 72.73 | 77.27 | 36.36 |
| $\beta_{3lag}$ | -0.0063 | 0.0294 | 0.0160 | 0.0011 | -0.0070 | 0.0542$^{1}$ | 0.0688$^{1}$ | 0.0170 | 0.0787$^{1}$ | 0.0248$^{2}$ |
| | -0.29 | 1.33 | 1.26 | 0.07 | -0.70 | 4.61 | 4.54 | 0.94 | 3.77 | 2.29 |
| | 48.68 | 55.26 | 50.00 | 46.05 | 46.05 | 90.91 | 72.73 | 54.55 | 72.73 | 59.09 |
| $\beta_3 + \beta_{3lag}$ | 0.0011 | 0.0663$^{2}$ | 0.0457$^{2}$ | 0.0319 | -0.0084 | 0.0697$^{1}$ | 0.0951$^{1}$ | 0.0427 | 0.1324$^{1}$ | 0.0314 |
| | 0.03 | 2.12 | 2.45 | 1.13 | -0.46 | 3.41 | 3.69 | 1.69 | 3.32 | 1.54 |
| | 50.66 | 59.21 | 57.24 | 53.29 | 46.71 | 81.82 | 70.45 | 63.64 | 75.00 | 47.73 |
| $\beta_4$ | -0.0738 | -0.1727 | -0.1097 | -0.1645 | -0.7103$^{1}$ | 0.0436 | -0.2361 | -0.3083$^{1}$ | -0.8664$^{1}$ | -1.4014$^{1}$ |
| | -0.59 | -1.20 | -0.91 | -1.07 | -4.90 | 0.28 | -1.32 | -3.10 | -4.75 | -7.19 |
| | 50.00 | 47.37 | 43.42 | 39.47 | 26.32 | 40.91 | 31.82 | 18.18 | 9.09 | 4.55 |
| $\beta_5$ | 0.0556$^{3}$ | 0.0096 | 0.0681$^{2}$ | 0.1966$^{1}$ | 0.3777$^{1}$ | 0.0267 | -0.0671$^{3}$ | -0.0202 | 0.1361$^{2}$ | 0.2397$^{1}$ |
| | 1.79 | 0.32 | 2.63 | 5.11 | 9.29 | 0.68 | -1.90 | -0.79 | 2.27 | 4.54 |
| | 53.95 | 42.11 | 57.89 | 77.63 | 93.42 | 50.00 | 36.36 | 40.91 | 68.18 | 95.45 |
| $\beta_6$ | -0.0976 | 0.4799 | 0.2030 | -0.7517$^{3}$ | -0.4956 | 0.3268 | 0.3672 | 0.4412 | 0.0964 | 0.8443$^{3}$ |
| | -0.23 | 1.01 | 0.49 | -1.74 | -1.39 | 0.77 | 0.48 | 1.03 | 0.15 | 1.98 |
| | 50.00 | 55.26 | 56.58 | 42.11 | 40.79 | 68.18 | 54.55 | 59.09 | 50.00 | 72.73 |
| $\beta_7$ | 3.6479$^{1}$ | 4.3091$^{1}$ | 3.4903$^{1}$ | 2.0788$^{1}$ | 1.7646$^{1}$ | 5.2816$^{1}$ | 3.2024$^{2}$ | 2.8226$^{1}$ | 2.1844$^{2}$ | 3.0804$^{1}$ |
| | 6.71 | 6.63 | 7.76 | 3.93 | 4.55 | 7.29 | 2.75 | 4.51 | 2.31 | 4.50 |
| | 76.32 | 75.00 | 76.32 | 59.21 | 65.79 | 86.36 | 68.18 | 68.18 | 63.64 | 77.27 |
| $intercept$ | 3.0020$^{1}$ | 2.8754$^{1}$ | 3.0888$^{1}$ | 3.5216$^{1}$ | 4.7662$^{1}$ | 1.6439$^{1}$ | 1.8398$^{1}$ | 2.0599$^{1}$ | 2.5377$^{1}$ | 2.8194$^{1}$ |
| | 7.62 | 8.68 | 9.12 | 9.93 | 14.94 | 4.20 | 3.10 | 4.64 | 3.74 | 6.90 |
| | 81.58 | 81.58 | 92.11 | 92.11 | 96.05 | 81.82 | 68.18 | 90.91 | 86.36 | 95.45 |
| $adj\ R^2$ | 3.67 | 3.04 | 4.41 | 3.88 | 7.08 | 1.52 | 0.55 | 0.42 | 1.38 | 6.06 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A4
## Liquidity Comovement between Call Options and Call Options Market (Percentage Spread)

This table presents the results of liquidity comovement between call options and their options market. For each stock in its maturity and moneyness portfolio, all call options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i} DSL_{i,t} + \beta_{2,i} DSL_{m,t} + \beta_{2lag,i} DSL_{m,t-1} + \beta_{3,i} DOSL_{m,t}^{res} + \beta_{3lag,i} DOSL_{m,t-1}^{res} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 respectively, $DOSL_{m,t}^{res}$ and $DOSL_{m,t-1}^{res}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of call options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have +ve coeficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0119 | 0.0024 | 0.0018 | 0.0065 | -0.0039 | 0.0043 | 0.0023 | -0.0021 | 0.0012 | -0.0039 |
| | 1.66 | 0.60 | 0.66 | 1.64 | -0.64 | 1.21 | 0.85 | -1.07 | 0.51 | -1.41 |
| | 56.16 | 57.33 | 50.67 | 49.32 | 39.44 | 53.42 | 50.68 | 45.21 | 42.47 | 48.61 |
| $\beta_2$ | $0.2744^{2}$ | $0.2789^{1}$ | $0.4499^{1}$ | $0.3341^{1}$ | $0.4875^{2}$ | $0.5259^{1}$ | $0.6115^{1}$ | $0.5330^{1}$ | $0.4783^{1}$ | $0.3145^{1}$ |
| | 2.25 | 2.73 | 6.33 | 4.45 | 2.69 | 6.48 | 7.36 | 11.26 | 7.64 | 5.14 |
| | 56.16 | 69.33 | 80.00 | 75.34 | 74.65 | 82.19 | 86.30 | 94.52 | 83.56 | 76.39 |
| $\beta_{2lag}$ | 0.0181 | -0.0893 | 0.0126 | 0.0332 | $0.3292^{3}$ | -0.0635 | -0.0797 | 0.0067 | $0.1015^{2}$ | $0.2226^{1}$ |
| | 0.11 | -0.78 | 0.19 | 0.44 | 1.78 | -1.01 | -1.66 | 0.18 | 2.41 | 4.73 |
| | 45.21 | 50.67 | 45.33 | 50.68 | 61.97 | 42.47 | 36.99 | 53.42 | 56.16 | 69.44 |
| $\beta_2 + \beta_{2lag}$ | 0.2925 | 0.1896 | $0.4624^{1}$ | $0.3672^{1}$ | $0.8166^{2}$ | $0.4624^{1}$ | $0.5318^{1}$ | $0.5397^{1}$ | $0.5798^{1}$ | $0.5371^{1}$ |
| | 1.22 | 1.03 | 4.02 | 2.87 | 2.81 | 4.38 | 5.32 | 8.68 | 6.93 | 5.96 |
| | 50.68 | 54.00 | 48.00 | 50.00 | 50.70 | 47.95 | 43.84 | 49.32 | 49.32 | 59.03 |
| $\beta_3$ | 0.0376 | 0.0272 | 0.0251 | $-0.0265^{3}$ | 0.0352 | -0.0136 | 0.0277 | $0.0479^{1}$ | $0.0489^{2}$ | 0.0210 |
| | 0.79 | 1.35 | 1.58 | -1.81 | 0.86 | -0.60 | 1.15 | 2.88 | 2.12 | 0.99 |
| | 38.36 | 48.00 | 53.33 | 41.10 | 59.15 | 52.05 | 60.27 | 60.27 | 57.53 | 51.39 |
| $\beta_{3lag}$ | 0.0135 | -0.0152 | 0.0025 | $-0.0363^{2}$ | 0.0317 | -0.0029 | $0.0790^{1}$ | $0.0935^{1}$ | $0.0825^{1}$ | $0.0680^{1}$ |
| | 0.38 | -0.64 | 0.18 | -2.06 | 0.99 | -0.09 | 3.05 | 4.40 | 3.42 | 3.11 |
| | 45.21 | 38.67 | 45.33 | 43.84 | 52.11 | 49.32 | 58.90 | 67.12 | 58.90 | 58.33 |
| $\beta_3 + \beta_{3lag}$ | 0.0511 | 0.0119 | 0.0275 | $-0.0628^{2}$ | 0.0670 | -0.0165 | $0.1066^{2}$ | $0.1414^{1}$ | $0.1314^{1}$ | $0.0891^{2}$ |
| | 0.75 | 0.35 | 1.15 | -2.50 | 1.18 | -0.35 | 2.63 | 4.31 | 3.25 | 2.42 |
| | 41.78 | 43.33 | 49.33 | 42.47 | 55.63 | 50.68 | 59.59 | 63.70 | 58.22 | 54.86 |
| $\beta_4$ | $3.0772^{1}$ | $3.4141^{1}$ | $2.3491^{1}$ | -0.0985 | -0.7301 | $3.2186^{1}$ | $3.6630^{1}$ | $1.9003^{1}$ | 0.0585 | $-1.0233^{1}$ |
| | 7.06 | 13.60 | 8.27 | -0.37 | -1.43 | 10.71 | 14.21 | 9.92 | 0.25 | -4.19 |
| | 73.97 | 88.00 | 88.00 | 50.68 | 40.85 | 90.41 | 95.89 | 90.41 | 45.21 | 23.61 |
| $\beta_5$ | $0.2702^{1}$ | $0.2513^{1}$ | $0.2461^{2}$ | 0.1060 | 0.0968 | $0.3020^{1}$ | -0.0004 | $0.1215^{2}$ | $0.1172^{3}$ | 0.0581 |
| | 3.42 | 3.10 | 2.56 | 1.20 | 1.70 | 3.50 | -0.01 | 2.45 | 1.85 | 0.74 |
| | 63.01 | 61.33 | 54.67 | 47.95 | 54.93 | 73.97 | 52.05 | 50.68 | 43.84 | 56.94 |
| $\beta_6$ | -0.1940 | $1.6157^{3}$ | 0.9214 | $1.5015^{2}$ | -0.5849 | $-2.2720^{1}$ | -0.4523 | -0.5564 | -0.3584 | -0.9605 |
| | -0.13 | 1.91 | 1.55 | 2.26 | -0.31 | -2.77 | -0.69 | -1.51 | -0.69 | -1.34 |
| | 47.95 | 58.67 | 61.33 | 67.12 | 39.44 | 41.10 | 45.21 | 46.58 | 56.16 | 45.83 |
| $\beta_7$ | $4.9209^{3}$ | $5.8676^{1}$ | $2.9279^{1}$ | 1.3879 | 0.7082 | 0.2442 | $2.3229^{2}$ | $1.2840^{2}$ | -0.0032 | -0.7068 |
| | 2.00 | 5.07 | 4.30 | 1.22 | 0.21 | 0.20 | 2.60 | 2.63 | -0.01 | -0.61 |
| | 50.68 | 61.33 | 69.33 | 47.95 | 36.62 | 53.42 | 60.27 | 61.64 | 52.05 | 44.44 |
| $intercept$ | $5.0625^{1}$ | $1.7033^{2}$ | $1.4981^{2}$ | $1.3839^{2}$ | $4.5958^{1}$ | $5.4888^{1}$ | $3.8184^{1}$ | $3.4417^{1}$ | $2.8051^{1}$ | $4.6133^{1}$ |
| | 3.55 | 2.54 | 2.47 | 2.16 | 3.06 | 6.84 | 8.47 | 8.45 | 5.72 | 6.62 |
| | 69.86 | 62.67 | 68.00 | 54.79 | 70.42 | 82.19 | 84.93 | 87.67 | 73.97 | 81.94 |
| $adj\ R^2$ | 9.04 | 6.40 | 7.33 | 2.15 | 3.81 | 8.70 | 8.29 | 5.71 | 2.91 | 3.96 |
| $N$ | 24 | 62 | 70 | 63 | 20 | 67 | 70 | 70 | 70 | 64 |

**Table A4 (Continued)**
**Liquidity Comovement between Call Options and Call Options Market (Percentage Spread)**

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0037 | -0.0036 | -0.0006 | 0.0021 | 0.0021 | 0.0020 | -0.0013 | -0.0001 | 0.0036 | -0.0002 |
| | -1.04 | -1.01 | -0.23 | 0.73 | 0.63 | 1.08 | -0.66 | -0.10 | 1.55 | -0.16 |
| | 49.32 | 39.73 | 42.47 | 48.65 | 48.61 | 51.32 | 42.11 | 51.32 | 53.95 | 43.24 |
| $\beta_2$ | 0.3981$^{1}$ | 0.5614$^{1}$ | 0.4968$^{1}$ | 0.4943$^{1}$ | 0.4197$^{1}$ | 0.6624$^{1}$ | 0.7067$^{1}$ | 0.6154$^{1}$ | 0.5782$^{1}$ | 0.4946$^{1}$ |
| | 4.45 | 5.84 | 7.08 | 7.10 | 6.72 | 8.91 | 7.75 | 10.50 | 9.13 | 12.27 |
| | 69.86 | 76.71 | 76.71 | 79.73 | 80.56 | 94.74 | 84.21 | 86.84 | 88.16 | 91.89 |
| $\beta_{2lag}$ | -0.1947$^{1}$ | -0.1425$^{2}$ | -0.1542$^{1}$ | -0.0086 | 0.0216 | -0.0884$^{1}$ | -0.0510 | -0.0430 | 0.0973 | 0.1045$^{1}$ |
| | -3.50 | -2.35 | -4.56 | -0.19 | 0.48 | -2.71 | -1.46 | -1.44 | 1.29 | 2.78 |
| | 34.25 | 36.99 | 34.25 | 47.30 | 48.61 | 40.79 | 44.74 | 47.37 | 50.00 | 54.05 |
| $\beta_2 + \beta_{2lag}$ | 0.2033$^{3}$ | 0.4189$^{1}$ | 0.3426$^{1}$ | 0.4857$^{1}$ | 0.4413$^{1}$ | 0.5740$^{1}$ | 0.6557$^{1}$ | 0.5725$^{1}$ | 0.6755$^{1}$ | 0.5991$^{1}$ |
| | 1.92 | 3.47 | 4.11 | 5.46 | 5.08 | 7.55 | 6.89 | 9.56 | 5.97 | 9.98 |
| | 41.78 | 38.36 | 38.36 | 47.97 | 48.61 | 46.05 | 43.42 | 49.34 | 51.97 | 48.65 |
| $\beta_3$ | 0.0744$^{3}$ | 0.0096 | -0.0307 | 0.0297 | -0.0255 | 0.0391$^{1}$ | 0.0721$^{1}$ | 0.0537$^{1}$ | 0.0421$^{2}$ | 0.0087 |
| | 1.89 | 0.27 | -1.38 | 1.02 | -0.88 | 3.35 | 4.31 | 4.81 | 2.52 | 0.96 |
| | 58.90 | 54.79 | 47.95 | 54.05 | 54.17 | 61.84 | 65.79 | 64.47 | 65.79 | 60.81 |
| $\beta_{3lag}$ | 0.0035 | -0.0605 | -0.0494$^{2}$ | -0.0256 | -0.0022 | -0.0076 | 0.0294$^{3}$ | 0.0175 | 0.0138 | -0.0037 |
| | 0.09 | -1.13 | -2.10 | -0.88 | -0.07 | -0.55 | 1.92 | 1.50 | 0.97 | -0.46 |
| | 45.21 | 42.47 | 41.10 | 51.35 | 48.61 | 47.37 | 57.89 | 53.95 | 61.84 | 44.59 |
| $\beta_3 + \beta_{3lag}$ | 0.0779 | -0.0509 | -0.0801$^{2}$ | 0.0041 | -0.0277 | 0.0315 | 0.1015$^{1}$ | 0.0711$^{1}$ | 0.0559$^{2}$ | 0.0050 |
| | 1.16 | -0.69 | -2.02 | 0.08 | -0.52 | 1.59 | 4.31 | 3.82 | 2.04 | 0.36 |
| | 52.05 | 48.63 | 44.52 | 52.70 | 51.39 | 54.61 | 61.84 | 59.21 | 63.82 | 52.70 |
| $\beta_4$ | 3.7323$^{1}$ | 3.3396$^{1}$ | 1.7254$^{1}$ | 0.3344 | -0.7108$^{1}$ | 1.9436$^{1}$ | 1.4568$^{1}$ | 1.1745$^{1}$ | 0.6638$^{1}$ | -0.4569$^{1}$ |
| | 11.89 | 9.57 | 8.86 | 1.54 | -3.19 | 12.71 | 7.50 | 7.97 | 4.41 | -3.41 |
| | 93.15 | 91.78 | 89.04 | 55.41 | 37.50 | 92.11 | 80.26 | 77.63 | 65.79 | 36.49 |
| $\beta_5$ | 0.2890$^{1}$ | 0.0794 | 0.0842$^{3}$ | -0.1007 | 0.2007$^{1}$ | 0.1618$^{1}$ | 0.1127$^{2}$ | 0.1115$^{1}$ | 0.0628$^{3}$ | 0.1025$^{1}$ |
| | 2.84 | 0.73 | 1.92 | -1.34 | 2.80 | 4.49 | 2.43 | 2.93 | 1.93 | 3.28 |
| | 58.90 | 54.79 | 52.05 | 41.89 | 62.50 | 76.32 | 56.58 | 60.53 | 55.26 | 59.46 |
| $\beta_6$ | 0.8203 | -1.0350 | -0.8973 | -0.3650 | -0.5212 | 0.1360 | -0.4476 | 0.0407 | -0.4751 | -1.3360$^{1}$ |
| | 0.64 | -0.84 | -1.37 | -0.52 | -0.83 | 0.34 | -0.75 | 0.14 | -1.25 | -4.44 |
| | 58.90 | 50.68 | 41.10 | 51.35 | 45.83 | 55.26 | 46.05 | 48.68 | 36.84 | 32.43 |
| $\beta_7$ | 4.1024$^{1}$ | 3.3214$^{2}$ | 1.0570 | 0.2601 | -0.8394 | 2.6866$^{1}$ | 4.4330$^{1}$ | 2.6638$^{1}$ | 1.8777$^{1}$ | -0.4027 |
| | 2.92 | 2.65 | 1.36 | 0.36 | -0.84 | 4.18 | 4.65 | 5.91 | 3.49 | -0.89 |
| | 61.64 | 68.49 | 64.38 | 56.76 | 47.22 | 65.79 | 68.42 | 72.37 | 61.84 | 32.43 |
| $intercept$ | 2.9668$^{2}$ | 3.6047$^{1}$ | 3.4170$^{1}$ | 3.9182$^{1}$ | 3.3724$^{1}$ | 2.8681$^{1}$ | 2.8030$^{1}$ | 2.4896$^{1}$ | 2.5811$^{1}$ | 3.6698$^{1}$ |
| | 2.64 | 3.36 | 5.22 | 5.88 | 5.76 | 7.29 | 4.63 | 8.74 | 7.49 | 11.56 |
| | 69.86 | 69.86 | 75.34 | 77.03 | 76.39 | 82.89 | 75.00 | 86.84 | 81.58 | 94.59 |
| $adj\ R^2$ | 8.92 | 7.63 | 5.78 | 2.28 | 5.71 | 6.23 | 4.19 | 4.11 | 2.80 | 4.11 |
| $N$ | 65 | 68 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A4 (Continued)
## Liquidity Comovement between Call Options and Call Options Market (Percentage Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0005 | 0.0033 | -0.0029 | -0.0020 | -0.0013 | 0.0017 | 0.0004 | -0.0016 | -0.0020 | -0.0032$^{3}$ |
| | 0.22 | 1.01 | -1.55 | -1.11 | -0.87 | 0.53 | 0.12 | -0.70 | -0.85 | -1.91 |
| | 47.37 | 51.32 | 43.42 | 52.63 | 44.00 | 42.86 | 40.91 | 50.00 | 31.82 | 40.91 |
| $\beta_2$ | 0.7601$^{1}$ | 0.8619$^{1}$ | 0.8243$^{1}$ | 0.6718$^{1}$ | 0.4755$^{1}$ | 0.2578$^{1}$ | 0.1833$^{3}$ | 0.1041 | 0.1838$^{2}$ | 0.0677 |
| | 8.55 | 8.70 | 10.09 | 8.70 | 8.35 | 3.76 | 2.07 | 1.23 | 2.20 | 1.11 |
| | 88.16 | 90.79 | 89.47 | 81.58 | 82.67 | 85.71 | 68.18 | 54.55 | 68.18 | 54.55 |
| $\beta_{2lag}$ | -0.0015 | 0.1252$^{2}$ | 0.0617$^{3}$ | 0.0947$^{2}$ | 0.0978$^{1}$ | 0.0480 | 0.1055 | 0.0405 | 0.1134$^{3}$ | 0.0426 |
| | -0.05 | 2.53 | 1.99 | 2.06 | 3.82 | 0.65 | 1.59 | 0.57 | 1.79 | 0.81 |
| | 55.26 | 53.95 | 52.63 | 60.53 | 65.33 | 52.38 | 50.00 | 50.00 | 68.18 | 50.00 |
| $\beta_2 + \beta_{2lag}$ | 0.7585$^{1}$ | 0.9871$^{1}$ | 0.8861$^{1}$ | 0.7665$^{1}$ | 0.5734$^{1}$ | 0.3058$^{2}$ | 0.2888$^{2}$ | 0.1446 | 0.2972$^{2}$ | 0.1103 |
| | 8.47 | 8.96 | 10.22 | 8.49 | 9.51 | 2.66 | 2.39 | 1.05 | 2.43 | 1.14 |
| | 51.32 | 52.63 | 48.03 | 56.58 | 54.67 | 47.62 | 45.45 | 50.00 | 50.00 | 45.45 |
| $\beta_3$ | 0.0383$^{2}$ | 0.0697$^{1}$ | 0.0402$^{1}$ | 0.0365$^{2}$ | 0.0122 | 0.0277$^{3}$ | 0.0500$^{3}$ | 0.0347$^{2}$ | 0.0443 | 0.0196 |
| | 2.46 | 3.92 | 3.20 | 2.21 | 1.20 | 1.75 | 1.94 | 2.65 | 1.57 | 1.57 |
| | 57.89 | 60.53 | 59.21 | 53.95 | 57.33 | 52.38 | 63.64 | 77.27 | 59.09 | 50.00 |
| $\beta_{3lag}$ | 0.0026 | 0.0080 | 0.0055 | -0.0049 | -0.0144 | 0.0332$^{3}$ | 0.0587$^{2}$ | 0.0221 | 0.0769$^{1}$ | 0.0400$^{1}$ |
| | 0.16 | 0.40 | 0.50 | -0.26 | -1.45 | 1.91 | 2.19 | 1.28 | 3.76 | 3.66 |
| | 44.74 | 51.32 | 47.37 | 39.47 | 45.33 | 61.90 | 63.64 | 63.64 | 77.27 | 68.18 |
| $\beta_3 + \beta_{3lag}$ | 0.0409 | 0.0777$^{2}$ | 0.0457$^{2}$ | 0.0315 | -0.0023 | 0.0609$^{2}$ | 0.1086$^{2}$ | 0.0568$^{2}$ | 0.1212$^{1}$ | 0.0596$^{1}$ |
| | 1.61 | 2.42 | 2.43 | 1.03 | -0.14 | 2.52 | 2.36 | 2.71 | 2.91 | 3.19 |
| | 51.32 | 55.92 | 53.29 | 46.71 | 51.33 | 57.14 | 63.64 | 70.45 | 68.18 | 59.09 |
| $\beta_4$ | 1.7491$^{1}$ | 0.7537$^{1}$ | 0.9039$^{1}$ | 0.3618$^{2}$ | -0.4786$^{1}$ | 1.2214$^{2}$ | 0.7348 | 0.4096 | 0.2749 | -0.3419 |
| | 8.91 | 3.58 | 6.56 | 2.53 | -3.97 | 2.23 | 1.29 | 1.59 | 1.07 | -1.61 |
| | 81.58 | 64.47 | 75.00 | 63.16 | 32.00 | 66.67 | 54.55 | 54.55 | 50.00 | 36.36 |
| $\beta_5$ | 0.0895$^{1}$ | 0.0853$^{2}$ | 0.0161 | 0.0431 | 0.0821$^{1}$ | 0.0748 | -0.0292 | -0.0379 | 0.0311 | 0.0605 |
| | 3.20 | 2.02 | 0.63 | 1.17 | 2.96 | 1.58 | -0.58 | -1.30 | 0.48 | 1.50 |
| | 67.11 | 57.89 | 44.74 | 53.95 | 65.33 | 52.38 | 50.00 | 45.45 | 63.64 | 59.09 |
| $\beta_6$ | 0.6434$^{3}$ | 0.2712 | 0.2785 | -0.5908 | -0.4544 | 0.8726$^{3}$ | 0.3016 | 0.3051 | 0.2165 | 0.1352 |
| | 1.74 | 0.42 | 0.73 | -1.35 | -1.07 | 1.86 | 0.37 | 0.74 | 0.22 | 0.28 |
| | 60.53 | 57.89 | 55.26 | 40.79 | 41.33 | 57.14 | 54.55 | 54.55 | 63.64 | 54.55 |
| $\beta_7$ | 4.0330$^{1}$ | 4.0481$^{1}$ | 3.2227$^{1}$ | 2.0161$^{1}$ | 0.5184 | 5.0770$^{1}$ | 3.4381$^{2}$ | 2.5960$^{1}$ | 2.0077 | 1.4465$^{3}$ |
| | 6.91 | 5.30 | 7.54 | 3.19 | 1.19 | 6.40 | 2.49 | 3.70 | 1.68 | 1.81 |
| | 71.05 | 67.11 | 77.63 | 63.16 | 53.33 | 90.48 | 68.18 | 68.18 | 59.09 | 68.18 |
| $intercept$ | 2.3360$^{1}$ | 2.4510$^{1}$ | 2.6825$^{1}$ | 2.7329$^{11}$ | 2.9743$^{1}$ | 1.1991$^{2}$ | 1.6539$^{3}$ | 2.0318$^{1}$ | 2.2858$^{2}$ | 2.6020$^{1}$ |
| | 6.62 | 4.64 | 7.43 | 5.49 | 7.66 | 2.80 | 1.95 | 5.68 | 2.43 | 4.05 |
| | 81.58 | 76.32 | 82.89 | 82.89 | 82.67 | 61.90 | 72.73 | 72.73 | 68.18 | 90.91 |
| $adj\ R^2$ | 4.87 | 4.06 | 3.79 | 2.95 | 2.61 | 2.28 | 1.70 | 1.07 | 0.84 | 1.39 |
| $N$ | 68 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A5

## Liquidity Comovement between Put Options and Put Options Market (Percentage Spread)

This table presents the results of liquidity comovement between put options and their options market. For each stock in its maturity and moneyness portfolio, all put options are averaged at time t, and at stock level, we estimate the following time-series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of put options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have +ve coeficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.014 | -0.012$^{2}$ | -0.002 | -0.007 | 0.001 | -0.003 | -0.000 | 0.003 | 0.001 | 0.004 |
| | 1.07 | -2.52 | -0.58 | -1.95 | 0.08 | -0.70 | -0.16 | 1.04 | 0.38 | 1.33 |
| | 59.72 | 27.40 | 44.00 | 37.33 | 58.33 | 41.10 | 45.21 | 47.95 | 46.58 | 52.78 |
| $\beta_2$ | 0.9919$^{1}$ | 0.6271$^{1}$ | 0.5756$^{1}$ | 0.3681$^{1}$ | 0.1699$^{1}$ | 0.5518$^{1}$ | 0.6491$^{1}$ | 0.7243$^{1}$ | 0.5717$^{1}$ | 0.3661$^{1}$ |
| | 5.33 | 6.01 | 9.45 | 5.27 | 1.47 | 5.67 | 11.73 | 16.47 | 11.96 | 8.90 |
| | 68.06 | 82.19 | 82.67 | 68.00 | 70.83 | 78.08 | 94.52 | 98.63 | 94.52 | 90.28 |
| $\beta_{2lag}$ | 0.0603 | 0.0933 | 0.0235 | -0.0387 | -0.0659 | 0.1143$^{3}$ | 0.1218$^{2}$ | 0.0445 | -0.0315 | -0.0025 |
| | 0.21 | 0.76 | 0.42 | -0.51 | -0.54 | 1.68 | 2.52 | 0.77 | -0.78 | -0.07 |
| | 54.17 | 56.16 | 52.00 | 48.00 | 52.78 | 61.64 | 57.53 | 53.42 | 43.84 | 52.78 |
| $\beta_2 + \beta_{2lag}$ | 1.0523$^{2}$ | 0.7204$^{1}$ | 0.5991$^{1}$ | 0.3294$^{1}$ | 0.1039 | 0.6662$^{1}$ | 0.7709$^{1}$ | 0.7688$^{1}$ | 0.5401$^{1}$ | 0.3636$^{1}$ |
| | 2.70 | 4.11 | 6.69 | 2.83 | 0.53 | 5.10 | 10.48 | 11.89 | 8.39 | 6.25 |
| | 61.11 | 69.18 | 67.33 | 58.00 | 61.81 | 69.86 | 76.03 | 76.03 | 69.18 | 71.53 |
| $\beta_3$ | -0.0415 | 0.0288 | 0.0609$^{1}$ | 0.0448$^{2}$ | 0.0005 | 0.0877$^{2}$ | 0.0675 | 0.0791$^{1}$ | 0.0518$^{2}$ | -0.0191 |
| | -0.46 | 0.83 | 3.92 | 2.32 | 0.02 | 2.36 | 2.60 | 4.08 | 2.43 | -0.80 |
| | 54.17 | 56.16 | 65.33 | 60.00 | 56.94 | 63.01 | 58.90 | 68.49 | 63.01 | 43.06 |
| $\beta_{3lag}$ | -0.1154 | -0.0328 | -0.0027 | 0.0004 | 0.0219 | 0.0642$^{3}$ | 0.1144$^{1}$ | 0.1240$^{1}$ | 0.0978$^{1}$ | 0.0654$^{1}$ |
| | -1.19 | -1.11 | -0.16 | 0.02 | 0.87 | 1.72 | 4.19 | 4.19 | 4.08 | 3.73 |
| | 43.06 | 36.99 | 48.00 | 52.00 | 50.00 | 56.16 | 73.97 | 73.97 | 64.38 | 59.72 |
| $\beta_3 + \beta_{3lag}$ | -0.1569 | -0.0040 | 0.0583$^{2}$ | 0.0452 | 0.0224 | 0.1518$^{2}$ | 0.1819$^{1}$ | 0.2031$^{1}$ | 0.1495$^{1}$ | 0.0463 |
| | -0.89 | -0.08 | 2.11 | 1.37 | 0.57 | 2.41 | 3.89 | 5.16 | 3.81 | 1.34 |
| | 48.61 | 46.58 | 56.67 | 56.00 | 53.47 | 59.59 | 66.44 | 71.23 | 63.70 | 51.39 |
| $\beta_4$ | -5.629$^{1}$ | -5.6765$^{1}$ | -3.881$^{1}$ | -2.074$^{1}$ | -1.303$^{1}$ | -4.888$^{1}$ | -4.422$^{1}$ | -3.158$^{1}$ | -1.240$^{1}$ | -0.687$^{1}$ |
| | -6.55 | -15.76 | -12.60 | -7.29 | -2.88 | -16.21 | -16.47 | -14.89 | -5.70 | -3.71 |
| | 12.50 | 2.74 | 2.67 | 16.00 | 31.94 | 1.37 | 0.00 | 2.74 | 20.55 | 29.17 |
| $\beta_5$ | 0.2952$^{2}$ | 0.1554 | 0.1207 | -0.0232 | 0.2046$^{3}$ | 0.3649$^{1}$ | 0.1232$^{2}$ | 0.1116$^{2}$ | -0.0673$^{3}$ | 0.1744$^{1}$ |
| | 2.17 | 1.28 | 1.20 | -0.38 | 1.89 | 3.89 | 2.08 | 2.39 | -1.86 | 2.65 |
| | 47.22 | 49.32 | 52.00 | 50.67 | 65.28 | 68.49 | 57.53 | 57.53 | 41.10 | 63.89 |
| $\beta_6$ | 1.4281 | 1.8249 | 0.5470 | 1.3890 | 1.0414 | -0.8633 | -0.7255 | -0.6865 | -1.3758$^{1}$ | -1.1024$^{3}$ |
| | 0.64 | 1.28 | 0.93 | 1.44 | 1.15 | -0.67 | -1.21 | -1.41 | -2.71 | -1.98 |
| | 52.78 | 50.68 | 54.67 | 52.00 | 62.50 | 52.05 | 45.21 | 52.05 | 35.62 | 48.61 |
| $\beta_7$ | 2.3783 | 4.1060$^{2}$ | 2.9688$^{1}$ | 1.8705$^{3}$ | 5.0368$^{2}$ | 1.3170 | 2.8987$^{1}$ | 1.5399$^{2}$ | -0.1474 | -1.0147 |
| | 0.54 | 2.59 | 4.23 | 1.85 | 2.64 | 0.78 | 2.94 | 2.52 | -0.24 | -1.06 |
| | 33.33 | 56.16 | 61.33 | 60.00 | 51.39 | 53.42 | 64.38 | 61.64 | 50.68 | 51.39 |
| $intercept$ | 4.6915$^{2}$ | 2.3540$^{3}$ | 2.1461$^{1}$ | 2.3273$^{1}$ | 2.3182$^{1}$ | 6.0123$^{1}$ | 3.6725$^{1}$ | 3.6953$^{1}$ | 3.9585$^{1}$ | 3.6568$^{1}$ |
| | 2.66 | 1.98 | 3.78 | 3.77 | 2.85 | 5.53 | 6.00 | 8.17 | 7.00 | 6.06 |
| | 63.89 | 72.60 | 64.00 | 69.33 | 59.72 | 76.71 | 75.34 | 90.41 | 84.93 | 75.00 |
| $adj\ R^2$ | 28.48 | 18.81 | 16.32 | 5.36 | 5.12 | 21.3 | 13.2 | 13.46 | 6.02 | 5.23 |
| $N$ | 15 | 43 | 70 | 68 | 35 | 59 | 70 | 70 | 70 | 70 |

**Table A5 (Continued)**
**Liquidity Comovement between Put Options and Put Options Market (Percentage Spread)**

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.003 | -0.003 | -0.004[3] | -0.005 | -0.003 | -0.000 | -0.000 | 0.001 | -0.002 | 0.001 |
| | -1.06 | -0.65 | -1.74 | -1.24 | -0.91 | -0.13 | -0.15 | 0.73 | -0.91 | 0.69 |
| | 47.95 | 36.99 | 45.21 | 39.73 | 30.56 | 48.00 | 44.00 | 52.63 | 39.47 | 48.68 |
| $\beta_2$ | 0.8135[1] | 0.6998[1] | 0.6412[1] | 0.4215[1] | 0.4649[1] | 0.6750[1] | 0.7613[1] | 0.6706[1] | 0.5845[1] | 0.4960[1] |
| | 5.40 | 8.97 | 10.15 | 6.31 | 10.55 | 11.16 | 12.11 | 13.67 | 11.40 | 14.54 |
| | 78.08 | 86.30 | 95.89 | 79.45 | 87.50 | 94.67 | 93.33 | 96.05 | 90.79 | 93.42 |
| $\beta_{2lag}$ | 0.1160[3] | -0.1146 | -0.0437 | -0.0608 | -0.0734 | 0.0122 | -0.0114 | -0.0007 | -0.0101 | 0.0204 |
| | 1.71 | -2.50 | -1.28 | -1.44 | -2.11 | 0.36 | -0.27 | -0.02 | -0.43 | 0.72 |
| | 50.68 | 35.62 | 39.73 | 42.47 | 37.50 | 49.33 | 48.00 | 47.37 | 39.47 | 48.68 |
| $\beta_2 + \beta_{2lag}$ | 0.9294[1] | 0.5852[1] | 0.5976[1] | 0.3608[1] | 0.3915[1] | 0.6872[1] | 0.7500[1] | 0.6699[1] | 0.5744[1] | 0.5164[1] |
| | 5.38 | 6.24 | 7.41 | 4.03 | 6.34 | 10.51 | 11.06 | 13.64 | 10.62 | 10.98 |
| | 64.38 | 60.96 | 67.81 | 60.96 | 62.50 | 72.00 | 70.67 | 71.71 | 65.13 | 71.05 |
| $\beta_3$ | 0.0809[3] | 0.0183 | 0.0338 | 0.0620 | 0.0391[3] | 0.0560[1] | 0.0784[1] | 0.0655[1] | 0.0798[1] | 0.0620[1] |
| | 1.93 | 0.57 | 1.27 | 2.05 | 1.87 | 4.06 | 4.09 | 5.19 | 5.02 | 5.57 |
| | 54.79 | 56.16 | 56.16 | 65.75 | 62.50 | 62.67 | 66.67 | 75.00 | 72.37 | 67.11 |
| $\beta_{3lag}$ | -0.0339 | -0.0492 | -0.0146 | 0.0425 | 0.0055 | 0.0074 | 0.0626[1] | 0.0198[3] | 0.0077 | 0.0283[1] |
| | -0.90 | -1.40 | -0.68 | 1.61 | 0.26 | 0.48 | 3.31 | 1.72 | 0.55 | 2.66 |
| | 49.32 | 39.73 | 47.95 | 56.16 | 52.78 | 49.33 | 64.00 | 57.89 | 53.95 | 51.32 |
| $\beta_3 + \beta_{3lag}$ | 0.0470 | -0.0309 | 0.0192 | 0.1045 | 0.0446 | 0.0634 | 0.1410[1] | 0.0853[1] | 0.0875[1] | 0.0904[1] |
| | 0.68 | -0.53 | 0.47 | 2.42 | 1.25 | 2.54 | 4.51 | 4.79 | 3.89 | 4.96 |
| | 52.05 | 47.95 | 52.05 | 60.96 | 57.64 | 56.00 | 65.33 | 66.45 | 63.16 | 59.21 |
| $\beta_4$ | -4.177[1] | -4.084[1] | -2.660[1] | -1.525[1] | -0.761[1] | -3.103[1] | -2.612[1] | -2.170[1] | -1.492[1] | -0.981[1] |
| | -13.84 | -16.31 | -15.96 | -6.10 | -3.74 | -19.34 | -14.55 | -13.65 | -9.26 | -7.92 |
| | 6.85 | 4.11 | 6.85 | 17.81 | 26.39 | 1.33 | 1.33 | 1.32 | 6.58 | 13.16 |
| $\beta_5$ | 0.4391[1] | -0.0624 | 0.0232 | 0.0437 | 0.0820 | 0.1917[1] | 0.0835 | 0.1288[1] | 0.1095[1] | 0.1082[1] |
| | 3.47 | -1.12 | 0.62 | 0.72 | 1.58 | 4.01 | 2.42 | 3.85 | 3.29 | 3.76 |
| | 82.19 | 54.79 | 61.64 | 47.95 | 65.28 | 69.33 | 64.00 | 68.42 | 64.47 | 71.05 |
| $\beta_6$ | -1.3222 | -1.1871 | -1.3742 | -1.0306 | -0.4170 | -1.0613 | 0.8924 | 0.1889 | -0.7007 | -0.4415 |
| | -1.22 | -1.65 | -2.59 | -1.52 | -0.59 | -2.33 | 2.09 | 0.61 | -1.54 | -1.23 |
| | 43.84 | 38.36 | 45.21 | 47.95 | 52.78 | 33.33 | 61.33 | 46.05 | 44.74 | 39.47 |
| $\beta_7$ | 2.4133 | 1.5648[3] | 1.1357[3] | 0.6033 | 0.0386 | 2.3099[1] | 4.2530[1] | 2.8314[1] | 1.1992 | 0.4948 |
| | 1.57 | 1.84 | 1.69 | 0.83 | 0.05 | 3.46 | 6.17 | 6.18 | 2.08 | 1.28 |
| | 56.16 | 53.42 | 64.38 | 53.42 | 48.61 | 65.33 | 72.00 | 65.79 | 57.89 | 52.63 |
| $intercept$ | 4.8189[1] | 4.8647[1] | 3.9371[1] | 3.5880[1] | 3.8391[1] | 4.1739[1] | 2.8074[1] | 2.8599[1] | 3.3740[1] | 3.3607[1] |
| | 5.06 | 7.67 | 7.65 | 5.63 | 5.54 | 10.29 | 7.31 | 10.21 | 8.77 | 10.81 |
| | 72.60 | 82.19 | 87.67 | 79.45 | 87.50 | 89.33 | 85.33 | 86.84 | 86.84 | 86.84 |
| $adj\ R^2$ | 16.72 | 10.49 | 11.11 | 5.85 | 7.29 | 10.96 | 7.56 | 6.93 | 4.75 | 5.88 |
| $N$ | 58 | 68 | 70 | 69 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A5 (Continued)
## Liquidity Comovement between Put Options and Put Options Market (Percentage Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0007 | -0.0031 | -0.0010 | 0.0007 | 0.0000 | -0.0026 | 0.0051$^{3}$ | -0.0005 | 0.0011 | 0.0018 |
| | -0.20 | -1.17 | -0.58 | 0.19 | -0.02 | -1.53 | 1.76 | -0.29 | 0.62 | 0.79 |
| | 42.67 | 44.74 | 50.00 | 50.00 | 44.74 | 40.91 | 68.18 | 54.55 | 40.91 | 57.14 |
| $\beta_2$ | 0.9201$^{1}$ | 0.8956$^{1}$ | 0.8423$^{1}$ | 0.7965$^{1}$ | 0.5738$^{1}$ | 0.3902$^{1}$ | 0.2850$^{1}$ | 0.3322$^{1}$ | 0.2495$^{1}$ | 0.1003 |
| | 10.26 | 9.72 | 10.90 | 8.75 | 9.98 | 5.23 | 4.26 | 6.75 | 5.09 | 1.06 |
| | 92.00 | 88.16 | 92.11 | 85.53 | 90.79 | 90.91 | 86.36 | 86.36 | 81.82 | 71.43 |
| $\beta_{2lag}$ | 0.1341$^{1}$ | 0.1296$^{1}$ | 0.1355$^{1}$ | 0.1583$^{1}$ | 0.0468 | 0.0395 | 0.0476 | 0.0457 | 0.0001 | 0.0084 |
| | 3.73 | 3.09 | 4.34 | 3.32 | 1.45 | 1.25 | 1.00 | 1.73 | 0.00 | 0.20 |
| | 62.67 | 61.84 | 69.74 | 59.21 | 57.89 | 72.73 | 54.55 | 63.64 | 50.00 | 52.38 |
| $\beta_2 + \beta_{2lag}$ | 1.0542$^{1}$ | 1.0252$^{1}$ | 0.9777$^{1}$ | 0.9549$^{1}$ | 0.6206$^{1}$ | 0.4297$^{1}$ | 0.3326$^{1}$ | 0.3779$^{1}$ | 0.2497$^{1}$ | 0.1088 |
| | 10.74 | 9.41 | 10.87 | 8.36 | 9.17 | 4.73 | 3.46 | 5.81 | 3.37 | 0.89 |
| | 77.33 | 75.00 | 80.92 | 72.37 | 74.34 | 81.82 | 70.45 | 75.00 | 65.91 | 61.90 |
| $\beta_3$ | 0.0169 | 0.0433$^{2}$ | 0.0591$^{1}$ | 0.0604$^{1}$ | 0.0232$^{3}$ | 0.0415$^{2}$ | 0.0146 | 0.0256 | 0.0321 | 0.0322 |
| | 1.04 | 2.07 | 4.81 | 3.44 | 1.93 | 2.24 | 0.60 | 1.28 | 1.52 | 1.40 |
| | 58.67 | 63.16 | 68.42 | 59.21 | 55.26 | 77.27 | 50.00 | 59.09 | 63.64 | 66.67 |
| $\beta_{3lag}$ | -0.0166 | 0.0254 | 0.0078 | 0.0160 | -0.0022 | 0.0840$^{1}$ | 0.0979$^{1}$ | 0.0090 | 0.0969$^{1}$ | 0.0359$^{2}$ |
| | -0.72 | 0.89 | 0.52 | 0.76 | -0.14 | 4.98 | 4.59 | 0.33 | 3.50 | 2.11 |
| | 46.67 | 51.32 | 50.00 | 51.32 | 52.63 | 86.36 | 77.27 | 50.00 | 72.73 | 61.90 |
| $\beta_3 + \beta_{3lag}$ | 0.0003 | 0.0686 | 0.0669$^{1}$ | 0.0765$^{1}$ | 0.0209 | 0.1255$^{1}$ | 0.1125$^{1}$ | 0.0346 | 0.1290$^{1}$ | 0.0681$^{2}$ |
| | 0.01 | 1.63 | 3.54 | 2.74 | 0.92 | 4.33 | 3.15 | 0.88 | 3.45 | 2.15 |
| | 52.67 | 57.24 | 59.21 | 55.26 | 53.95 | 81.82 | 63.64 | 54.55 | 68.18 | 64.29 |
| $\beta_4$ | -2.701$^{1}$ | -2.092$^{1}$ | -1.841$^{1}$ | -1.119$^{1}$ | -0.892$^{1}$ | -2.548$^{1}$ | -2.339$^{1}$ | -1.974$^{1}$ | -1.865$^{1}$ | -1.697$^{1}$ |
| | -13.96 | -8.80 | -9.28 | -5.15 | -6.23 | -10.50 | -7.18 | -7.33 | -7.96 | -7.23 |
| | 5.33 | 10.53 | 14.47 | 17.11 | 23.68 | 0.00 | 0.00 | 0.00 | 4.55 | 0.00 |
| $\beta_5$ | 0.1818$^{1}$ | 0.1256$^{1}$ | 0.1128$^{1}$ | 0.0937$^{2}$ | 0.0758$^{1}$ | 0.0473 | 0.0040 | 0.0258 | 0.0648$^{3}$ | 0.0324 |
| | 4.00 | 3.10 | 3.65 | 2.62 | 2.82 | 1.04 | 0.10 | 0.77 | 1.78 | 1.39 |
| | 74.67 | 65.79 | 65.79 | 64.47 | 55.26 | 72.73 | 59.09 | 63.64 | 63.64 | 66.67 |
| $\beta_6$ | 0.1390 | 1.6606$^{1}$ | 0.3508 | 0.3882 | 0.6063 | -0.2904 | -0.0775 | 0.7414 | -0.6405 | 1.3448$^{3}$ |
| | 0.25 | 2.93 | 0.81 | 0.72 | 1.54 | -0.45 | -0.07 | 1.39 | -0.69 | 2.08 |
| | 58.67 | 57.89 | 51.32 | 56.58 | 56.58 | 68.18 | 59.09 | 68.18 | 45.45 | 61.90 |
| $\beta_7$ | 4.1308$^{1}$ | 5.2051$^{1}$ | 3.9336$^{1}$ | 2.9317$^{1}$ | 2.2388$^{1}$ | 5.2675$^{1}$ | 2.4188 | 3.3350$^{1}$ | 1.3326 | 3.7235$^{1}$ |
| | 6.30 | 6.18 | 7.14 | 4.57 | 5.12 | 4.95 | 1.47 | 3.93 | 1.60 | 5.14 |
| | 74.67 | 72.37 | 75.00 | 69.74 | 61.84 | 81.82 | 63.64 | 68.18 | 54.55 | 85.71 |
| $intercept$ | 2.9159$^{1}$ | 2.0605$^{1}$ | 2.6174$^{1}$ | 2.4525$^{1}$ | 2.5186$^{1}$ | 2.0984$^{1}$ | 2.0937$^{3}$ | 1.2859$^{2}$ | 2.5739$^{1}$ | 1.6329$^{1}$ |
| | 5.42 | 4.39 | 6.64 | 6.42 | 7.48 | 3.55 | 2.01 | 2.70 | 3.19 | 4.31 |
| | 78.67 | 67.11 | 81.58 | 77.63 | 80.26 | 86.36 | 59.09 | 68.18 | 77.27 | 85.71 |
| $adj\ R^2$ | 9.24 | 6.79 | 5.98 | 5.08 | 4.47 | 8.57 | 4.39 | 4.05 | 2.41 | 2.16 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

**Table A6**

**Liquidity Comovement between All Options and their Options Market (Percentage Spread)**

The table presents the results of liquidity comovement between all options (both call and put options combined) and their options market. For each stock in its maturity and moneyness portfolio, all put options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of put options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have +ve coeficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0000 | -0.0009 | -0.0007 | 0.0013 | -0.0029 | 0.0014 | 0.0005 | 0.0007 | 0.0019 | 0.0028 |
| | 0.00 | -0.27 | -0.27 | 0.54 | -0.53 | 0.51 | 0.25 | 0.37 | 0.85 | 1.09 |
| | 59.46 | 46.67 | 45.33 | 48.00 | 50.00 | 49.32 | 52.05 | 49.32 | 50.68 | 47.22 |
| $\beta_2$ | 0.6940$^{1}$ | 0.4722$^{1}$ | 0.5425$^{1}$ | 0.3279$^{1}$ | 0.3265$^{1}$ | 0.5827$^{1}$ | 0.6817$^{1}$ | 0.6465$^{1}$ | 0.5357$^{1}$ | 0.3453$^{1}$ |
| | 4.31 | 5.10 | 7.71 | 5.33 | 2.81 | 6.79 | 12.13 | 14.88 | 9.77 | 8.74 |
| | 67.57 | 69.33 | 81.33 | 68.00 | 77.78 | 82.19 | 95.89 | 98.63 | 91.78 | 88.89 |
| $\beta_{2lag}$ | 0.2179 | 0.0068 | 0.0172 | -0.0139 | 0.1889$^{3}$ | 0.0057 | -0.0035 | 0.0352 | 0.0393 | 0.1086$^{1}$ |
| | 0.88 | 0.07 | 0.25 | -0.23 | 1.98 | 0.12 | -0.08 | 0.88 | 1.10 | 3.62 |
| | 45.95 | 49.33 | 42.67 | 50.67 | 61.11 | 50.68 | 45.21 | 50.68 | 49.32 | 69.44 |
| $\beta_2 + \beta_{2lag}$ | 0.9118$^{2}$ | 0.4790$^{1}$ | 0.5597$^{1}$ | 0.3140$^{1}$ | 0.5154$^{1}$ | 0.5884$^{1}$ | 0.6782$^{1}$ | 0.6817$^{1}$ | 0.5750$^{1}$ | 0.4539$^{1}$ |
| | 2.56 | 3.01 | 4.85 | 3.17 | 2.96 | 5.91 | 9.78 | 11.55 | 8.19 | 7.67 |
| | 56.76 | 59.33 | 62.00 | 59.33 | 69.44 | 66.44 | 70.55 | 74.66 | 70.55 | 79.17 |
| $\beta_3$ | 0.1010 | 0.0300$^{3}$ | 0.0427$^{1}$ | 0.0183 | 0.0340 | 0.0095 | 0.0500$^{1}$ | 0.0659$^{1}$ | 0.0551$^{1}$ | -0.0106 |
| | 1.37 | 1.78 | 2.99 | 1.49 | 1.29 | 0.40 | 2.73 | 4.14 | 2.84 | -0.62 |
| | 54.05 | 57.33 | 62.67 | 62.67 | 56.94 | 60.27 | 60.27 | 68.49 | 64.38 | 44.44 |
| $\beta_{3lag}$ | -0.0484 | -0.0359$^{2}$ | -0.0032 | -0.0067 | 0.0241 | 0.0189 | 0.0886$^{1}$ | 0.0901$^{1}$ | 0.0892$^{1}$ | 0.0603$^{1}$ |
| | -1.37 | -2.04 | -0.23 | -0.49 | 1.04 | 0.67 | 4.07 | 3.15 | 4.41 | 3.53 |
| | 39.19 | 36.00 | 45.33 | 48.00 | 54.17 | 52.05 | 68.49 | 72.60 | 65.75 | 52.78 |
| $\beta_3 + \beta_{3lag}$ | 0.0527 | -0.0059 | 0.0395 | 0.0116 | 0.0581 | 0.0284 | 0.1386$^{1}$ | 0.1560$^{1}$ | 0.1442$^{1}$ | 0.0497$^{3}$ |
| | 0.53 | -0.22 | 1.61 | 0.54 | 1.49 | 0.65 | 3.96 | 4.24 | 4.34 | 1.83 |
| | 46.62 | 46.67 | 54.00 | 55.33 | 55.56 | 56.16 | 64.38 | 70.55 | 65.07 | 48.61 |
| $\beta_4$ | -0.4289 | -0.2544 | -0.6498$^{2}$ | -1.0170$^{1}$ | -0.8971$^{1}$ | -0.0569 | -0.0878 | -0.6941$^{1}$ | -0.6946$^{1}$ | -0.6961$^{1}$ |
| | -1.05 | -1.05 | -2.29 | -6.91 | -3.81 | -0.22 | -0.51 | -4.99 | -3.96 | -4.39 |
| | 41.89 | 45.33 | 28.00 | 13.33 | 33.33 | 42.47 | 45.21 | 20.55 | 23.29 | 20.83 |
| $\beta_5$ | 0.6187$^{1}$ | 0.5783$^{1}$ | 0.2764$^{2}$ | 0.0189 | 0.1367$^{2}$ | 0.6631$^{1}$ | 0.3513$^{1}$ | 0.1212$^{1}$ | -0.0014 | 0.1103$^{1}$ |
| | 4.68 | 5.83 | 2.46 | 0.29 | 2.33 | 7.71 | 6.72 | 2.66 | -0.04 | 2.82 |
| | 82.43 | 88.00 | 61.33 | 40.00 | 62.50 | 97.26 | 91.78 | 56.16 | 36.99 | 62.50 |
| $\beta_6$ | -0.1702 | 0.2933 | 0.7267 | 0.9951$^{3}$ | 1.7367 | -2.4758$^{1}$ | -1.0517$^{3}$ | -0.8982$^{3}$ | -0.7929$^{3}$ | -0.7908 |
| | -0.11 | 0.37 | 1.31 | 1.69 | 1.18 | -2.86 | -1.94 | -1.81 | -1.87 | -1.64 |
| | 44.59 | 52.00 | 58.67 | 56.00 | 54.17 | 36.99 | 45.21 | 47.95 | 39.73 | 40.28 |
| $\beta_7$ | 1.8626 | 3.8882$^{1}$ | 3.1773$^{1}$ | 0.8296 | 3.5057$^{2}$ | -0.0584 | 3.2795$^{1}$ | 1.1631$^{3}$ | -0.1786 | -0.0192 |
| | 0.69 | 2.97 | 4.84 | 0.90 | 2.27 | -0.05 | 3.74 | 1.88 | -0.34 | -0.03 |
| | 45.95 | 57.33 | 70.67 | 53.33 | 48.61 | 50.68 | 60.27 | 65.75 | 47.95 | 51.39 |
| $intercept$ | 6.5739$^{1}$ | 3.5566$^{1}$ | 1.6516$^{1}$ | 1.7386$^{1}$ | 2.7635$^{1}$ | 6.6426$^{1}$ | 4.3993$^{1}$ | 3.7814$^{1}$ | 3.3853$^{1}$ | 3.6893$^{1}$ |
| | 4.71 | 5.39 | 2.81 | 3.60 | 3.66 | 8.62 | 9.79 | 8.30 | 7.61 | 7.40 |
| | 74.32 | 73.33 | 64.00 | 64.00 | 68.06 | 90.41 | 87.67 | 90.41 | 82.19 | 81.94 |
| $adj\ R^2$ | 10.47 | 6.49 | 6.64 | 1.78 | 5.11 | 10.27 | 5.21 | 5.71 | 4.52 | 4.27 |
| $N$ | 34 | 70 | 70 | 70 | 40 | 70 | 70 | 70 | 70 | 70 |

## Table A6 (Continued)

## Liquidity Comovement between All Options and their Options Market (Percentage Spread)

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0045 | -0.0044 | -0.0022 | -0.0002 | -0.0010 | 0.0012 | -0.0006 | 0.0010 | 0.0017 | 0.0011 |
| | -1.47 | -1.53 | -1.18 | -0.10 | -0.35 | 0.84 | -0.30 | 0.71 | 1.01 | 0.86 |
| | 43.84 | 43.84 | 42.47 | 40.54 | 38.89 | 47.37 | 53.95 | 53.95 | 50.00 | 47.37 |
| $\beta_2$ | 0.5659[1] | 0.6604[1] | 0.6437[1] | 0.5174[1] | 0.4675[1] | 0.7019[1] | 0.7786[1] | 0.6937[1] | 0.6004[1] | 0.5071[1] |
| | 5.50 | 8.54 | 10.08 | 8.73 | 10.01 | 10.22 | 10.52 | 12.71 | 10.47 | 14.56 |
| | 71.23 | 89.04 | 94.52 | 83.78 | 90.28 | 94.74 | 90.79 | 96.05 | 89.47 | 94.74 |
| $\beta_{2lag}$ | -0.135[1] | -0.184[1] | -0.090[1] | -0.024 | -0.002 | -0.061[2] | -0.047 | -0.025 | 0.024 | 0.080[2] |
| | -2.77 | -4.91 | -2.91 | -0.67 | -0.06 | -2.27 | -1.45 | -0.88 | 0.65 | 2.49 |
| | 32.88 | 20.55 | 34.25 | 41.89 | 50.00 | 36.84 | 40.79 | 47.37 | 48.68 | 56.58 |
| $\beta_2 + \beta_{2lag}$ | 0.4307[1] | 0.4763[1] | 0.5536[1] | 0.4934[1] | 0.4656[1] | 0.6414[1] | 0.7314[1] | 0.6687[1] | 0.6243[1] | 0.5872[1] |
| | 3.84 | 5.53 | 7.20 | 6.41 | 6.77 | 9.33 | 9.67 | 12.57 | 8.98 | 11.96 |
| | 52.05 | 54.79 | 64.38 | 62.84 | 70.14 | 65.79 | 65.79 | 71.71 | 69.08 | 75.66 |
| $\beta_3$ | 0.0924[1] | -0.0015 | -0.0025 | 0.0378 | 0.0073 | 0.0420[1] | 0.0732[1] | 0.0619[1] | 0.0574[1] | 0.0320[1] |
| | 2.92 | -0.05 | -0.10 | 1.32 | 0.33 | 3.57 | 5.16 | 6.04 | 4.73 | 3.55 |
| | 60.27 | 52.05 | 54.79 | 58.11 | 56.94 | 63.16 | 72.37 | 77.63 | 71.05 | 65.79 |
| $\beta_{3lag}$ | -0.016 | -0.067[2] | -0.034 | 0.012 | -0.004 | -0.0045 | 0.034[2] | 0.013 | 0.004 | 0.015[3] |
| | -0.51 | -2.15 | -1.58 | 0.56 | -0.19 | -0.35 | 2.47 | 1.26 | 0.35 | 1.86 |
| | 46.58 | 39.73 | 45.21 | 56.76 | 54.17 | 42.11 | 59.21 | 55.26 | 55.26 | 52.63 |
| $\beta_3 + \beta_{3lag}$ | 0.0767 | -0.0682 | -0.0371 | 0.0497 | 0.0036 | 0.0375[3] | 0.1072[1] | 0.0752[1] | 0.0616[1] | 0.0465[1] |
| | 1.40 | -1.29 | -0.90 | 1.13 | 0.09 | 1.86 | 5.02 | 4.67 | 2.96 | 3.35 |
| | 53.42 | 45.89 | 50.00 | 57.43 | 55.56 | 52.63 | 65.79 | 66.45 | 63.16 | 59.21 |
| $\beta_4$ | 0.056 | -0.399[3] | -0.466[1] | -0.473[2] | -0.637[1] | -0.425[1] | -0.575[1] | -0.512[1] | -0.352[1] | -0.762[1] |
| | 0.21 | -1.97 | -2.88 | -2.54 | -4.67 | -3.50 | -4.34 | -4.62 | -2.70 | -8.24 |
| | 49.32 | 28.77 | 21.92 | 29.73 | 20.83 | 27.63 | 21.05 | 26.32 | 27.63 | 14.47 |
| $\beta_5$ | 0.6674[1] | 0.2209[1] | 0.0651[3] | -0.0974[2] | 0.1240[1] | 0.3157[1] | 0.1577[1] | 0.1273[1] | 0.0633[2] | 0.1007[1] |
| | 7.46 | 3.30 | 1.77 | -2.02 | 2.97 | 7.11 | 4.36 | 3.88 | 2.40 | 3.65 |
| | 94.52 | 80.82 | 53.42 | 39.19 | 68.06 | 90.79 | 68.42 | 65.79 | 63.16 | 63.16 |
| $\beta_6$ | -1.7586[2] | -1.6978[3] | -1.5266[2] | -0.9836[3] | -1.0213[3] | -1.2581[1] | -0.0285 | -0.0786 | -0.6525[2] | -1.1384[1] |
| | -2.22 | -1.94 | -2.44 | -1.68 | -1.94 | -2.88 | -0.07 | -0.28 | -2.07 | -4.16 |
| | 41.10 | 41.10 | 36.99 | 48.65 | 51.39 | 35.53 | 44.74 | 46.05 | 36.84 | 34.21 |
| $\beta_7$ | 2.4739[2] | 2.5622[2] | 1.2182 | 0.1114 | -0.4026 | 1.9488 | 4.7559[1] | 2.6705[1] | 1.5947[1] | 0.0023 |
| | 2.15 | 2.62 | 1.59 | 0.19 | -0.64 | 2.96 | 5.86 | 5.83 | 3.48 | 0.01 |
| | 54.79 | 67.12 | 64.38 | 47.30 | 52.78 | 53.95 | 75.00 | 71.05 | 60.53 | 43.42 |
| $intercept$ | 5.6527[1] | 5.0643[1] | 3.9408[1] | 4.0787[1] | 4.3845[1] | 4.3986[1] | 2.8384[1] | 2.8976[1] | 3.0220[1] | 3.6443[1] |
| | 7.44 | 6.56 | 6.60 | 7.35 | 8.35 | 10.21 | 7.62 | 10.82 | 10.87 | 12.42 |
| | 89.04 | 83.56 | 86.30 | 79.73 | 90.28 | 90.79 | 82.89 | 88.16 | 90.79 | 89.47 |
| $adj\ R^2$ | 9.07 | 5.96 | 7.59 | 4.9 | 7.25 | 7.87 | 4.46 | 5.3 | 3.58 | 6.27 |
| $N$ | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

**Table A6 (Continued)**
**Liquidity Comovement between All Options and their Options Market (Percentage Spread)**

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0016 | -0.0005 | -0.0018 | -0.0002 | 0.0008 | -0.0002 | 0.0024 | -0.0007 | -0.0001 | -0.0008 |
| | 0.46 | -0.22 | -1.12 | -0.11 | 0.46 | -0.10 | 0.82 | -0.38 | -0.05 | -0.54 |
| | 44.74 | 43.42 | 44.74 | 46.05 | 46.05 | 40.91 | 63.64 | 45.45 | 45.45 | 45.45 |
| $\beta_2$ | 0.9481$^{1}$ | 0.9271$^{1}$ | 0.9048$^{1}$ | 0.7998$^{1}$ | 0.5554$^{1}$ | 0.3313$^{1}$ | 0.2443$^{1}$ | 0.2110$^{1}$ | 0.2221$^{1}$ | 0.0721 |
| | 9.64 | 9.63 | 10.74 | 9.74 | 9.84 | 5.92 | 4.09 | 3.65 | 3.92 | 1.17 |
| | 93.42 | 90.79 | 93.42 | 86.84 | 84.21 | 90.91 | 81.82 | 77.27 | 81.82 | 68.18 |
| $\beta_{2lag}$ | 0.0942$^{1}$ | 0.1308$^{1}$ | 0.1280$^{1}$ | 0.1397$^{1}$ | 0.0814$^{1}$ | 0.0160 | 0.0269 | 0.0216 | 0.0405 | 0.0376 |
| | 2.74 | 3.59 | 3.84 | 3.51 | 2.78 | 0.46 | 0.58 | 0.61 | 0.89 | 1.09 |
| | 63.16 | 67.11 | 65.79 | 65.79 | 65.79 | 68.18 | 59.09 | 40.91 | 72.73 | 59.09 |
| $\beta_2 + \beta_{2lag}$ | 1.0423$^{1}$ | 1.0579$^{1}$ | 1.0328$^{1}$ | 0.9395$^{1}$ | 0.6368$^{1}$ | 0.3473$^{1}$ | 0.2712$^{1}$ | 0.2325$^{2}$ | 0.2627$^{1}$ | 0.1097 |
| | 9.82 | 9.75 | 10.49 | 9.94 | 10.03 | 5.91 | 2.92 | 2.80 | 3.01 | 1.24 |
| | 78.29 | 78.95 | 79.61 | 76.32 | 75.00 | 79.55 | 70.45 | 59.09 | 77.27 | 63.64 |
| $\beta_3$ | 0.0215 | 0.0550$^{1}$ | 0.0495$^{1}$ | 0.0548$^{1}$ | 0.0178$^{3}$ | 0.0237$^{3}$ | 0.0401$^{2}$ | 0.0352$^{2}$ | 0.0501$^{2}$ | 0.0226$^{3}$ |
| | 1.39 | 3.42 | 4.62 | 3.79 | 1.93 | 1.78 | 2.59 | 2.86 | 2.38 | 1.98 |
| | 60.53 | 64.47 | 68.42 | 67.11 | 57.89 | 77.27 | 72.73 | 72.73 | 72.73 | 50.00 |
| $\beta_{3lag}$ | -0.0237 | 0.0126 | 0.0039 | -0.0029 | -0.0155 | 0.0575$^{1}$ | 0.0720$^{1}$ | 0.0181 | 0.0696$^{1}$ | 0.0201$^{3}$ |
| | -1.02 | 0.56 | 0.32 | -0.19 | -1.63 | 4.24 | 4.83 | 0.90 | 3.46 | 1.97 |
| | 46.05 | 52.63 | 44.74 | 48.68 | 43.42 | 90.91 | 86.36 | 54.55 | 72.73 | 77.27 |
| $\beta_3 + \beta_{3lag}$ | -0.0022 | 0.0676$^{2}$ | 0.0534$^{1}$ | 0.0519$^{2}$ | 0.0022 | 0.0812$^{1}$ | 0.1121$^{1}$ | 0.0532$^{3}$ | 0.1197$^{1}$ | 0.0427$^{2}$ |
| | -0.07 | 2.04 | 2.94 | 2.10 | 0.14 | 3.71 | 4.30 | 2.05 | 3.15 | 2.42 |
| | 53.29 | 58.55 | 56.58 | 57.89 | 50.66 | 84.09 | 79.55 | 63.64 | 72.73 | 63.64 |
| $\beta_4$ | -0.6192$^{1}$ | -0.6631$^{1}$ | -0.4961 | -0.3148$^{2}$ | -0.6780$^{1}$ | -0.9193$^{1}$ | -1.0541$^{1}$ | -0.8213$^{1}$ | -0.7813$^{1}$ | -0.9676$^{1}$ |
| | -4.49 | -4.17 | -3.71 | -2.24 | -6.97 | -5.24 | -6.49 | -7.15 | -6.60 | -8.96 |
| | 30.26 | 23.68 | 32.89 | 28.95 | 21.05 | 9.09 | 4.55 | 4.55 | 9.09 | 4.55 |
| $\beta_5$ | 0.2907$^{1}$ | 0.1747$^{1}$ | 0.0833$^{1}$ | 0.0346 | 0.0404$^{2}$ | 0.1778$^{1}$ | 0.0075 | 0.0060 | 0.0478 | 0.0276 |
| | 7.21 | 4.61 | 3.16 | 1.08 | 2.25 | 2.94 | 0.19 | 0.20 | 1.02 | 1.01 |
| | 89.47 | 75.00 | 61.84 | 55.26 | 60.53 | 81.82 | 45.45 | 45.45 | 54.55 | 54.55 |
| $\beta_6$ | -0.2941 | 0.5450 | 0.2360 | -0.2934 | -0.2037 | 0.4734 | 0.4038 | 0.6885 | -0.1493 | 0.7540$^{2}$ |
| | -0.65 | 1.17 | 0.60 | -0.75 | -0.63 | 0.99 | 0.53 | 1.64 | -0.27 | 2.12 |
| | 47.37 | 52.63 | 52.63 | 52.63 | 46.05 | 72.73 | 63.64 | 59.09 | 45.45 | 50.00 |
| $\beta_7$ | 3.6525$^{1}$ | 4.4620$^{1}$ | 3.6168$^{1}$ | 2.3016$^{1}$ | 1.2768$^{1}$ | 5.7356$^{1}$ | 3.5525$^{2}$ | 3.1646$^{1}$ | 1.9004$^{2}$ | 2.9960$^{1}$ |
| | 6.23 | 6.47 | 7.99 | 4.21 | 3.91 | 6.77 | 2.81 | 4.50 | 2.41 | 4.71 |
| | 72.37 | 75.00 | 76.32 | 64.47 | 59.21 | 86.36 | 68.18 | 72.73 | 63.64 | 81.82 |
| $intercept$ | 3.3494$^{1}$ | 2.5101$^{1}$ | 2.6573$^{1}$ | 2.6696$^{1}$ | 2.9795$^{1}$ | 1.6181$^{1}$ | 1.5479$^{2}$ | 1.4805$^{1}$ | 2.2731$^{1}$ | 1.8027$^{1}$ |
| | 7.59 | 7.07 | 7.80 | 7.54 | 10.68 | 3.63 | 2.63 | 4.23 | 3.89 | 4.36 |
| | 84.21 | 80.26 | 85.53 | 80.26 | 88.16 | 90.91 | 72.73 | 72.73 | 77.27 | 77.27 |
| $adj\ R^2$ | 7.06 | 5 | 5.21 | 4.15 | 4.49 | 5.46 | 1.95 | 1.66 | 1.44 | 1.75 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

**Table A7 (a)**
**Size Effects in Liquidity Comovement between Call Options and their Market (Proportional Spreads)**

This table reports regression results for size quartile portfolios. After estimating the time-series market model regressions for each stock in maturity and moneyness portfolio, we group the results in quartiles by firm size. Firm size is based on time-series average of market capitalization for a stock over entire sample from 22 February 2008 to 31 December 2010. We take the cross-sectional average of regression coefficients across stocks within each quartile. Due to the panel nature of options, we report results for liquidity comovement between options and their markets. We also report the difference in coefficients of options market liquidity for small and big firms and the t-statistic. Table A7(a), Table A7(b) and Table A7(c) report the results for call, put, all (both calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B – S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 days | **1.05-1.10** | 12 | -0.1216 | 0.1148 | -0.1355 | -0.0003 | 18 | 0.121 |
| | | | -0.23 | 0.45 | -0.66 | 0.00 | | 0.90 |
| | **0.95-1.05** | 17 | 0.5717*** | 0.5871*** | 0.2471 | 0.3397*** | 18 | -0.232*** |
| | | | 2.45 | 2.70 | 0.81 | 2.94 | | -3.76 |
| | **0.90-0.95** | 15 | 0.6312** | 0.4990 | 0.2607 | 0.1893 | 18 | -0.442*** |
| | | | 2.26 | 1.14 | 0.92 | 1.35 | | -5.88 |
| 31-60 | **1.05-1.10** | 17 | 0.8723*** | 0.5619*** | 0.8079*** | 0.3640*** | 18 | -0.508*** |
| | | | 3.12 | 3.66 | 4.95 | 5.51 | | -7.51 |
| | **0.95-1.05** | 17 | 0.5479*** | 0.6383*** | 0.8129*** | 0.4097*** | 18 | -0.138*** |
| | | | 4.20 | 5.88 | 4.48 | 4.75 | | -3.72 |
| | **0.90-0.95** | 17 | 0.5293*** | 0.6586*** | 0.6160*** | 0.3107*** | 18 | -0.219*** |
| | | | 2.94 | 4.78 | 3.46 | 3.90 | | -4.69 |
| 61-91 | **1.05-1.10** | 16 | 0.6132*** | 0.3409*** | 0.4243*** | 0.1457 | 18 | -0.467*** |
| | | | 2.96 | 2.40 | 2.48 | 1.49 | | -8.58 |
| | **0.95-1.05** | 17 | 0.4970*** | 0.4072** | 0.7028*** | 0.6637* | 18 | 0.167 |
| | | | 3.53 | 2.34 | 3.56 | 1.90 | | 1.63 |
| | **0.90-0.95** | 17 | 0.3618** | 0.4721*** | 0.5668*** | 0.0699 | 18 | -0.292*** |
| | | | 2.35 | 3.24 | 3.50 | 1.12 | | -7.44 |
| 92-182 | **1.05-1.10** | 17 | 0.6983*** | 0.4121*** | 0.6122*** | 0.2097* | 18 | -0.489*** |
| | | | 5.33 | 4.02 | 3.98 | 1.97 | | -12.14 |
| | **0.95-1.05** | 17 | 0.5945*** | 0.5075*** | 0.6980*** | 0.1855*** | 18 | -0.409*** |
| | | | 5.08 | 4.59 | 6.86 | 2.81 | | -12.83 |
| | **0.90-0.95** | 17 | 0.5771*** | 0.4246*** | 0.5673*** | 0.1696** | 18 | -0.408*** |
| | | | 4.59 | 4.34 | 4.78 | 2.27 | | -11.74 |
| 183-273 | **1.05-1.10** | 16 | 0.5990*** | 0.6180*** | 0.3992*** | 0.3141** | 18 | -0.285*** |
| | | | 3.38 | 3.84 | 2.74 | 2.19 | | -5.18 |
| | **0.95-1.05** | 16 | 0.5727*** | 0.4880*** | 0.6276*** | 0.3720*** | 18 | -0.201*** |
| | | | 5.93 | 4.27 | 6.37 | 3.30 | | -5.54 |
| | **0.90-0.95** | 16 | 0.3275*** | 0.4256*** | 0.4824*** | 0.2249** | 18 | -0.103*** |
| | | | 2.86 | 3.99 | 4.00 | 2.02 | | -2.65 |

**Table A7 (b)**
**Size Effects in Liquidity Comovement between Put Options and their Market (Proportional Spreads)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 days | **1.05-1.10** | 7 | 0.5989*** | 0.2327 | 0.3722* | 0.4169*** | 18 | -0.182*** |
| | | | 3.41 | 0.78 | 1.75 | 2.67 | | -2.53 |
| | **0.95-1.05** | 17 | 0.5297** | 0.9026*** | 1.0340*** | 0.5311*** | 19 | 0.001 |
| | | | 1.99 | 2.56 | 6.03 | 4.76 | | 0.02 |
| | **0.90-0.95** | 16 | 0.5869* | 0.4818 | 1.0648*** | 0.2740* | 19 | -0.313*** |
| | | | 1.76 | 1.17 | 3.79 | 1.84 | | -3.68 |
| 31-60 | **1.05-1.10** | 17 | 0.5597*** | 0.6868*** | 0.6681*** | 0.2422*** | 19 | -0.317*** |
| | | | 3.01 | 4.26 | 6.01 | 2.52 | | -6.54 |
| | **0.95-1.05** | 17 | 0.4361** | 0.6933*** | 0.9236*** | 0.4545*** | 19 | 0.018 |
| | | | 2.00 | 4.71 | 5.47 | 4.53 | | 0.33 |
| | **0.90-0.95** | 17 | 0.6779*** | 0.5106*** | 0.8105*** | 0.4357*** | 19 | -0.242*** |
| | | | 3.10 | 3.27 | 5.04 | 4.32 | | -4.35 |
| 61-91 | **1.05-1.10** | 16 | 0.6712*** | 0.3073** | 0.7615*** | 0.2205** | 19 | -0.451*** |
| | | | 4.65 | 2.25 | 5.02 | 1.99 | | -10.46 |
| | **0.95-1.05** | 17 | 1.0337*** | 0.8180*** | 0.9545*** | 0.3387*** | 19 | -0.695*** |
| | | | 3.13 | 3.40 | 4.84 | 2.47 | | -8.40 |
| | **0.90-0.95** | 16 | 0.6524*** | 0.8192*** | 0.5273*** | 0.2308*** | 19 | -0.422*** |
| | | | 3.62 | 3.12 | 5.00 | 2.41 | | -8.84 |
| 92-182 | **1.05-1.10** | 17 | 0.6907*** | 0.5507*** | 0.7987*** | 0.5111*** | 19 | -0.180*** |
| | | | 4.64 | 5.91 | 6.20 | 6.70 | | -4.63 |
| | **0.95-1.05** | 17 | 0.6874*** | 0.6909*** | 0.8853*** | 0.2051*** | 19 | -0.482*** |
| | | | 5.19 | 4.11 | 3.59 | 4.20 | | -14.81 |
| | **0.90-0.95** | 17 | 0.5841*** | 0.6544*** | 0.6476*** | 0.3153*** | 19 | -0.269*** |
| | | | 4.49 | 5.37 | 4.85 | 3.66 | | -7.38 |
| 183-273 | **1.05-1.10** | 16 | 0.8037*** | 0.5674*** | 0.6165*** | 0.3163*** | 19 | -0.487*** |
| | | | 4.21 | 6.68 | 4.83 | 4.66 | | -10.40 |
| | **0.95-1.05** | 16 | 0.6564*** | 0.6191*** | 0.7062*** | 0.3578** | 19 | -0.299*** |
| | | | 5.29 | 5.61 | 7.07 | 2.35 | | -6.29 |
| | **0.90-0.95** | 16 | 0.4811*** | 0.5985*** | 0.5773*** | 0.2879* | 19 | -0.193*** |
| | | | 3.02 | 3.99 | 4.63 | 1.82 | | -3.58 |

**Table A7 (c)**
**Size Effects in Liquidity Comovement between All Options and their Market (Proportional Spreads)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| **Upto 30** | **1.05-1.10** | 17 | 0.3125 | 0.6120** | 0.8109*** | 0.6826*** | 18 | 0.370*** |
| | | | 0.78 | 2.19 | 3.51 | 4.79 | | 3.70 |
| | **0.95-1.05** | 17 | 0.5906*** | 0.7535*** | 1.1918*** | 0.7863*** | 18 | 0.196*** |
| | | | 3.27 | 3.98 | 4.64 | 6.32 | | 3.75 |
| | **0.90-0.95** | 17 | 0.7729** | 0.3639 | 0.8388** | 0.4737*** | 18 | -0.299*** |
| | | | 2.18 | 1.10 | 2.11 | 2.72 | | -3.19 |
| **31-60** | **1.05-1.10** | 17 | 1.2383*** | 1.0517*** | 1.2592*** | 0.5572*** | 18 | -0.681*** |
| | | | 6.15 | 6.02 | 5.31 | 7.92 | | -13.51 |
| | **0.95-1.05** | 17 | 0.5849** | 0.9252*** | 1.3381*** | 0.7077*** | 18 | 0.123* |
| | | | 2.08 | 4.67 | 5.16 | 6.52 | | 1.72 |
| | **0.90-0.95** | 17 | 0.6745*** | 0.7758*** | 0.9345*** | 0.4678*** | 18 | -0.207*** |
| | | | 2.94 | 4.02 | 2.80 | 5.24 | | -3.55 |
| **61-91** | **1.05-1.10** | 17 | 0.9970*** | 0.7659*** | 1.0792*** | 0.5225*** | 18 | -0.475*** |
| | | | 4.34 | 5.36 | 4.92 | 5.12 | | -7.98 |
| | **0.95-1.05** | 17 | 1.1239*** | 0.8012*** | 0.9994*** | 1.1116*** | 18 | -0.012 |
| | | | 3.07 | 3.36 | 4.18 | 2.45 | | -0.09 |
| | **0.90-0.95** | 17 | 0.5385*** | 1.0496*** | 0.7579*** | 0.3930*** | 18 | -0.146*** |
| | | | 3.10 | 3.41 | 4.55 | 3.69 | | -3.01 |
| **92-182** | **1.05-1.10** | 17 | 1.0869*** | 0.9031*** | 1.2549*** | 0.6847*** | 18 | -0.402*** |
| | | | 5.74 | 9.62 | 5.69 | 6.40 | | -7.79 |
| | **0.95-1.05** | 17 | 0.8965*** | 0.9937*** | 1.2467*** | 0.4501*** | 18 | -0.446*** |
| | | | 5.39 | 4.45 | 3.97 | 7.49 | | -10.67 |
| | **0.90-0.95** | 17 | 0.8171*** | 0.7159*** | 0.9263*** | 0.4605*** | 18 | -0.357*** |
| | | | 4.98 | 5.85 | 5.71 | 4.26 | | -7.63 |
| **183-273** | **1.05-1.10** | 16 | 1.0641*** | 0.9364*** | 0.9407*** | 0.5168*** | 18 | -0.547*** |
| | | | 4.37 | 6.89 | 4.78 | 4.03 | | -8.34 |
| | **0.95-1.05** | 16 | 0.9545*** | 0.8039*** | 1.0874*** | 0.5644*** | 18 | -0.390*** |
| | | | 6.58 | 6.23 | 7.62 | 2.87 | | -6.51 |
| | **0.90-0.95** | 16 | 0.5497*** | 0.7655*** | 0.8802*** | 0.4587*** | 18 | -0.091 |
| | | | 3.85 | 4.48 | 5.50 | 2.53 | | -1.61 |

## Table A8 (a)

## Size Effects in Liquidity Comovement between Call Options and their Market (Percentage Spread)

This table reports regression results for size quartile portfolios. After estimating the time-series market model regressions for each stock in maturity and moneyness portfolios, we group the results in quartiles by firm size. Firm size is based on time-series average of market capitalization for a stock over entire sample from 22 February 2008 to 31 December 2010. We take the cross-sectional average of regression coefficients across stocks within each quartile. Due to the panel nature of options, we report results for liquidity comovement between put options and their markets. We also report the difference in coefficients of options market liquidity for small and big firms and the t-statistic. Table A8(a), Table A8(b) and Table A8(c) reports the results of call, put and all (both calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B – S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05 - 1.10** | 12 | -0.5539 | 0.8052*** | 0.3228* | 0.0465 | 18 | 0.600*** |
| | | | -0.98 | 2.55 | 1.94 | 0.12 | | 3.47 |
| | **0.95 - 1.05** | 17 | 0.1326 | 0.6228*** | 0.7531*** | 0.3318** | 18 | 0.199*** |
| | | | 0.77 | 2.52 | 2.49 | 2.19 | | 3.64 |
| | **0.90 - 0.95** | 15 | 0.4727*** | 0.4799 | 0.4580 | 0.1111 | 18 | -0.362*** |
| | | | 2.83 | 1.46 | 1.51 | 0.51 | | -5.26 |
| 31-60 | **1.05 - 1.10** | 17 | 0.6699*** | 0.4780*** | 0.5938*** | 0.3902** | 18 | -0.280*** |
| | | | 2.53 | 2.63 | 3.15 | 2.33 | | -3.76 |
| | **0.95 - 1.05** | 17 | 0.6559*** | 0.4434*** | 0.6735*** | 0.3870*** | 18 | -0.269*** |
| | | | 5.20 | 4.63 | 4.26 | 3.88 | | -7.01 |
| | **0.90 - 0.95** | 17 | 0.4975*** | 0.5982*** | 0.7706*** | 0.4493*** | 18 | -0.048 |
| | | | 2.48 | 3.72 | 3.96 | 4.38 | | -0.90 |
| 61-91 | **1.05 - 1.10** | 16 | 0.6694*** | 0.5136* | 0.3987 | 0.1258 | 18 | -0.544*** |
| | | | 2.66 | 1.96 | 1.45 | 0.72 | | -7.39 |
| | **0.95 - 1.05** | 17 | 0.5814*** | 0.5250*** | 0.2513** | 0.0359 | 18 | -0.546*** |
| | | | 2.90 | 2.66 | 2.00 | 0.32 | | -10.03 |
| | **0.90 - 0.95** | 17 | 0.8356*** | 0.5028*** | 0.2679** | 0.3569*** | 18 | -0.479*** |
| | | | 3.11 | 2.90 | 2.00 | 4.80 | | -7.28 |
| 92-182 | **1.05 - 1.10** | 17 | 0.8814*** | 0.5219*** | 0.9232*** | 0.3014* | 18 | -0.580*** |
| | | | 4.94 | 4.22 | 3.83 | 1.82 | | -9.98 |
| | **0.95 - 1.05** | 17 | 0.7945*** | 0.4736*** | 0.7258*** | 0.3027*** | 18 | -0.492*** |
| | | | 8.02 | 3.82 | 5.74 | 3.16 | | -14.92 |
| | **0.90 - 0.95** | 17 | 1.1941*** | 0.5780*** | 0.6656*** | 0.2879** | 18 | -0.906*** |
| | | | 3.21 | 4.27 | 4.80 | 2.08 | | -9.65 |
| 183-273 | **1.05 - 1.10** | 16 | 0.9637*** | 1.1996*** | 1.1473*** | 0.6471*** | 18 | -0.317*** |
| | | | 3.70 | 6.63 | 4.01 | 6.17 | | -4.74 |
| | **0.95 - 1.05** | 16 | 1.0774*** | 0.8738*** | 1.0689*** | 0.5447*** | 18 | -0.533*** |
| | | | 4.83 | 7.26 | 5.53 | 4.44 | | -8.76 |
| | **0.90 - 0.95** | 16 | 0.8094*** | 0.8364*** | 0.9469*** | 0.4819*** | 18 | -0.328*** |
| | | | 3.69 | 6.61 | 4.71 | 3.02 | | -5.01 |

**Table A8 (b)**
**Size Effects in Liquidity Comovement between Put Options and their Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05 - 1.10** | 17 | 0.4256 | 0.3717 | 1.0279** | 0.8557*** | 18 | 0.430*** |
| | | | 0.78 | 1.31 | 2.30 | 3.35 | | 2.72 |
| | **0.95 - 1.05** | 17 | 0.4224* | 0.4970*** | 0.9044*** | 0.5756*** | 19 | 0.153*** |
| | | | 1.91 | 3.11 | 4.61 | 4.44 | | 2.57 |
| | **0.90 - 0.95** | 16 | 0.4657* | 0.3514 | 0.4555 | 0.0833 | 19 | -0.382*** |
| | | | 1.79 | 1.69 | 1.65 | 0.43 | | -5.00 |
| 31-60 | **1.05 - 1.10** | 17 | 0.9586*** | 0.8246*** | 0.3902*** | 0.8956*** | 19 | -0.063 |
| | | | 5.97 | 4.88 | 3.50 | 7.74 | | -1.36 |
| | **0.95 - 1.05** | 17 | 0.9332*** | 0.7182*** | 0.7198*** | 0.7108*** | 19 | -0.222*** |
| | | | 4.54 | 7.05 | 7.74 | 7.71 | | -4.26 |
| | **0.90 - 0.95** | 17 | 0.7469*** | 0.4077*** | 0.5784*** | 0.4394*** | 19 | -0.307*** |
| | | | 5.33 | 3.52 | 3.86 | 4.23 | | -7.53 |
| 61-91 | **1.05 - 1.10** | 16 | 0.5590*** | 0.5029*** | 0.3728* | 0.8665*** | 19 | 0.308*** |
| | | | 2.43 | 3.13 | 1.85 | 5.77 | | 4.75 |
| | **0.95 - 1.05** | 17 | 0.8292*** | 0.5664*** | 0.5281*** | 0.4804*** | 19 | -0.349*** |
| | | | 4.05 | 2.76 | 4.35 | 4.93 | | -6.64 |
| | **0.90 - 0.95** | 16 | 0.4478** | 0.3708* | 0.3460* | 0.2917*** | 19 | -0.156*** |
| | | | 2.11 | 1.81 | 1.77 | 2.46 | | -2.74 |
| 92-182 | **1.05 - 1.10** | 17 | 0.8521*** | 0.7116*** | 0.7826*** | 0.6636*** | 19 | -0.188*** |
| | | | 6.87 | 4.82 | 4.64 | 6.15 | | -4.87 |
| | **0.95 - 1.05** | 17 | 0.7730*** | 0.7836*** | 0.7284*** | 0.4236*** | 19 | -0.349*** |
| | | | 7.78 | 8.68 | 7.21 | 5.10 | | -11.49 |
| | **0.90 - 0.95** | 17 | 0.6552*** | 0.6056*** | 0.7391*** | 0.3266*** | 19 | -0.329*** |
| | | | 6.20 | 5.84 | 6.76 | 3.40 | | -9.77 |
| 183-273 | **1.05 - 1.10** | 16 | 1.2864*** | 1.0917*** | 1.2421*** | 0.5517*** | 19 | -0.735*** |
| | | | 5.14 | 6.67 | 4.38 | 4.44 | | -11.27 |
| | **0.95 - 1.05** | 16 | 1.2041*** | 1.0077*** | 1.2643*** | 0.5040*** | 19 | -0.700*** |
| | | | 5.04 | 9.51 | 5.82 | 6.88 | | -12.14 |
| | **0.90 - 0.95** | 16 | 1.3002*** | 1.0863*** | 1.2090*** | 0.3190*** | 19 | -0.981*** |
| | | | 4.32 | 5.41 | 5.51 | 2.77 | | -13.15 |

## Table A8 (c)
**Size Effects in Liquidity Comovement between All Options and their Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05-1.10** | 19 | 0.7531*** | 0.5911*** | 0.5605*** | 0.7328*** | 17 | -0.020 |
| | | | 4.81 | 4.63 | 3.84 | 4.48 | | -0.38 |
| | **0.95-1.05** | 20 | 0.6931*** | 0.4360*** | 0.3392 | 0.4619*** | 17 | -0.231*** |
| | | | 4.35 | 2.94 | 1.66 | 3.00 | | -4.47 |
| | **0.90-0.95** | 19 | 0.9051*** | 0.7230*** | 0.7139*** | 0.3753*** | 17 | -0.530*** |
| | | | 7.49 | 7.13 | 4.03 | 2.80 | | -12.48 |
| 31-60 | **1.05-1.10** | 20 | 0.7792*** | 0.6001*** | 0.7325*** | 0.6729*** | 17 | -0.106*** |
| | | | 4.73 | 4.47 | 4.20 | 5.29 | | -2.17 |
| | **0.95-1.05** | 20 | 0.7431*** | 0.4151*** | 0.3667*** | 0.4733*** | 17 | -0.270*** |
| | | | 3.59 | 3.12 | 4.38 | 4.97 | | -4.94 |
| | **0.90-0.95** | 20 | 0.8509*** | 0.6567*** | 0.6952*** | 0.6945*** | 17 | -0.156*** |
| | | | 5.45 | 5.65 | 6.17 | 5.15 | | -3.23 |
| 61-91 | **1.05-1.10** | 20 | 0.3324*** | 0.6123*** | 0.4210*** | 0.4569*** | 17 | 0.125*** |
| | | | 2.86 | 3.92 | 5.87 | 4.74 | | 3.50 |
| | **0.95-1.05** | 20 | 0.4539*** | 0.4719*** | 0.3629*** | 0.4806*** | 17 | 0.027 |
| | | | 2.46 | 3.56 | 4.27 | 5.05 | | 0.54 |
| | **0.90-0.95** | 20 | 0.5595*** | 0.6743*** | 0.5495*** | 0.5693*** | 17 | 0.010 |
| | | | 5.01 | 6.81 | 4.65 | 6.15 | | 0.29 |
| 92-182 | **1.05-1.10** | 20 | 0.5446*** | 0.3446* | 0.3505 | 0.5631 | 18 | 0.018 |
| | | | 2.80 | 1.76 | 1.64 | 4.29 | | 0.34 |
| | **0.95-1.05** | 19 | 0.7597*** | 0.3762*** | 0.4650*** | 0.5005*** | 18 | -0.259*** |
| | | | 3.29 | 2.43 | 4.41 | 6.14 | | -4.50 |
| | **0.90-0.95** | 19 | 1.0037*** | 1.1641*** | 0.8143*** | 0.6368*** | 18 | -0.367*** |
| | | | 4.85 | 7.65 | 4.75 | 5.20 | | -6.51 |
| 183-273 | **1.05-1.10** | 20 | 0.5914*** | 0.2809 | 0.4791*** | 0.7294*** | 18 | 0.138** |
| | | | 2.52 | 1.33 | 2.48 | 8.16 | | 2.35 |
| | **0.95-1.05** | 19 | 1.0310*** | 0.6618*** | 0.8749*** | 0.4936*** | 18 | -0.537*** |
| | | | 5.54 | 5.36 | 4.67 | 4.63 | | -10.70 |
| | **0.90-0.95** | 19 | 1.3705*** | 1.1039*** | 1.0965*** | 0.5696*** | 18 | -0.801*** |
| | | | 6.25 | 7.46 | 3.90 | 6.63 | | -14.48 |

**Table A9 (a)**

**Volatility Effects in Liquidity Comovement between Call Options and their Market (Proportional Spread)**

This table reports regression results for volatility quartile portfolios. After estimating time-series market model regressions for each stock in maturity and moneyness portfolios, we group the results in quartiles by average implied volatility of a stock. Implied volatility is calculated by inverting the Black-Scholes option pricing formula. Implied volatility assigned to a stock is calculated as a time-series average of implied volatility of options for the entire sample period from 22 February 2008 to 31 December 2010. We compute results based on the stocks in volatility quartiles by calculating the cross-sectional average of regression coefficients across stocks within each quartile. Due to the panel nature of options, we report the results for liquidity comovement between options and their markets. We also report the difference in coefficients of options market liquidity for small and big firms and the t-statistic. Table A9(a), Table A9(b) and Table A9(c) reports the results of call, put and all (both calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H – L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05-1.10** | 14 | -0.3961 | -0.1187 | -0.0249 | 0.3882** | 15 | 0.784*** |
| | | | -1.45 | -0.64 | -0.06 | 2.34 | | 9.41 |
| | **0.95-1.05** | 16 | 0.4671** | 0.0380 | 0.6430** | 0.5513*** | 18 | 0.084 |
| | | | 2.05 | 0.19 | 2.22 | 4.06 | | 1.33 |
| | **0.90-0.95** | 14 | 0.3611 | 0.0933 | 0.9292*** | 0.0505 | 15 | -0.311*** |
| | | | 1.50 | 0.34 | 2.92 | 0.23 | | -3.61 |
| 31-60 | **1.05-1.10** | 16 | 0.7563*** | 0.6881*** | 0.8295*** | 0.3287 | 18 | -0.428*** |
| | | | 4.21 | 4.60 | 4.62 | 1.63 | | -6.49 |
| | **0.95-1.05** | 16 | 0.8858*** | 0.6716*** | 0.5191*** | 0.3734*** | 18 | -0.512*** |
| | | | 4.93 | 5.60 | 4.28 | 4.05 | | -10.65 |
| | **0.90-0.95** | 16 | 0.7857*** | 0.4998*** | 0.4760*** | 0.3757*** | 18 | -0.410*** |
| | | | 4.06 | 4.05 | 3.08 | 3.26 | | -7.61 |
| 61-91 | **1.05-1.10** | 16 | 0.1742 | 0.4219*** | 0.4745*** | 0.4082*** | 17 | 0.234*** |
| | | | 1.10 | 2.78 | 2.60 | 2.93 | | 4.52 |
| | **0.95-1.05** | 16 | 0.6417*** | 0.7535*** | 0.2044 | 0.7226** | 18 | 0.081 |
| | | | 3.42 | 4.21 | 1.48 | 2.09 | | 0.83 |
| | **0.90-0.95** | 16 | 0.5217*** | 0.4599*** | 0.2697** | 0.2414 | 18 | -0.280*** |
| | | | 2.78 | 4.18 | 2.44 | 1.60 | | -4.82 |
| 92-182 | **1.05-1.10** | 16 | 0.5324*** | 0.5128*** | 0.6179*** | 0.2608*** | 18 | -0.272*** |
| | | | 3.51 | 3.46 | 4.79 | 3.00 | | -6.50 |
| | **0.95-1.05** | 16 | 0.5473*** | 0.5593*** | 0.6572*** | 0.2159*** | 18 | -0.331*** |
| | | | 4.86 | 6.85 | 5.05 | 3.09 | | -10.43 |
| | **0.90-0.95** | 16 | 0.5647*** | 0.5687*** | 0.4776*** | 0.1397 | 18 | -0.425*** |
| | | | 4.75 | 6.10 | 4.70 | 1.33 | | -11.07 |
| 183-273 | **1.05-1.10** | 16 | 0.6987*** | 0.4992*** | 0.4509** | 0.2860** | 18 | -0.413*** |
| | | | 3.98 | 4.33 | 2.35 | 2.28 | | -7.96 |
| | **0.95-1.05** | 16 | 0.6956*** | 0.6268*** | 0.4337*** | 0.3256*** | 18 | -0.370*** |
| | | | 6.78 | 6.46 | 3.71 | 3.58 | | -11.14 |
| | **0.90-0.95** | 16 | 0.6187*** | 0.4675*** | 0.2277* | 0.1813*** | 18 | -0.437*** |
| | | | 4.85 | 4.89 | 1.80 | 2.42 | | -12.35 |

**Table A9 (b)**
**Volatility Effects in Liquidity Comovement between Put Options and their Market (Proportional Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05-1.10** | 6 | 0.6423* | 0.6184*** | 0.1749 | 0.3449* | 14 | -0.297*** |
| | | | 1.76 | 3.36 | 1.04 | 1.93 | | -2.49 |
| | **0.95-1.05** | 17 | 0.8471*** | 0.7692*** | 0.6653* | 0.7018*** | 19 | -0.145*** |
| | | | 4.74 | 3.36 | 1.89 | 4.26 | | -2.54 |
| | **0.90-0.95** | 17 | 0.9011*** | 0.4745 | 0.5672 | 0.4285*** | 17 | -0.473*** |
| | | | 2.87 | 1.54 | 1.51 | 2.58 | | -5.49 |
| 31-60 | **1.05-1.10** | 17 | 0.7105*** | 0.5264*** | 0.4452*** | 0.4545*** | 19 | -0.256*** |
| | | | 4.33 | 4.38 | 2.48 | 4.29 | | -5.62 |
| | **0.95-1.05** | 17 | 0.8173*** | 0.7529*** | 0.4593** | 0.4910*** | 19 | -0.326*** |
| | | | 5.32 | 4.65 | 2.19 | 4.07 | | -7.12 |
| | **0.90-0.95** | 17 | 0.7611*** | 0.4914*** | 0.7569*** | 0.4125*** | 19 | -0.349*** |
| | | | 4.38 | 3.38 | 4.11 | 3.06 | | -6.77 |
| 61-91 | **1.05-1.10** | 17 | 0.3631** | 0.5784*** | 0.6336*** | 0.3506*** | 17 | -0.012 |
| | | | 2.34 | 3.33 | 4.52 | 3.54 | | -0.28 |
| | **0.95-1.05** | 17 | 0.8590*** | 0.9094*** | 0.9088*** | 0.4542*** | 19 | -0.405*** |
| | | | 4.38 | 3.58 | 2.83 | 3.04 | | -7.01 |
| | **0.90-0.95** | 17 | 0.6889*** | 0.6551*** | 0.6079*** | 0.2544** | 18 | -0.435*** |
| | | | 3.09 | 3.65 | 3.63 | 2.21 | | -7.30 |
| 92-182 | **1.05-1.10** | 17 | 0.6085*** | 0.7094*** | 0.7424*** | 0.4913*** | 19 | -0.117*** |
| | | | 5.33 | 6.20 | 5.63 | 5.16 | | -3.36 |
| | **0.95-1.05** | 17 | 0.8337*** | 0.6943*** | 0.6545*** | 0.2798*** | 19 | -0.554*** |
| | | | 3.03 | 5.46 | 4.92 | 4.23 | | -8.52 |
| | **0.90-0.95** | 17 | 0.7423*** | 0.5908*** | 0.5729*** | 0.2983*** | 19 | -0.444*** |
| | | | 6.40 | 4.20 | 4.94 | 3.16 | | -12.66 |
| 183-273 | **1.05-1.10** | 17 | 0.4770*** | 0.6148*** | 0.8654*** | 0.3335*** | 19 | -0.143*** |
| | | | 5.83 | 4.99 | 4.86 | 4.30 | | -5.40 |
| | **0.95-1.05** | 17 | 0.6743*** | 0.7937*** | 0.5943*** | 0.2929*** | 19 | -0.381*** |
| | | | 5.57 | 4.81 | 4.43 | 5.25 | | -12.35 |
| | **0.90-0.95** | 17 | 0.7925*** | 0.6482*** | 0.5111*** | 0.0328 | 19 | -0.760*** |
| | | | 4.68 | 5.89 | 3.06 | 0.44 | | -17.75 |

**Table A9 (c)**
**Volatility Effects in Liquidity Comovement between All Options and their Market (Proportional Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05- 1.10 | 17 | 0.7402*** | 0.4455*** | 0.2994 | 0.9133*** | 19 | 0.173** |
| | | | 2.49 | 2.50 | 0.77 | 5.02 | | 2.13 |
| | 0.95- 1.05 | 17 | 1.0000*** | 0.5978*** | 0.6112*** | 1.1001*** | 19 | 0.100 |
| | | | 6.83 | 3.35 | 3.66 | 4.41 | | 1.44 |
| | 0.90- 0.95 | 17 | 0.5535 | 0.4446 | 0.6084* | 0.8231*** | 19 | 0.270*** |
| | | | 1.49 | 1.41 | 1.78 | 2.98 | | 2.49 |
| 31-60 | 1.05- 1.10 | 17 | 1.4303*** | 0.9229*** | 1.1567*** | 0.6294*** | 19 | -0.801*** |
| | | | 5.62 | 5.69 | 7.16 | 4.89 | | -12.11 |
| | 0.95- 1.05 | 17 | 1.4052*** | 1.1047*** | 0.5311** | 0.5684*** | 19 | -0.837*** |
| | | | 5.84 | 4.94 | 2.05 | 4.65 | | -13.36 |
| | 0.90- 0.95 | 17 | 0.9847*** | 0.6281*** | 0.6675*** | 0.5858*** | 19 | -0.399*** |
| | | | 2.81 | 3.34 | 3.40 | 3.85 | | -4.51 |
| 61-91 | 1.05- 1.10 | 17 | 0.6525*** | 1.1175*** | 0.9740*** | 0.6397*** | 19 | -0.013 |
| | | | 4.48 | 5.30 | 4.25 | 4.81 | | -0.28 |
| | 0.95- 1.05 | 17 | 0.9558*** | 1.2573*** | 0.9171*** | 0.9217** | 19 | -0.034 |
| | | | 5.30 | 4.43 | 2.50 | 2.12 | | -0.30 |
| | 0.90- 0.95 | 17 | 0.9873*** | 0.8419*** | 0.5043*** | 0.4233*** | 19 | -0.564*** |
| | | | 3.51 | 4.03 | 3.23 | 3.11 | | -7.79 |
| 92-182 | 1.05- 1.10 | 17 | 1.1473*** | 0.9547*** | 1.1683*** | 0.6919*** | 19 | -0.455*** |
| | | | 5.73 | 5.57 | 6.86 | 6.15 | | -8.53 |
| | 0.95- 1.05 | 17 | 1.2839*** | 0.9654*** | 0.9463*** | 0.4395*** | 19 | -0.844*** |
| | | | 3.59 | 6.58 | 5.68 | 4.33 | | -9.88 |
| | 0.90- 0.95 | 17 | 0.8543*** | 0.9567*** | 0.7594*** | 0.3855*** | 19 | -0.469*** |
| | | | 6.53 | 6.27 | 5.59 | 2.98 | | -10.79 |
| 183-273 | 1.05- 1.10 | 17 | 1.0460*** | 0.7440*** | 1.0856*** | 0.5989*** | 19 | -0.447*** |
| | | | 5.95 | 5.39 | 4.28 | 4.15 | | -8.38 |
| | 0.95- 1.05 | 17 | 1.0400*** | 1.0625*** | 0.8905*** | 0.4570*** | 19 | -0.583*** |
| | | | 7.40 | 5.09 | 5.81 | 4.80 | | -14.70 |
| | 0.90- 0.95 | 17 | 1.1394*** | 0.7543*** | 0.5658*** | 0.2456*** | 19 | -0.894*** |
| | | | 5.54 | 6.03 | 3.53 | 2.51 | | -16.94 |

**Table A10 (a)**
**Volatility Effects in Liquidity Comovement between Call Options and their Market (Percentage Spread)**

This table reports regression results for volatility quartile portfolios. We estimate time-series market model regressions for each stock in maturity and moneyness portfolio, and then we group the results in quartiles by average implied volatility of a stock. Implied volatility is calculated by inverting the Black-Scholes option pricing formula. Implied volatility assigned to a stock is then calculated as a time-series average of implied volatility of options for the entire sample period from 22 February 2008 to 31 December 2010. We compute results based on the stocks in volatility quartiles by calculating the cross-sectional average of regression coefficients across stocks within each quartile for each moneyness and maturity portfolio. Due to the panel nature of options, we report results for liquidity comovement between options and their market. We use percentage option bid-ask spread (option bid-ask spread as a percentage of stock price) as a measure of option liquidity. We also report the difference in coefficients of options market liquidity for the small and big firms and the t-statistic. Table A10(a), Table A10(b) and Table A10(c) reports the results of call, put and all (both calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05-1.10 | 14 | -0.2764 | 0.5263** | 0.1305 | 0.3323 | 15 | 0.609*** |
| | | | -0.64 | 2.04 | 0.28 | 1.22 | | 4.59 |
| | 0.95-1.05 | 16 | 0.2191 | 0.3227** | 0.7268*** | 0.5316*** | 18 | 0.313*** |
| | | | 0.77 | 2.31 | 2.44 | 3.64 | | 4.12 |
| | 0.90-0.95 | 14 | 0.2627 | 0.0521 | 0.6845*** | 0.4203 | 15 | 0.158 |
| | | | 0.95 | 0.27 | 2.48 | 1.62 | | 1.58 |
| 31-60 | 1.05-1.10 | 16 | 0.7760*** | 0.6528*** | 0.8135*** | -0.0969 | 18 | -0.873*** |
| | | | 4.07 | 4.32 | 4.37 | -0.50 | | -13.15 |
| | 0.95-1.05 | 16 | 0.6513*** | 0.6479*** | 0.6231*** | 0.2503** | 18 | -0.401*** |
| | | | 3.57 | 10.31 | 6.48 | 2.08 | | -7.66 |
| | 0.90-0.95 | 16 | 0.7011*** | 0.6208*** | 0.5185*** | 0.4981*** | 18 | -0.203*** |
| | | | 3.23 | 5.24 | 3.21 | 2.86 | | -3.02 |
| 61-91 | 1.05-1.10 | 16 | 0.1543 | 0.3966 | 0.5157** | 0.5877*** | 17 | 0.433*** |
| | | | 0.58 | 1.46 | 2.31 | 2.75 | | 5.19 |
| | 0.95-1.05 | 16 | 0.3428* | 0.2667*** | 0.3729* | 0.3819** | 18 | 0.039 |
| | | | 1.96 | 2.81 | 1.81 | 2.22 | | 0.66 |
| | 0.90-0.95 | 16 | 0.2960** | 0.3394** | 0.7006*** | 0.5656*** | 18 | 0.270*** |
| | | | 2.23 | 2.28 | 3.16 | 3.27 | | 5.04 |
| 92-182 | 1.05-1.10 | 16 | 0.4736** | 0.7658*** | 0.9055*** | 0.4501*** | 18 | -0.024 |
| | | | 2.46 | 2.81 | 5.95 | 3.94 | | -0.44 |
| | 0.95-1.05 | 16 | 0.5521*** | 0.6211*** | 0.8200*** | 0.2834*** | 18 | -0.269*** |
| | | | 4.36 | 5.45 | 6.37 | 4.00 | | -7.74 |
| | 0.90-0.95 | 16 | 0.4675*** | 0.6467*** | 1.1420*** | 0.3953*** | 18 | -0.072 |
| | | | 3.87 | 4.92 | 3.30 | 2.69 | | -1.55 |
| 183-273 | 1.05-1.10 | 16 | 0.9811*** | 1.2789*** | 1.2182*** | 0.4859*** | 18 | -0.495*** |
| | | | 3.97 | 5.26 | 5.55 | 3.95 | | -7.54 |
| | 0.95-1.05 | 16 | 1.0893*** | 0.9265*** | 1.0352*** | 0.5180*** | 18 | -0.571*** |
| | | | 6.36 | 5.91 | 5.15 | 3.83 | | -10.85 |
| | 0.90-0.95 | 16 | 0.9587*** | 0.7662*** | 0.8724*** | 0.4900*** | 18 | -0.469*** |
| | | | 5.64 | 4.05 | 4.50 | 3.05 | | -8.27 |

**Table A10 (b)**
**Volatility Effects in Liquidity Comovement between Put Options and their Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05-1.10 | 6 | -0.3569 | 0.6864** | 0.7271** | 1.2002*** | 14 | 1.557*** |
| | | | -0.83 | 2.17 | 2.18 | 4.40 | | 9.85 |
| | 0.95-1.05 | 17 | 0.3461** | 0.5753*** | 0.5071*** | 0.9328*** | 19 | 0.587*** |
| | | | 2.01 | 4.30 | 2.76 | 4.84 | | 9.59 |
| | 0.90-0.95 | 17 | -0.0046 | 0.2215 | 0.5237* | 0.5593** | 17 | 0.564*** |
| | | | -0.02 | 1.59 | 1.95 | 2.40 | | 6.86 |
| 31-60 | 1.05-1.10 | 17 | 0.5544*** | 0.7642*** | 1.1674*** | 0.5948*** | 19 | 0.040 |
| | | | 3.50 | 6.94 | 7.54 | 5.00 | | 0.87 |
| | 0.95-1.05 | 17 | 0.7139*** | 0.8624*** | 0.9664*** | 0.5519*** | 19 | -0.162*** |
| | | | 8.25 | 7.72 | 5.22 | 6.02 | | -5.44 |
| | 0.90-0.95 | 17 | 0.5286*** | 0.5557*** | 0.7455*** | 0.3427*** | 19 | -0.186*** |
| | | | 3.41 | 7.68 | 5.60 | 2.76 | | -3.99 |
| 61-91 | 1.05-1.10 | 17 | 0.1640 | 0.7962*** | 0.6461*** | 0.7433*** | 17 | 0.579*** |
| | | | 1.12 | 3.62 | 3.33 | 4.69 | | 11.06 |
| | 0.95-1.05 | 17 | 0.6363*** | 0.6785*** | 0.7126*** | 0.3858*** | 19 | -0.251*** |
| | | | 3.55 | 5.07 | 4.71 | 2.24 | | -4.28 |
| | 0.90-0.95 | 17 | 0.1999 | 0.3797** | 0.5834*** | 0.2731*** | 18 | 0.073 |
| | | | 1.28 | 2.31 | 3.81 | 1.20 | | 1.10 |
| 92-182 | 1.05-1.10 | 17 | 0.7755*** | 0.8764*** | 0.9310*** | 0.4491*** | 19 | -0.326*** |
| | | | 5.85 | 5.43 | 6.74 | 5.01 | | -8.73 |
| | 0.95-1.05 | 17 | 0.5751*** | 0.8015*** | 0.8484*** | 0.4748*** | 19 | -0.100*** |
| | | | 5.46 | 9.33 | 9.10 | 5.58 | | -3.16 |
| | 0.90-0.95 | 17 | 0.5534*** | 0.6712*** | 0.7379*** | 0.3566*** | 19 | -0.197*** |
| | | | 5.15 | 6.18 | 7.95 | 3.30 | | -5.47 |
| 183-273 | 1.05-1.10 | 17 | 1.0277*** | 1.0407*** | 1.1951*** | 0.8579*** | 19 | -0.170** |
| | | | 4.70 | 5.78 | 5.06 | 3.67 | | -2.24 |
| | 0.95-1.05 | 17 | 0.9685*** | 1.0129*** | 1.4192*** | 0.5614*** | 19 | -0.407*** |
| | | | 6.36 | 5.69 | 6.76 | 4.46 | | -8.78 |
| | 0.90-0.95 | 17 | 0.8771*** | 0.8735*** | 1.4642*** | 0.6372*** | 19 | -0.240*** |
| | | | 3.75 | 5.80 | 4.90 | 3.71 | | -3.53 |

**Table A10 (c)**
**Volatility Effects in Liquidity Comovement between All Options and their Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05-1.10 | 17 | 0.0861 | 0.5054*** | 0.4782* | 0.8076*** | 19 | 0.722*** |
| | | | 0.21 | 2.43 | 1.72 | 2.46 | | 5.79 |
| | 0.95-1.05 | 17 | 0.3113 | 0.4983*** | 0.4474*** | 0.9373*** | 19 | 0.626*** |
| | | | 1.10 | 3.72 | 2.47 | 3.50 | | 6.81 |
| | 0.90-0.95 | 17 | -0.0058 | 0.1386 | 0.4951*** | 0.5951*** | 19 | 0.601*** |
| | | | -0.03 | 1.15 | 2.66 | 2.56 | | 8.23 |
| 31-60 | 1.05-1.10 | 17 | 0.7257*** | 0.6406*** | 1.1180*** | 0.2760*** | 19 | -0.450*** |
| | | | 5.24 | 6.07 | 8.29 | 2.68 | | -11.14 |
| | 0.95-1.05 | 17 | 0.7423*** | 0.8051*** | 0.8239*** | 0.3898*** | 19 | -0.352*** |
| | | | 5.80 | 9.32 | 5.69 | 4.69 | | -9.90 |
| | 0.90-0.95 | 17 | 0.6104*** | 0.6263*** | 0.6508*** | 0.4297*** | 19 | -0.181*** |
| | | | 3.26 | 6.81 | 4.73 | 3.19 | | -3.34 |
| 61-91 | 1.05-1.10 | 17 | 0.2000 | 0.6503*** | 0.6217*** | 0.4376*** | 19 | 0.238*** |
| | | | 1.27 | 3.37 | 3.46 | 2.87 | | 4.59 |
| | 0.95-1.05 | 17 | 0.5838*** | 0.5647*** | 0.6796*** | 0.4039*** | 19 | -0.180*** |
| | | | 3.80 | 5.11 | 3.49 | 2.68 | | -3.54 |
| | 0.90-0.95 | 17 | 0.3504*** | 0.4803*** | 0.7157*** | 0.4341*** | 19 | 0.084* |
| | | | 3.16 | 3.99 | 3.77 | 2.50 | | 1.70 |
| 92-182 | 1.05-1.10 | 17 | 0.7876*** | 0.7517*** | 1.0027*** | 0.4202*** | 19 | -0.367*** |
| | | | 4.65 | 4.67 | 6.56 | 4.28 | | -8.07 |
| | 0.95-1.05 | 17 | 0.6630*** | 0.7369*** | 0.8931*** | 0.4117*** | 19 | -0.251*** |
| | | | 6.28 | 8.70 | 7.63 | 4.57 | | -7.71 |
| | 0.90-0.95 | 17 | 0.5308*** | 0.6968*** | 0.9610*** | 0.3417** | 19 | -0.189*** |
| | | | 4.78 | 6.88 | 6.39 | 2.33 | | -4.32 |
| 183-273 | 1.05-1.10 | 17 | 1.2170*** | 1.1442*** | 1.3175*** | 0.6199*** | 19 | -0.597*** |
| | | | 4.66 | 8.40 | 4.96 | 3.74 | | -8.28 |
| | 0.95-1.05 | 17 | 1.1214*** | 1.0856*** | 1.4256*** | 0.5757*** | 19 | -0.546*** |
| | | | 6.40 | 5.68 | 5.85 | 4.25 | | -10.52 |
| | 0.90-0.95 | 17 | 1.0240*** | 0.8834*** | 1.2768*** | 0.6300*** | 19 | -0.394*** |
| | | | 5.07 | 6.20 | 5.31 | 4.22 | | -6.70 |

## Table A11
## Liquidity Comovement between Call Options and their Underlying Stock Market (Proportional spread)

This table presents the results of liquidity comovement between call options and their underlying stock market. Option liquidity is measured by proportional bid-ask spread (option spread as a percentage of option bid-ask midpoint). For each stock in its maturity and moneyness portfolio, all call options are averaged at time t, and at stock level, we run the time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 years respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call options, put options and all options markets. This table reports, for each parameter, three stacked values: average coefficient, t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of $N$ have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0095 | 0.0028 | 0.0037 | 0.0078 | 0.0044 | 0.0037 | 0.0035 | -0.0010 | 0.0018 | -0.0015 |
| | 1.33 | 0.72 | 1.06 | 1.42 | 0.45 | 1.21 | 1.34 | -0.49 | 0.64 | -0.50 |
| | 52.05 | 54.67 | 46.67 | 52.05 | 50.70 | 53.42 | 49.32 | 46.58 | 49.32 | 48.61 |
| $\beta_2$ | 0.0358 | 0.0752$^{1}$ | 0.1070$^{1}$ | 0.0226 | 0.0885 | 0.0129 | 0.0683$^{1}$ | 0.0972$^{1}$ | 0.0799$^{1}$ | 0.0135 |
| | 0.80 | 3.77 | 6.14 | 0.95 | 1.39 | 0.52 | 2.83 | 4.78 | 2.72 | 0.49 |
| | 46.58 | 64.00 | 77.33 | 53.42 | 53.52 | 57.53 | 69.86 | 69.86 | 63.01 | 52.78 |
| $\beta_{2lag}$ | -0.000 | -0.017 | 0.0135 | -0.0393 | 0.0477 | 0.0088 | 0.1010$^{1}$ | 0.1337$^{1}$ | 0.1350$^{1}$ | 0.1145$^{1}$ |
| | -0.01 | -0.69 | 0.84 | -1.49 | 1.19 | 0.29 | 4.00 | 5.63 | 4.62 | 3.28 |
| | 36.99 | 46.67 | 42.67 | 46.58 | 50.70 | 49.32 | 64.38 | 79.45 | 73.97 | 70.83 |
| $\beta_2 + \beta_{2lag}$ | 0.0356 | 0.0579 | 0.1205$^{1}$ | -0.0167 | 0.1361 | 0.0217 | 0.1693$^{1}$ | 0.2308$^{1}$ | 0.2149$^{1}$ | 0.1280$^{2}$ |
| | 0.52 | 1.60 | 4.35 | -0.42 | 1.46 | 0.47 | 3.96 | 5.82 | 4.29 | 2.28 |
| | 41.78 | 55.33 | 60.00 | 50.00 | 52.11 | 53.42 | 67.12 | 74.66 | 68.49 | 61.81 |
| $\beta_3$ | 0.1603 | 0.5417$^{1}$ | 0.6481$^{1}$ | 0.6249$^{1}$ | 0.5566$^{2}$ | 0.4426$^{1}$ | 0.7409$^{1}$ | 0.7180$^{1}$ | 0.5064$^{1}$ | 0.1339$^{1}$ |
| | 1.41 | 7.70 | 10.16 | 8.01 | 2.24 | 5.79 | 9.18 | 10.21 | 8.21 | 2.73 |
| | 50.68 | 80.00 | 85.33 | 83.56 | 64.79 | 79.45 | 94.52 | 97.26 | 91.78 | 63.89 |
| $\beta_{3lag}$ | -0.261$^{2}$ | -0.136$^{3}$ | 0.0524 | 0.1421$^{2}$ | 0.2116 | -0.0196 | 0.0123 | 0.0467$^{1}$ | 0.0645$^{1}$ | 0.0219 |
| | -2.64 | -1.85 | 1.17 | 2.40 | 1.19 | -0.60 | 0.62 | 3.20 | 3.48 | 0.95 |
| | 32.88 | 44.00 | 50.67 | 68.49 | 46.48 | 47.95 | 53.42 | 64.38 | 61.64 | 50.00 |
| $\beta_3 + \beta_{3lag}$ | -0.100 | 0.401$^{1}$ | 0.701$^{1}$ | 0.767$^{1}$ | 0.768$^{3}$ | 0.423$^{1}$ | 0.753$^{1}$ | 0.765$^{1}$ | 0.571$^{1}$ | 0.156$^{2}$ |
| | -0.59 | 4.0335 | 8.2308 | 6.7129 | 2.0651 | 5.1374 | 8.8978 | 10.3265 | 8.0221 | 2.5346 |
| | 41.78 | 62.00 | 68.00 | 76.02 | 55.63 | 63.69 | 73.97 | 80.82 | 76.71 | 56.94 |
| $\beta_4$ | -2.386$^{1}$ | -3.928$^{1}$ | -9.607$^{1}$ | -15.027$^{1}$ | -11.608$^{1}$ | -1.229$^{1}$ | -2.036$^{1}$ | -6.109$^{1}$ | -10.785$^{1}$ | -11.596$^{1}$ |
| | -5.05 | -14.28 | -17.51 | -20.03 | -13.19 | -4.28 | -8.11 | -19.23 | -19.64 | -20.60 |
| | 16.44 | 4.00 | 0.00 | 0.00 | 2.82 | 21.92 | 13.70 | 0.00 | 1.37 | 0.00 |
| $\beta_5$ | 0.185$^{1}$ | 0.0612 | 0.1836 | 0.5823$^{1}$ | 0.4610$^{1}$ | 0.1525$^{3}$ | -0.1358$^{1}$ | 0.1067$^{2}$ | 0.4091$^{1}$ | 0.4900$^{1}$ |
| | 3.01 | 0.85 | 1.26 | 2.95 | 3.09 | 1.76 | -2.85 | 2.20 | 4.28 | 3.45 |
| | 58.90 | 44.00 | 54.67 | 53.42 | 70.42 | 65.75 | 39.73 | 58.90 | 69.86 | 84.72 |
| $\beta_6$ | 0.256 | 0.3217 | -1.4566$^{3}$ | 0.4937 | 2.6149 | -1.6209$^{2}$ | -0.3940 | -0.8864$^{2}$ | -1.1087$^{3}$ | -0.4095 |
| | 0.19 | 0.39 | -1.79 | 0.42 | 1.16 | -2.13 | -0.63 | -2.24 | -1.98 | -0.42 |
| | 47.95 | 49.33 | 41.33 | 57.53 | 45.07 | 47.95 | 41.10 | 43.84 | 41.10 | 50.00 |
| $\beta_7$ | 3.786 | 3.5928$^{1}$ | 1.2328 | 3.7177$^{2}$ | 1.3964 | 0.3654 | 1.6634$^{3}$ | 1.0567$^{2}$ | 0.4648 | 0.4130 |
| | 1.59 | 3.08 | 1.40 | 2.37 | 0.36 | 0.29 | 1.96 | 2.09 | 0.67 | 0.27 |
| | 43.84 | 50.67 | 54.67 | 54.79 | 33.80 | 49.32 | 54.79 | 54.79 | 57.53 | 50.00 |
| $intercept$ | 3.958$^{1}$ | 4.6081$^{1}$ | 9.4960$^{1}$ | 16.0505$^{1}$ | 18.6812$^{1}$ | 6.5586$^{1}$ | 6.2133$^{1}$ | 7.5963$^{1}$ | 9.7755$^{1}$ | 11.6162$^{1}$ |
| | 3.08 | 6.23 | 11.37 | 13.37 | 8.61 | 8.50 | 12.25 | 18.21 | 17.11 | 12.70 |
| | 67.12 | 80.00 | 92.00 | 94.52 | 76.06 | 89.04 | 95.89 | 100.00 | 98.63 | 95.83 |
| $adj\ R^2$ | 7.28 | 11.73 | 36.98 | 39.8 | 46.01 | 7 | 8.45 | 26.17 | 35.36 | 43.11 |
| $N$ | 24 | 62 | 70 | 63 | 20 | 67 | 70 | 70 | 70 | 64 |

## Table A11 (Continued)
## Liquidity Comovement between Call Options and their Underlying Stock Market (Proportional spread)

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.002 | -0.003 | 0.0004 | 0.005 | 0.006 | 0.002 | -0.0004 | 0.0006 | $0.005^{3}$ | -0.0003 |
| | -0.65 | -0.82 | 0.13 | 1.09 | 1.19 | 1.12 | -0.19 | 0.42 | 1.86 | -0.16 |
| | 56.16 | 36.99 | 41.10 | 50.00 | 45.83 | 50.00 | 43.42 | 56.58 | 53.95 | 45.95 |
| $\beta_2$ | $0.1142^{1}$ | $0.1046^{1}$ | $0.0831^{1}$ | $0.1033^{1}$ | 0.0014 | $0.0599^{1}$ | $0.0922^{1}$ | $0.0908^{1}$ | $0.0702^{1}$ | $0.0213^{3}$ |
| | 2.69 | 3.09 | 3.48 | 3.11 | 0.04 | 4.85 | 5.96 | 7.78 | 3.79 | 1.86 |
| | 64.38 | 65.75 | 63.01 | 70.27 | 51.39 | 68.42 | 77.63 | 76.32 | 75.00 | 68.92 |
| $\beta_{2lag}$ | -0.001 | -0.056 | $-0.046^{3}$ | -0.0339 | -0.0173 | 0.0088 | $0.0469^{1}$ | $0.0380^{1}$ | $0.0258^{3}$ | $0.0140^{3}$ |
| | -0.04 | -1.13 | -1.83 | -1.05 | -0.47 | 0.66 | 3.04 | 3.16 | 1.72 | 1.70 |
| | 47.95 | 39.73 | 46.58 | 50.00 | 54.17 | 56.58 | 60.53 | 64.47 | 75.00 | 59.46 |
| $\beta_2 + \beta_{2lag}$ | $0.1127^{3}$ | 0.0486 | 0.0373 | 0.0694 | -0.0159 | $0.0687^{1}$ | $0.1391^{1}$ | $0.1288^{1}$ | $0.0960^{1}$ | $0.0353^{2}$ |
| | 1.70 | 0.76 | 0.88 | 1.24 | -0.25 | 3.34 | 5.78 | 6.41 | 3.22 | 2.30 |
| | 56.16 | 52.74 | 54.79 | 60.14 | 52.78 | 62.50 | 69.08 | 70.39 | 75.00 | 64.19 |
| $\beta_3$ | $0.422^{1}$ | $0.5806^{1}$ | $0.6981^{1}$ | $0.4223^{1}$ | $0.1734^{1}$ | $0.5503^{1}$ | $0.5831^{1}$ | $0.6141^{1}$ | $0.4870^{1}$ | $0.2141^{1}$ |
| | 5.61 | 7.73 | 6.27 | 6.78 | 4.78 | 12.04 | 10.57 | 12.63 | 9.36 | 8.85 |
| | 78.08 | 86.30 | 94.52 | 82.43 | 77.78 | 94.74 | 88.16 | 93.42 | 89.47 | 90.54 |
| $\beta_{3lag}$ | -0.005 | $-0.085^{2}$ | -0.0382 | -0.0504 | -0.0548 | -0.0154 | -0.0183 | 0.0065 | 0.0305 | -0.0019 |
| | -0.15 | -2.05 | -1.39 | -1.57 | -1.41 | -0.95 | -0.83 | 0.53 | 1.05 | -0.15 |
| | 52.05 | 45.21 | 46.58 | 44.59 | 50.00 | 51.32 | 48.68 | 53.95 | 57.89 | 54.05 |
| $\beta_3 + \beta_{3lag}$ | $0.417^{1}$ | $0.496^{1}$ | $0.6599^{1}$ | $0.3720^{1}$ | $0.1186^{2}$ | $0.5349^{1}$ | $0.5648^{1}$ | $0.6205^{1}$ | $0.5175^{1}$ | $0.2122^{1}$ |
| | 5.83 | 6.54 | 5.43 | 5.06 | 2.24 | 12.95 | 10.05 | 12.21 | 8.85 | 7.50 |
| | 65.06 | 65.75 | 70.54 | 63.51 | 63.88 | 73.02 | 68.42 | 73.68 | 73.68 | 72.29 |
| $\beta_4$ | -0.056 | $-1.442^{1}$ | $-4.480^{1}$ | $-8.036^{1}$ | $-10.126^{1}$ | $-0.7072^{1}$ | $-2.1659^{1}$ | $-3.2849^{1}$ | $-4.9523^{1}$ | $-7.2409^{1}$ |
| | -0.18 | -4.66 | -17.01 | -19.03 | -21.61 | -5.09 | -10.76 | -17.68 | -20.42 | -24.10 |
| | 42.47 | 21.92 | 1.37 | 1.35 | 0.00 | 28.95 | 9.21 | 2.63 | 0.00 | 0.00 |
| $\beta_5$ | $0.2086^{2}$ | $-0.0801^{2}$ | $0.0834^{2}$ | -0.0049 | $0.5275^{1}$ | $0.1237^{1}$ | 0.0520 | $0.0892^{2}$ | $0.0567^{3}$ | $0.2413^{1}$ |
| | 2.32 | -0.93 | 2.45 | -0.06 | 5.97 | 3.71 | 1.33 | 2.34 | 1.98 | 5.48 |
| | 53.42 | 49.32 | 63.01 | 48.65 | 90.28 | 72.37 | 56.58 | 64.47 | 60.53 | 79.73 |
| $\beta_6$ | 0.2505 | $-2.3952^{3}$ | $-1.6189^{2}$ | -0.5805 | -1.2722 | -0.0418 | -0.7045 | $-0.4803^{3}$ | $-1.1016^{1}$ | $-1.3587^{1}$ |
| | 0.22 | -1.91 | -2.60 | -0.70 | -1.38 | -0.13 | -1.28 | -1.77 | -2.77 | -3.52 |
| | 57.53 | 43.84 | 36.99 | 45.95 | 48.61 | 52.63 | 42.11 | 35.53 | 31.58 | 36.49 |
| $\beta_7$ | $3.1360^{2}$ | $1.9842^{3}$ | 0.4259 | 1.1420 | -0.5570 | $2.3670^{1}$ | $3.9795^{1}$ | $1.9106^{1}$ | $1.2598^{2}$ | -0.6732 |
| | 2.38 | 1.68 | 0.60 | 1.47 | -0.45 | 4.09 | 4.38 | 4.13 | 2.33 | -1.38 |
| | 60.27 | 63.01 | 57.53 | 58.11 | 59.72 | 61.84 | 65.79 | 63.16 | 53.95 | 33.78 |
| *intercept* | $4.1275^{1}$ | $6.2634^{1}$ | $6.8866^{1}$ | $7.4562^{1}$ | $8.4109^{1}$ | $4.6359^{1}$ | $4.7961^{1}$ | $5.3550^{1}$ | $5.9961^{1}$ | $7.0184^{1}$ |
| | 3.82 | 5.44 | 11.30 | 11.15 | 9.58 | 12.07 | 8.85 | 17.31 | 16.10 | 18.89 |
| | 75.34 | 80.82 | 97.26 | 93.24 | 91.67 | 90.79 | 92.11 | 98.68 | 96.05 | 98.65 |
| $adj\ R^2$ | 2.84 | 7 | 19.45 | 22.9 | 39.34 | 4.21 | 6.54 | 10.59 | 13.43 | 28.72 |
| $N$ | 65 | 68 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A11 (Continued)
## Liquidity Comovement between Call Options and their Underlying Stock Market (Proportional spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0007 | 0.0044 | -0.0028 | -0.0016 | -0.0014 | 0.0015 | 0.0012 | -0.0009 | -0.0015 | -0.0019 |
| | 0.35 | 1.35 | -1.46 | -0.84 | -0.86 | 0.50 | 0.39 | -0.39 | -0.70 | -1.04 |
| | 47.37 | 48.68 | 44.74 | 52.63 | 45.33 | 38.10 | 45.45 | 54.55 | 31.82 | 45.45 |
| $\beta_2$ | 0.0529[1] | 0.0894[1] | 0.0617[1] | 0.0628[1] | 0.0179 | 0.0456[2] | 0.0717[2] | 0.0489[1] | 0.0591[3] | 0.0221 |
| | 3.45 | 4.74 | 4.98 | 3.66 | 1.47 | 2.39 | 2.80 | 3.59 | 2.07 | 1.37 |
| | 63.16 | 71.05 | 71.05 | 69.74 | 60.00 | 61.90 | 68.18 | 81.82 | 72.73 | 54.55 |
| $\beta_{2lag}$ | 0.0212 | 0.0341[3] | 0.0257[2] | 0.0131 | -0.0018 | 0.0369[3] | 0.0678[2] | 0.0214 | 0.0817[1] | 0.0528[1] |
| | 1.35 | 1.84 | 2.20 | 0.65 | -0.16 | 2.02 | 2.43 | 1.10 | 3.82 | 3.36 |
| | 55.26 | 59.21 | 53.95 | 56.58 | 50.67 | 66.67 | 63.64 | 59.09 | 77.27 | 63.64 |
| $\beta_2 + \beta_{2lag}$ | 0.0741[1] | 0.1234[1] | 0.0874[1] | 0.0759[2] | 0.0161 | 0.0824[1] | 0.1395[1] | 0.0702[2] | 0.1408[1] | 0.0749[2] |
| | 2.93 | 3.89 | 4.45 | 2.28 | 0.80 | 2.89 | 2.93 | 2.69 | 3.26 | 2.78 |
| | 59.21 | 65.13 | 62.50 | 63.16 | 55.33 | 64.29 | 65.91 | 70.45 | 75.00 | 59.09 |
| $\beta_3$ | 0.5056[1] | 0.5337[1] | 0.5994[1] | 0.4506[1] | 0.2737[1] | 0.3113[1] | 0.3328[1] | 0.2480[1] | 0.1675[1] | 0.0868[2] |
| | 9.45 | 8.59 | 13.06 | 11.13 | 6.95 | 5.04 | 4.08 | 5.77 | 3.28 | 2.57 |
| | 85.53 | 82.89 | 96.05 | 89.47 | 82.67 | 90.48 | 81.82 | 86.36 | 81.82 | 72.73 |
| $\beta_{3lag}$ | -0.0316 | -0.0467 | -0.0219 | -0.0602[2] | 0.0115 | -0.0225 | 0.0012 | 0.0025 | -0.0352 | 0.0402[2] |
| | -1.62 | -1.63 | -1.14 | -2.18 | 0.64 | -0.54 | 0.03 | 0.06 | -0.73 | 2.12 |
| | 44.74 | 40.79 | 47.37 | 31.58 | 49.33 | 57.14 | 63.64 | 59.09 | 45.45 | 54.55 |
| $\beta_3 + \beta_{3lag}$ | 0.4740[1] | 0.4869[1] | 0.5776[1] | 0.3904[1] | 0.2852[1] | 0.2888[1] | 0.3340[1] | 0.2505[1] | 0.1323 | 0.1270[1] |
| | 9.1298 | 7.6438 | 12.2646 | 6.9871 | 6.1710 | 3.7757 | 3.7524 | 4.1121 | 1.6942 | 2.9515 |
| | 65.13 | 61.84 | 71.71 | 60.52 | 66.00 | 73.80 | 72.72 | 72.72 | 63.63 | 63.63 |
| $\beta_4$ | -0.4919[2] | -2.1616[1] | -2.4660[1] | -3.7822[1] | -5.7032[1] | -0.6197 | -1.5857[1] | -2.2718[1] | -3.0353[1] | -4.4263[1] |
| | -2.47 | -9.20 | -15.62 | -17.32 | -24.00 | -1.35 | -2.95 | -10.55 | -11.11 | -10.73 |
| | 31.58 | 14.47 | 1.32 | 0.00 | 0.00 | 14.29 | 4.55 | 0.00 | 4.55 | 4.55 |
| $\beta_5$ | 0.0512[3] | 0.0472 | 0.0076 | 0.0203 | 0.1339[1] | 0.0654 | -0.0215 | -0.0405 | 0.0292 | 0.0831[2] |
| | 1.97 | 1.06 | 0.33 | 0.58 | 4.58 | 1.53 | -0.39 | -1.54 | 0.39 | 2.39 |
| | 57.89 | 53.95 | 44.74 | 57.89 | 74.67 | 57.14 | 59.09 | 40.91 | 54.55 | 81.82 |
| $\beta_6$ | 0.7889[2] | 0.2454 | 0.1660 | -0.8628[3] | -0.5719 | 0.6953 | -0.0137 | 0.0374 | 0.2647 | 0.2956 |
| | 2.27 | 0.39 | 0.42 | -1.87 | -1.33 | 1.48 | -0.02 | 0.09 | 0.29 | 0.63 |
| | 61.84 | 55.26 | 55.26 | 40.79 | 40.00 | 61.90 | 45.45 | 54.55 | 54.55 | 68.18 |
| $\beta_7$ | 4.1380[1] | 3.9829[1] | 3.0250[1] | 1.7470[1] | 0.5071 | 4.8803[1] | 2.9751[2] | 2.1902[1] | 2.0166 | 1.4700[3] |
| | 7.28 | 5.23 | 6.85 | 2.81 | 1.12 | 6.35 | 2.34 | 3.77 | 1.73 | 1.95 |
| | 72.37 | 67.11 | 75.00 | 60.53 | 53.33 | 90.48 | 59.09 | 68.18 | 59.09 | 68.18 |
| $intercept$ | 3.6554[1] | 4.0447[1] | 4.9228[1] | 4.8199[1] | 5.4378[1] | 2.0779[1] | 2.7397[1] | 3.1939[1] | 2.6542[2] | 3.5210[1] |
| | 9.28 | 7.48 | 13.35 | 10.99 | 13.54 | 4.38 | 3.17 | 7.37 | 2.80 | 5.31 |
| | 86.84 | 88.16 | 97.37 | 90.79 | 96.00 | 85.71 | 81.82 | 90.91 | 72.73 | 95.45 |
| $adj\ R^2$ | 2.67 | 6.34 | 7.08 | 9.21 | 19.79 | 3.08 | 5.66 | 5.91 | 7.47 | 17.92 |
| $N$ | 68 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A12
## Liquidity Comovement between Put Options and their Underlying Stock Market (Proportional spread)

This table presents the results of liquidity comovement between put options and their underlying stock market. Option liquidity is measured by the proportional bid-ask spread (option spread as a percentage of option bid-ask midpoint). For each stock in its maturity and moneyness portfolio, all put options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i} DSL_{i,t} + \beta_{2,i} DSL_{m,t} + \beta_{2lag,i} DSL_{m,t-1} + \beta_{3,i} DOSL^{res}_{m,t} + \beta_{3lag,i}\, DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 years respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call options, put options and all options markets. This table reports, for each parameter, three stacked values: average coefficient, t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of $N$ have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0108 | -0.0061 | -0.0003 | -0.0047 | 0.0022 | -0.0035 | -0.0029 | -0.0004 | -0.0014 | 0.0004 |
| | 0.92 | -1.08 | -0.10 | -0.92 | 0.19 | -0.75 | -1.14 | -0.16 | -0.54 | 0.10 |
| | 44.44 | 35.62 | 46.67 | 42.67 | 51.39 | 47.95 | 47.95 | 42.47 | 46.58 | 51.39 |
| $\beta_2$ | 0.0450 | 0.0176 | 0.0494[2] | -0.0019 | 0.0060 | 0.0902[1] | 0.0944[1] | 0.1037[1] | 0.0817[1] | -0.0172 |
| | 0.46 | 0.64 | 2.38 | -0.06 | 0.12 | 3.01 | 3.32 | 4.60 | 3.10 | -0.65 |
| | 51.39 | 61.64 | 62.67 | 54.67 | 50.00 | 63.01 | 64.38 | 69.86 | 65.75 | 44.44 |
| $\beta_{2lag}$ | -0.1212 | -0.0421[3] | -0.0330[3] | -0.0401 | -0.0012 | 0.0244 | 0.0572[2] | 0.0831[1] | 0.0874[1] | 0.0689[1] |
| | -1.37 | -1.98 | -1.89 | -1.41 | -0.04 | 0.72 | 2.40 | 3.06 | 3.37 | 3.19 |
| | 45.83 | 34.25 | 46.67 | 46.67 | 43.06 | 52.05 | 61.64 | 68.49 | 64.38 | 56.94 |
| $\beta_2 + \beta_{2lag}$ | -0.0762 | -0.0245 | 0.0164 | -0.0421 | 0.0048 | 0.1146[2] | 0.1516[1] | 0.1869[1] | 0.1691[1] | 0.0517 |
| | -0.44 | -0.60 | 0.48 | -0.79 | 0.08 | 2.13 | 3.29 | 4.56 | 3.57 | 1.27 |
| | 48.61 | 47.95 | 54.67 | 50.67 | 46.53 | 57.53 | 63.01 | 69.18 | 65.07 | 50.69 |
| $\beta_3$ | 0.7644[2] | 0.4321[1] | 0.6706[1] | 0.4906[1] | 0.4486[1] | 0.3351[1] | 0.5649[1] | 0.6037[1] | 0.5348[1] | 0.2696[1] |
| | 3.38 | 5.44 | 7.86 | 4.63 | 3.75 | 3.91 | 8.71 | 7.81 | 7.45 | 4.24 |
| | 63.89 | 76.71 | 78.67 | 66.67 | 73.61 | 71.23 | 90.41 | 91.78 | 90.41 | 73.61 |
| $\beta_{3lag}$ | -0.0937 | -0.0291 | 0.0759 | 0.1105 | 0.0425 | -0.0486 | -0.0422[3] | 0.0081 | 0.0600[1] | 0.0302 |
| | -0.90 | -0.47 | 1.36 | 1.62 | 0.41 | -1.01 | -1.89 | 0.39 | 2.88 | 1.47 |
| | 34.72 | 47.95 | 57.33 | 46.67 | 51.39 | 34.25 | 43.84 | 60.27 | 61.64 | 54.17 |
| $\beta_3 + \beta_{3lag}$ | -0.0762 | -0.0245 | 0.0164 | -0.0421 | 0.0048 | 0.1146[2] | 0.1516[1] | 0.1869[1] | 0.1691[1] | 0.0517 |
| | -0.44 | -0.60 | 0.48 | -0.79 | 0.08 | 2.13 | 3.29 | 4.56 | 3.57 | 1.27 |
| | 49.31 | 62.33 | 68.00 | 56.67 | 62.50 | 52.74 | 67.12 | 76.03 | 76.03 | 63.89 |
| $\beta_4$ | -0.2194 | 2.3059[1] | 9.1308[1] | 14.4388[1] | 13.0265[1] | 0.5967[2] | 2.4261[1] | 6.1306[1] | 9.8749[1] | 10.8045[1] |
| | -0.30 | 8.42 | 19.35 | 20.55 | 18.50 | 2.27 | 10.18 | 19.12 | 19.80 | 23.35 |
| | 52.78 | 89.04 | 97.33 | 96.00 | 98.61 | 63.01 | 90.41 | 100.00 | 100.00 | 100.00 |
| $\beta_5$ | 0.1509 | 0.0123 | 0.4727[1] | 0.7254[1] | 0.9654[1] | 0.1904[2] | 0.0151 | 0.2406[1] | 0.2928[1] | 0.6585[1] |
| | 1.40 | 0.13 | 5.21 | 5.92 | 3.38 | 2.30 | 0.24 | 3.51 | 4.74 | 5.02 |
| | 48.61 | 49.32 | 72.00 | 72.00 | 70.83 | 49.32 | 31.51 | 63.01 | 72.60 | 81.94 |
| $\beta_6$ | 0.9745 | 1.5710 | 2.1287[1] | 3.8445[1] | 4.2068[1] | -0.3530 | -0.7817 | -0.5423 | -0.7447 | -0.5315 |
| | 0.55 | 1.31 | 3.55 | 3.07 | 2.97 | -0.32 | -1.42 | -1.07 | -1.18 | -0.64 |
| | 50.00 | 61.64 | 58.67 | 61.33 | 72.22 | 53.42 | 43.84 | 50.68 | 45.21 | 54.17 |
| $\beta_7$ | -0.2271 | 1.8943 | 4.9903[1] | 6.7935[1] | 7.2334[1] | 0.1006 | 1.4104 | 1.6123[2] | 2.0940[2] | 1.1534 |
| | -0.06 | 1.34 | 6.34 | 4.86 | 4.01 | 0.07 | 1.55 | 2.27 | 2.63 | 1.04 |
| | 23.61 | 47.95 | 74.67 | 72.00 | 61.11 | 52.05 | 60.27 | 64.38 | 67.12 | 56.94 |
| $intercept$ | 6.5455[1] | 4.1419[1] | 7.8970[1] | 12.7354[1] | 13.6372[1] | 6.1687[1] | 5.6847[1] | 7.3123[1] | 9.3935[1] | 10.2047[1] |
| | 3.93 | 3.62 | 10.23 | 12.16 | 11.35 | 5.54 | 8.92 | 14.86 | 12.58 | 12.06 |
| | 63.89 | 76.71 | 96.00 | 94.67 | 93.06 | 71.23 | 90.41 | 98.63 | 93.15 | 91.67 |
| $adj\ R^2$ | 8.74 | 6.96 | 36.82 | 41.05 | 45.79 | 6.88 | 8.85 | 25.37 | 33.27 | 40.7 |
| $N$ | 15 | 43 | 70 | 68 | 35 | 59 | 70 | 70 | 70 | 70 |

**Table A12 (Continued)**
**Liquidity Comovement between Put Options and their Underlying Stock Market (Proportional spread)**

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0029 | -0.0009 | -0.0051[2] | -0.0058 | -0.0038 | -0.0002 | -0.0018 | 0.0006 | -0.0032[3] | -0.0002 |
| | -1.01 | -0.24 | -2.16 | -1.39 | -1.00 | -0.12 | -0.71 | 0.33 | -1.69 | -0.13 |
| | 42.47 | 43.84 | 47.95 | 39.73 | 31.94 | 46.67 | 45.33 | 50.00 | 40.79 | 48.68 |
| $\beta_2$ | 0.1210[1] | 0.0597[3] | 0.1169[1] | 0.1245[1] | 0.0715[1] | 0.0732[1] | 0.1019[1] | 0.0902[1] | 0.0888[1] | 0.0602[1] |
| | 2.89 | 1.89 | 4.13 | 3.59 | 2.79 | 5.20 | 4.71 | 5.60 | 5.44 | 4.52 |
| | 58.90 | 64.38 | 64.38 | 68.49 | 58.33 | 77.33 | 69.33 | 77.63 | 69.74 | 61.84 |
| $\beta_{2lag}$ | -0.0515 | -0.0704[3] | -0.0099 | 0.0615[2] | 0.0275 | 0.0058 | 0.0526[1] | 0.0216[3] | 0.0062 | 0.0302[1] |
| | -1.25 | -1.89 | -0.40 | 2.29 | 1.00 | 0.41 | 2.83 | 1.97 | 0.46 | 2.67 |
| | 41.10 | 46.58 | 50.68 | 61.64 | 55.56 | 50.67 | 62.67 | 61.84 | 50.00 | 56.58 |
| $\beta_2 + \beta_{2lag}$ | 0.0695 | -0.0106 | 0.1070[2] | 0.1861[1] | 0.0990[2] | 0.0790[1] | 0.1545[1] | 0.1118[1] | 0.0950[1] | 0.0904[1] |
| | 1.00 | -0.18 | 2.43 | 3.82 | 2.16 | 3.33 | 4.67 | 5.61 | 4.21 | 4.25 |
| | 50.00 | 55.48 | 57.53 | 65.07 | 56.94 | 64.00 | 66.00 | 69.74 | 59.87 | 59.21 |
| $\beta_3$ | 0.4235[1] | 0.4862[1] | 0.7062[1] | 0.4739[1] | 0.2150[1] | 0.4993[1] | 0.6378[1] | 0.5988[1] | 0.5232[1] | 0.2564[1] |
| | 3.94 | 7.61 | 6.70 | 6.17 | 7.55 | 9.21 | 10.82 | 7.48 | 8.76 | 7.24 |
| | 69.86 | 80.82 | 83.56 | 83.56 | 80.56 | 89.33 | 88.00 | 88.16 | 85.53 | 89.47 |
| $\beta_{3lag}$ | -0.0161 | -0.0002 | 0.0640[1] | 0.0621[1] | 0.0624 | -0.0127 | -0.0113 | 0.0019 | 0.0167 | 0.0354[2] |
| | -0.53 | -0.01 | 2.82 | 2.74 | 2.71 | -0.77 | -0.63 | 0.13 | 0.92 | 2.52 |
| | 58.90 | 56.16 | 68.49 | 68.49 | 68.06 | 49.33 | 52.00 | 50.00 | 59.21 | 57.89 |
| $\beta_3 + \beta_{3lag}$ | 0.0695 | -0.0106 | 0.1070[2] | 0.1861[1] | 0.0990[2] | 0.0790[1] | 0.1545[1] | 0.1118[1] | 0.0950[1] | 0.0904[1] |
| | 1.00 | -0.18 | 2.43 | 3.82 | 2.16 | 3.33 | 4.67 | 5.61 | 4.21 | 4.25 |
| | 64.38 | 68.49 | 76.03 | 76.03 | 74.31 | 69.33 | 70.00 | 69.08 | 72.37 | 73.68 |
| $\beta_4$ | 0.5640[3] | 1.9816[1] | 4.3715[1] | 7.2785[1] | 9.0883[1] | 0.5961[1] | 1.8086[1] | 3.0468[1] | 4.5516[1] | 5.9735[1] |
| | 1.73 | 7.42 | 16.32 | 18.74 | 21.54 | 3.62 | 10.91 | 17.57 | 19.05 | 22.26 |
| | 64.38 | 84.93 | 97.26 | 100.00 | 100.00 | 64.00 | 90.67 | 97.37 | 98.68 | 100.00 |
| $\beta_5$ | 0.2962[1] | -0.1822[1] | -0.0179 | 0.1599[2] | 0.2602[1] | 0.1012[2] | 0.0301 | 0.1237[1] | 0.1692[1] | 0.2309[1] |
| | 3.00 | -2.74 | -0.34 | 2.05 | 3.62 | 2.65 | 0.93 | 3.97 | 4.06 | 4.93 |
| | 57.53 | 31.51 | 38.36 | 54.79 | 72.22 | 56.00 | 48.00 | 67.11 | 61.84 | 73.68 |
| $\beta_6$ | -0.3712 | -0.0633 | 0.4812 | 1.7840[3] | 1.6811[3] | -0.9209[2] | 1.1588[2] | 0.7570[2] | 0.0892 | 0.8122[3] |
| | -0.41 | -0.09 | 0.95 | 1.83 | 1.68 | -2.05 | 2.53 | 2.28 | 0.20 | 1.96 |
| | 50.68 | 47.95 | 54.79 | 57.53 | 63.89 | 36.00 | 65.33 | 61.84 | 50.00 | 57.89 |
| $\beta_7$ | 2.3368 | 2.0626[2] | 2.4734[1] | 2.9900[1] | 1.7633 | 2.1621[1] | 4.1533[1] | 3.2481[1] | 2.3174[1] | 1.9934[1] |
| | 1.65 | 2.43 | 3.76 | 3.29 | 1.55 | 3.23 | 6.14 | 6.48 | 4.04 | 4.40 |
| | 56.16 | 57.53 | 68.49 | 61.64 | 61.11 | 62.67 | 73.33 | 73.68 | 61.84 | 71.05 |
| $intercept$ | 5.7669[1] | 6.3485[1] | 7.2954[1] | 6.1569[1] | 7.4413[1] | 6.0314[1] | 5.2719[1] | 5.5902[1] | 6.0559[1] | 5.6938[1] |
| | 6.11 | 9.67 | 10.98 | 7.70 | 6.85 | 13.48 | 11.75 | 11.64 | 13.57 | 13.70 |
| | 79.45 | 87.67 | 94.52 | 87.67 | 90.28 | 98.67 | 93.33 | 92.11 | 94.74 | 96.05 |
| $adj\ R^2$ | 4.18 | 5.82 | 20.67 | 24.24 | 35.38 | 3.8 | 5.8 | 10.24 | 13.74 | 23.41 |
| $N$ | 58 | 68 | 70 | 69 | 70 | 70 | 70 | 70 | 70 | 70 |

**Table A12 (Continued)**
**Liquidity Comovement between Put Options and their Underlying Stock Market (Proportional spread)**

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0017 | -0.0037 | -0.0021 | 0.0004 | -0.0006 | -0.0027 | 0.0050 | -0.0004 | 0.0004 | 0.0021 |
| | -0.53 | -1.46 | -1.21 | 0.11 | -0.26 | -1.47 | 1.56 | -0.24 | 0.24 | 0.91 |
| | 41.33 | 42.11 | 44.74 | 50.00 | 40.79 | 45.45 | 68.18 | 54.55 | 40.91 | 47.62 |
| $\beta_2$ | 0.0344[2] | 0.0630[1] | 0.0706[1] | 0.0639[1] | 0.0319[2] | 0.0319 | -0.0015 | 0.0195 | 0.0201 | 0.0166 |
| | 2.28 | 2.92 | 5.32 | 3.12 | 2.22 | 1.58 | -0.06 | 0.86 | 0.81 | 0.82 |
| | 68.00 | 64.47 | 68.42 | 55.26 | 53.95 | 68.18 | 40.91 | 59.09 | 63.64 | 47.62 |
| $\beta_{2lag}$ | -0.0139 | 0.0225 | -0.0011 | 0.0039 | 0.0035 | 0.0760[1] | 0.0934[1] | 0.0131 | 0.0917[1] | 0.0439[2] |
| | -0.63 | 0.77 | -0.07 | 0.17 | 0.24 | 4.67 | 4.25 | 0.56 | 3.24 | 2.66 |
| | 45.33 | 48.68 | 46.05 | 47.37 | 52.63 | 90.91 | 86.36 | 50.00 | 68.18 | 76.19 |
| $\beta_2 + \beta_{2lag}$ | 0.0205 | 0.0854[2] | 0.0696[1] | 0.0677[2] | 0.0355 | 0.1079[1] | 0.0919[2] | 0.0325 | 0.1118[2] | 0.0606[3] |
| | 0.64 | 2.06 | 3.28 | 2.02 | 1.47 | 3.50 | 2.58 | 0.86 | 2.87 | 2.07 |
| | 56.67 | 56.58 | 57.24 | 51.32 | 53.29 | 79.55 | 63.64 | 54.55 | 65.91 | 61.90 |
| $\beta_3$ | 0.5335[1] | 0.6043[1] | 0.5954[1] | 0.5123[1] | 0.4286[1] | 0.1432[2] | 0.0358 | 0.1487[1] | 0.0665 | 0.0162 |
| | 9.13 | 8.53 | 9.21 | 7.28 | 8.16 | 2.37 | 0.74 | 2.93 | 0.94 | 0.41 |
| | 84.00 | 88.16 | 89.47 | 81.58 | 84.21 | 68.18 | 54.55 | 72.73 | 59.09 | 52.38 |
| $\beta_{3lag}$ | -0.0480[3] | -0.0421 | -0.0198 | -0.0339 | 0.0223 | 0.0008 | 0.0379 | 0.0426 | 0.0277 | 0.0384 |
| | -1.78 | -1.59 | -0.80 | -1.15 | 1.05 | 0.02 | 1.01 | 1.57 | 0.93 | 1.38 |
| | 46.67 | 47.37 | 47.37 | 47.37 | 53.95 | 45.45 | 59.09 | 68.18 | 59.09 | 71.43 |
| $\beta_3 + \beta_{3lag}$ | 0.0205 | 0.0854[2] | 0.0696[1] | 0.0677[2] | 0.0355 | 0.1079[1] | 0.0919[2] | 0.0325 | 0.1118[2] | 0.0606[3] |
| | 0.64 | 2.06 | 3.28 | 2.02 | 1.47 | 3.50 | 2.58 | 0.86 | 2.87 | 2.07 |
| | 65.33 | 67.76 | 68.42 | 64.47 | 69.08 | 56.82 | 56.82 | 70.45 | 59.09 | 61.90 |
| $\beta_4$ | 0.3467[2] | 1.3930[1] | 2.1227[1] | 3.2629[1] | 4.2903[1] | 0.4516[3] | 1.1665[1] | 1.7004[1] | 2.1892[1] | 2.7914[1] |
| | 2.26 | 7.23 | 11.74 | 14.25 | 21.29 | 1.93 | 3.85 | 6.34 | 9.33 | 9.32 |
| | 66.67 | 88.16 | 92.11 | 97.37 | 100.00 | 63.64 | 81.82 | 90.91 | 90.91 | 100.00 |
| $\beta_5$ | 0.1247[1] | 0.0590[3] | 0.1151[1] | 0.1154[2] | 0.1057[1] | 0.0116 | -0.0252 | -0.0028 | 0.0629 | 0.0099 |
| | 3.13 | 1.84 | 3.71 | 2.46 | 2.89 | 0.26 | -0.67 | -0.08 | 1.55 | 0.38 |
| | 64.00 | 63.16 | 53.95 | 53.95 | 63.16 | 68.18 | 54.55 | 54.55 | 63.64 | 52.38 |
| $\beta_6$ | -0.0013 | 1.3151[2] | 0.4947 | 0.3755 | 1.0744[1] | -0.4005 | 0.1830 | 0.5750 | -0.1177 | 2.2465[1] |
| | 0.00 | 2.42 | 1.09 | 0.68 | 2.88 | -0.65 | 0.17 | 0.96 | -0.13 | 3.22 |
| | 52.00 | 59.21 | 55.26 | 51.32 | 61.84 | 63.64 | 59.09 | 63.64 | 54.55 | 71.43 |
| $\beta_7$ | 3.9767[1] | 5.0136[1] | 4.0715[1] | 3.1590[1] | 3.1961[1] | 5.0253[1] | 2.6999 | 3.1107[1] | 1.9504[2] | 4.5498[1] |
| | 6.37 | 6.35 | 7.35 | 5.09 | 7.08 | 5.31 | 1.70 | 3.81 | 2.52 | 6.52 |
| | 72.00 | 75.00 | 72.37 | 65.79 | 68.42 | 81.82 | 68.18 | 68.18 | 63.64 | 85.71 |
| $intercept$ | 5.1111[1] | 4.7613[1] | 5.2051[1] | 4.9175[1] | 5.1778[1] | 2.6117[1] | 2.2557[2] | 2.5926[1] | 2.7476[1] | 1.8783[1] |
| | 11.43 | 9.51 | 10.99 | 8.75 | 11.95 | 3.56 | 2.28 | 3.81 | 3.47 | 4.65 |
| | 90.67 | 86.84 | 96.05 | 90.79 | 96.05 | 77.27 | 72.73 | 77.27 | 81.82 | 85.71 |
| $adj\ R^2$ | 3.17 | 4.44 | 6.67 | 8.35 | 13.16 | 1.82 | 1.71 | 3.54 | 4.15 | 5.83 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A13

## Liquidity Comovement between All Options and their Underlying Stock Market (Proportional spread)

This table presents the results of liquidity comovement between all (calls and puts combined) options and their underlying stock market. Option liquidity is measured by the proportional bid-ask spread (option spread as a percentage of option bid-ask midpoint). For each stock in its maturity and moneyness portfolio, all (calls and puts combined) options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 years respectively, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call options, put options and all options markets. This table reports, for each parameter, three stacked values: average coefficient, t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of $N$ have positive coefficients). $adj\ R^2$ is average adjusted R$^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0037 | 0.0001 | 0.0013 | 0.0060 | -0.0051 | 0.0013 | -0.0001 | -0.0004 | 0.0018 | 0.0001 |
| | 0.66 | 0.03 | 0.53 | 1.60 | -0.63 | 0.56 | -0.04 | -0.19 | 0.67 | 0.03 |
| | 60.81 | 49.33 | 56.00 | 57.33 | 41.67 | 47.95 | 49.32 | 46.58 | 47.95 | 54.17 |
| $\beta_2$ | 0.0958 | 0.0904$^{1}$ | 0.1047$^{1}$ | 0.0395 | 0.0776 | 0.0762$^{1}$ | 0.1378$^{1}$ | 0.1285$^{1}$ | 0.0988$^{1}$ | 0.0154 |
| | 1.33 | 5.41 | 5.75 | 1.39 | 1.56 | 3.09 | 6.31 | 5.96 | 4.10 | 0.62 |
| | 58.11 | 68.00 | 73.33 | 56.00 | 59.72 | 61.64 | 79.45 | 78.08 | 71.23 | 48.61 |
| $\beta_{2lag}$ | -0.0600 | -0.0221 | -0.0064 | -0.0495$^{2}$ | -0.0250 | 0.0007 | 0.0640$^{1}$ | 0.0816$^{1}$ | 0.0986$^{1}$ | 0.1053$^{1}$ |
| | -1.36 | -1.23 | -0.43 | -2.51 | -0.96 | 0.03 | 3.47 | 3.21 | 4.14 | 3.86 |
| | 35.14 | 44.00 | 46.67 | 37.33 | 44.44 | 45.21 | 67.12 | 72.60 | 67.12 | 61.11 |
| $\beta_2 + \beta_{2lag}$ | 0.0358 | 0.0682$^{2}$ | 0.0983$^{1}$ | -0.0100 | 0.0527 | 0.0769$^{3}$ | 0.2018$^{1}$ | 0.2100$^{1}$ | 0.1974$^{1}$ | 0.1207$^{2}$ |
| | 0.36 | 2.44 | 3.53 | -0.24 | 0.80 | 1.90 | 5.64 | 5.24 | 4.70 | 2.62 |
| | 46.62 | 56.00 | 60.00 | 46.67 | 52.08 | 53.42 | 73.29 | 75.34 | 69.18 | 54.86 |
| $\beta_3$ | 0.3383 | 0.6621$^{1}$ | 0.8227$^{1}$ | 0.6107$^{1}$ | 0.4278$^{2}$ | 0.7076$^{1}$ | 1.0091$^{1}$ | 0.8597$^{1}$ | 0.6672$^{1}$ | 0.2633$^{1}$ |
| | 1.07 | 6.87 | 9.96 | 5.32 | 2.36 | 7.89 | 10.57 | 8.10 | 6.47 | 3.72 |
| | 67.57 | 77.33 | 88.00 | 66.67 | 62.50 | 83.56 | 95.89 | 93.15 | 94.52 | 65.28 |
| $\beta_{3lag}$ | 0.1449 | -0.0549 | 0.0103 | 0.0076 | -0.0648 | -0.0213 | 0.0053 | 0.0229 | 0.0352$^{3}$ | -0.0020 |
| | 0.54 | -0.66 | 0.20 | 0.11 | -0.66 | -0.73 | 0.27 | 1.28 | 1.79 | -0.11 |
| | 54.05 | 48.00 | 49.33 | 42.67 | 41.67 | 47.95 | 47.95 | 60.27 | 50.68 | 45.83 |
| $\beta_3 + \beta_{3lag}$ | 0.4832 | 0.6073$^{1}$ | 0.8330$^{1}$ | 0.6183$^{1}$ | 0.3630 | 0.6862$^{1}$ | 1.0144$^{1}$ | 0.8825 | 0.7023$^{1}$ | 0.2613$^{1}$ |
| | 1.12 | 4.48 | 8.47 | 3.87 | 1.50 | 7.34 | 10.72 | 7.88 | 6.20 | 3.31 |
| | 60.81 | 62.67 | 68.67 | 54.67 | 52.08 | 65.75 | 71.92 | 76.71 | 72.60 | 55.56 |
| $\beta_4$ | -1.2597$^{1}$ | -1.4651$^{1}$ | -0.2130 | 1.4126$^{1}$ | 3.8452$^{1}$ | -0.6009$^{1}$ | -0.2926$^{2}$ | -0.0216 | 0.1156 | 2.5462$^{1}$ |
| | -3.32 | -6.84 | -1.09 | 3.59 | 5.25 | -3.11 | -2.01 | -0.16 | 0.46 | 6.44 |
| | 31.08 | 24.00 | 41.33 | 57.33 | 76.39 | 32.88 | 35.62 | 45.21 | 47.95 | 76.39 |
| $\beta_5$ | -0.0520 | -0.3488$^{1}$ | 0.2149$^{2}$ | 1.7151$^{1}$ | 1.9281$^{1}$ | 0.1030$^{3}$ | -0.1998$^{1}$ | 0.1414$^{2}$ | 0.8780$^{1}$ | 1.3685$^{1}$ |
| | -0.66 | -5.70 | 2.48 | 7.76 | 6.93 | 1.67 | -6.06 | 2.64 | 7.51 | 9.65 |
| | 25.68 | 16.00 | 58.67 | 92.00 | 98.61 | 56.16 | 13.70 | 47.95 | 93.15 | 97.22 |
| $\beta_6$ | 0.1596 | 0.3474 | 1.2617$^{2}$ | 3.0963$^{2}$ | 4.4505$^{2}$ | -1.0467 | -0.5066 | -0.5824 | -0.5359 | -2.4708$^{22}$ |
| | 0.13 | 0.46 | 2.10 | 2.21 | 2.67 | -1.48 | -1.08 | -1.37 | -0.78 | -2.60 |
| | 50.00 | 54.67 | 56.00 | 58.67 | 56.94 | 46.58 | 45.21 | 49.32 | 52.05 | 41.67 |
| $\beta_7$ | 0.4663 | 1.8826 | 4.1119$^{1}$ | 9.9353$^{1}$ | 7.2101$^{1}$ | 0.1344 | 1.4845$^{3}$ | 1.1597$^{3}$ | 4.1330$^{1}$ | 1.8586 |
| | 0.23 | 1.63 | 6.28 | 6.53 | 3.11 | 0.13 | 1.93 | 1.99 | 4.77 | 1.44 |
| | 47.30 | 54.67 | 74.67 | 72.00 | 50.00 | 45.21 | 57.53 | 63.01 | 75.34 | 56.94 |
| $intercept$ | 6.5742$^{1}$ | 5.5759$^{1}$ | 8.7645$^{1}$ | 14.3478$^{1}$ | 15.6859$^{1}$ | 7.4634$^{1}$ | 7.4606$^{1}$ | 8.5430$^{1}$ | 9.5730$^{1}$ | 13.1872$^{1}$ |
| | 3.64 | 6.52 | 12.23 | 11.60 | 8.61 | 9.79 | 12.52 | 16.81 | 12.80 | 14.34 |
| | 67.57 | 78.67 | 93.33 | 92.00 | 91.67 | 94.52 | 95.89 | 100.00 | 95.89 | 97.22 |
| $adj\ R^2$ | 5.75 | 7.51 | 7.56 | 13.17 | 30.58 | 4.4 | 6.51 | 9.55 | 11.85 | 20.98 |
| $N$ | 34 | 70 | 70 | 70 | 40 | 70 | 70 | 70 | 70 | 70 |

**Table A13 (Continued)**
**Liquidity Comovement between All Options and their Underlying Stock Market (Proportional spread)**

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0027 | -0.0029 | -0.0028 | 0.0018 | -0.0002 | 0.0012 | -0.0007 | 0.0009 | 0.0018 | 0.0006 |
| | -0.90 | -1.14 | -1.49 | 0.52 | -0.04 | 0.87 | -0.36 | 0.60 | 1.02 | 0.38 |
| | 45.21 | 42.47 | 41.10 | 43.24 | 36.11 | 42.11 | 52.63 | 57.89 | 52.63 | 52.63 |
| $\beta_2$ | 0.1551[1] | 0.1073[1] | 0.1454[1] | 0.1409[1] | 0.0525[3] | 0.0969[1] | 0.1357[1] | 0.1253[1] | 0.0994[1] | 0.0420[1] |
| | 4.64 | 3.66 | 4.93 | 5.16 | 1.74 | 7.30 | 7.68 | 8.44 | 6.66 | 3.82 |
| | 75.34 | 67.12 | 73.97 | 71.62 | 68.06 | 82.89 | 85.53 | 82.89 | 77.63 | 67.11 |
| $\beta_{2lag}$ | -0.0318 | -0.0778[2] | -0.0217 | 0.0369 | 0.0062 | 0.0064 | 0.0482[1] | 0.0258[2] | 0.0089 | 0.0273[1] |
| | -1.19 | -2.56 | -0.98 | 1.42 | 0.21 | 0.53 | 3.42 | 2.46 | 0.76 | 3.14 |
| | 43.84 | 36.99 | 45.21 | 62.16 | 59.72 | 55.26 | 65.79 | 61.84 | 60.53 | 60.53 |
| $\beta_2 + \beta_{2lag}$ | 0.1233[2] | 0.0295 | 0.1237[1] | 0.1778[1] | 0.0587 | 0.1033[1] | 0.1839[1] | 0.1512[1] | 0.1083[1] | 0.0694[1] |
| | 2.54 | 0.59 | 2.70 | 3.95 | 1.09 | 4.90 | 7.16 | 7.75 | 4.76 | 4.17 |
| | 59.59 | 52.05 | 59.59 | 66.89 | 63.89 | 69.08 | 75.66 | 72.37 | 69.08 | 63.82 |
| $\beta_3$ | 0.6888[1] | 0.8228[1] | 0.9871[1] | 0.6445[1] | 0.1804[1] | 0.7803[1] | 0.9392[1] | 0.8867[1] | 0.7044[1] | 0.2366[1] |
| | 6.25 | 8.87 | 6.42 | 7.25 | 6.10 | 10.48 | 11.10 | 8.39 | 9.86 | 9.25 |
| | 79.45 | 87.67 | 90.41 | 91.89 | 83.33 | 90.79 | 92.11 | 94.74 | 89.47 | 90.79 |
| $\beta_{3lag}$ | 0.0405 | 0.0203 | 0.0203 | 0.0279 | -0.0111 | 0.0117 | 0.0351[3] | 0.0029 | 0.0210 | -0.0039 |
| | 1.31 | 0.77 | 0.82 | 0.99 | -0.37 | 0.77 | 2.00 | 0.21 | 1.31 | -0.32 |
| | 50.68 | 60.27 | 53.42 | 58.11 | 58.33 | 64.47 | 56.58 | 50.00 | 52.63 | 52.63 |
| $\beta_3 + \beta_{3lag}$ | 0.7293[1] | 0.8432[1] | 1.0074[1] | 0.6724[1] | 0.1692[1] | 0.7920[1] | 0.9743[1] | 0.8896[1] | 0.7253[1] | 0.2326[1] |
| | 6.85 | 9.15 | 6.10 | 6.61 | 4.50 | 10.76 | 11.75 | 8.10 | 10.07 | 8.77 |
| | 65.07 | 73.97 | 71.92 | 75.00 | 70.83 | 77.63 | 74.34 | 72.37 | 71.05 | 71.71 |
| $\beta_4$ | 0.2040 | 0.2305 | 0.0806 | -0.4212[3] | 0.5518[2] | -0.0793 | -0.0522 | -0.0657 | -0.2437[3] | -0.2088 |
| | 0.93 | 1.36 | 0.54 | -1.93 | 2.20 | -0.82 | -0.42 | -0.67 | -1.71 | -1.32 |
| | 41.10 | 50.68 | 45.21 | 47.30 | 55.56 | 35.53 | 47.37 | 50.00 | 40.79 | 43.42 |
| $\beta_5$ | 0.1482[2] | -0.2902[1] | 0.0009 | 0.3771[1] | 0.9417[1] | 0.0529[3] | 0.0226 | 0.0935[2] | 0.1877[1] | 0.5132[1] |
| | 2.07 | -5.51 | 0.02 | 4.80 | 10.89 | 1.84 | 0.75 | 3.02 | 5.68 | 9.18 |
| | 57.53 | 19.18 | 46.58 | 79.73 | 98.61 | 52.63 | 48.68 | 56.58 | 78.95 | 97.37 |
| $\beta_6$ | -0.3175 | -0.8417 | -0.4636 | -0.4240 | -2.7469[1] | -0.6768[3] | 0.0451 | -0.0116 | -0.6790[3] | -1.1074[1] |
| | -0.50 | -1.16 | -0.85 | -0.48 | -2.91 | -1.92 | 0.12 | -0.04 | -1.82 | -2.66 |
| | 52.05 | 45.21 | 50.68 | 43.24 | 43.06 | 35.53 | 47.37 | 48.68 | 39.47 | 34.21 |
| $\beta_7$ | 2.4442[2] | 2.0478[2] | 1.4908[2] | 1.5802[3] | -0.3323 | 1.9105[1] | 4.3010[1] | 2.4670[1] | 1.7818[1] | 0.8804[3] |
| | 2.54 | 2.45 | 2.15 | 1.95 | -0.32 | 3.29 | 5.74 | 5.43 | 3.78 | 1.87 |
| | 57.53 | 60.27 | 63.01 | 59.46 | 50.00 | 61.84 | 72.37 | 69.74 | 61.84 | 57.89 |
| $intercept$ | 6.7196[1] | 7.7375[1] | 8.6288[1] | 9.0982[1] | 11.4772[1] | 6.8309[1] | 6.7692[1] | 6.9679[1] | 7.0016[1] | 7.2280[1] |
| | 8.74 | 10.36 | 10.00 | 12.13 | 12.76 | 14.76 | 13.64 | 13.08 | 16.51 | 16.60 |
| | 87.67 | 91.78 | 97.26 | 94.59 | 97.22 | 96.05 | 94.74 | 96.05 | 94.74 | 96.05 |
| $adj\ R^2$ | 3.67 | 4.25 | 13.44 | 9.59 | 14.73 | 4.08 | 3.58 | 6.27 | 5.04 | 9.95 |
| $N$ | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A13 (Continued)
## Liquidity Comovement between All Options and their Underlying Stock Market (Proportional Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0010 | -0.0002 | -0.0022 | 0.0003 | -0.0002 | 0.0001 | 0.0026 | -0.0001 | 0.0004 | -0.0004 |
| | 0.35 | -0.07 | -1.32 | 0.11 | -0.13 | 0.03 | 0.90 | -0.09 | 0.21 | -0.23 |
| | 50.00 | 48.68 | 48.68 | 46.05 | 44.74 | 40.91 | 68.18 | 54.55 | 50.00 | 50.00 |
| $\beta_2$ | 0.0767[1] | 0.1109[1] | 0.1038[1] | 0.0916[1] | 0.0375[1] | 0.0400[2] | 0.0466[1] | 0.0445[1] | 0.0648[1] | 0.0090 |
| | 4.94 | 5.98 | 8.15 | 4.87 | 3.09 | 2.62 | 2.90 | 3.26 | 3.06 | 0.63 |
| | 71.05 | 76.32 | 80.26 | 73.68 | 57.89 | 77.27 | 77.27 | 72.73 | 77.27 | 40.91 |
| $\beta_{2lag}$ | -0.0093 | 0.0275 | 0.0135 | -0.0036 | -0.0069 | 0.0550[1] | 0.0717[1] | 0.0199 | 0.0791[1] | 0.0283[2] |
| | -0.44 | 1.21 | 1.02 | -0.22 | -0.66 | 4.54 | 4.75 | 1.05 | 3.79 | 2.65 |
| | 53.95 | 55.26 | 51.32 | 47.37 | 50.00 | 86.36 | 77.27 | 50.00 | 72.73 | 63.64 |
| $\beta_2 + \beta_{2lag}$ | 0.0674[2] | 0.1384[1] | 0.1173[1] | 0.0880[1] | 0.0306 | 0.0951[1] | 0.1183[1] | 0.0644[2] | 0.1439[1] | 0.0373 |
| | 2.22 | 4.03 | 5.60 | 2.87 | 1.62 | 4.34 | 4.57 | 2.41 | 3.69 | 1.70 |
| | 62.50 | 65.79 | 65.79 | 60.53 | 53.95 | 81.82 | 77.27 | 61.36 | 75.00 | 52.27 |
| $\beta_3$ | 0.8194[1] | 0.8757[1] | 0.8756[1] | 0.7192[1] | 0.4605[1] | 0.2906[1] | 0.2395[1] | 0.2229[1] | 0.1306 | 0.0279 |
| | 9.68 | 9.19 | 10.70 | 9.12 | 7.17 | 3.96 | 4.11 | 4.78 | 3.13 | 0.83 |
| | 89.47 | 86.84 | 90.79 | 85.53 | 86.84 | 77.27 | 81.82 | 77.27 | 68.18 | 63.64 |
| $\beta_{3lag}$ | -0.0352 | -0.0231 | -0.0287 | -0.0563[2] | 0.0010 | 0.0099 | 0.0348 | 0.0338 | 0.0048 | 0.0419[2] |
| | -1.27 | -0.82 | -1.13 | -2.01 | 0.06 | 0.41 | 1.10 | 1.14 | 0.15 | 2.30 |
| | 44.74 | 51.32 | 40.79 | 40.79 | 39.47 | 59.09 | 63.64 | 72.73 | 63.64 | 54.55 |
| $\beta_3 + \beta_{3lag}$ | 0.7842[1] | 0.8526[1] | 0.8469[1] | 0.6630[1] | 0.4614[1] | 0.3005[1] | 0.2743[1] | 0.2567[1] | 0.1353[2] | 0.0698 |
| | 9.54 | 9.41 | 10.57 | 8.00 | 6.75 | 3.81 | 4.33 | 4.15 | 2.18 | 1.70 |
| | 67.11 | 69.08 | 65.79 | 63.16 | 63.16 | 68.18 | 72.73 | 75.00 | 65.91 | 59.09 |
| $\beta_4$ | -0.0738 | -0.1727 | -0.1097 | -0.1645 | -0.7103[1] | 0.0436 | -0.2361 | -0.3083[1] | -0.8664[1] | -1.4014[1] |
| | -0.59 | -1.20 | -0.91 | -1.07 | -4.90 | 0.28 | -1.32 | -3.10 | -4.75 | -7.19 |
| | 51.32 | 47.37 | 43.42 | 39.47 | 26.32 | 40.91 | 31.82 | 18.18 | 9.09 | 4.55 |
| $\beta_5$ | 0.0556[3] | 0.0096 | 0.0681[2] | 0.1966[1] | 0.3777[1] | 0.0267 | -0.0671[3] | -0.0202 | 0.1361[2] | 0.2397[1] |
| | 1.79 | 0.32 | 2.63 | 5.11 | 9.29 | 0.68 | -1.90 | -0.79 | 2.27 | 4.54 |
| | 51.32 | 42.11 | 56.58 | 77.63 | 93.42 | 50.00 | 36.36 | 40.91 | 68.18 | 95.45 |
| $\beta_6$ | -0.0976 | 0.4799 | 0.2030 | -0.7517[3] | -0.4956 | 0.3268 | 0.3672 | 0.4412 | 0.0964 | 0.8443[3] |
| | -0.23 | 1.01 | 0.49 | -1.74 | -1.39 | 0.77 | 0.48 | 1.03 | 0.15 | 1.98 |
| | 50.00 | 55.26 | 56.58 | 42.11 | 40.79 | 68.18 | 54.55 | 59.09 | 50.00 | 72.73 |
| $\beta_7$ | 3.6479[1] | 4.3091[1] | 3.4903[1] | 2.0788[1] | 1.7646[1] | 5.2816[1] | 3.2024[2] | 2.8226[1] | 2.1844[2] | 3.0804[1] |
| | 6.71 | 6.63 | 7.76 | 3.93 | 4.55 | 7.29 | 2.75 | 4.51 | 2.31 | 4.50 |
| | 76.32 | 75.00 | 76.32 | 59.21 | 65.79 | 86.36 | 68.18 | 68.18 | 63.64 | 77.27 |
| $intercept$ | 6.1036[1] | 6.0769[1] | 6.3215[1] | 6.0624[1] | 6.6149[1] | 2.6509[1] | 2.6767[1] | 2.9644[1] | 2.7266[1] | 3.0134[1] |
| | 12.78 | 11.98 | 12.41 | 11.92 | 15.42 | 4.49 | 3.60 | 5.12 | 3.47 | 6.16 |
| | 96.05 | 89.47 | 97.37 | 96.05 | 97.37 | 86.36 | 77.27 | 81.82 | 86.36 | 100.00 |
| $adj\ R^2$ | 3.67 | 3.04 | 4.41 | 3.88 | 7.08 | 1.52 | 0.55 | 0.42 | 1.38 | 6.06 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A14
## Liquidity Comovement between Call Options and their Underlying Stock Market (Percentage Spread)

This table presents the results of liquidity comovement between call options and their underlying stock market. Option liquidity is measured by the percentage bid-ask spread (option spread as a percentage of stock price). For each stock in its maturity and moneyness portfolio, all call options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i} DSL_{i,t} + \beta_{2,i} DSL_{m,t} + \beta_{2lag,i} DSL_{m,t-1} + \beta_{3,i} DOSL_{m,t}^{res} + \beta_{3lag,i} DOSL_{m,t-1}^{res} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 years respectively, $DOSL_{m,t}^{res}$ and $DOSL_{m,t-1}^{res}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call options, put options and all options markets. This table reports, for each parameter, three stacked values: average coefficient, t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of $N$ have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.012 | 0.002 | 0.002 | 0.007 | -0.004 | 0.004 | 0.002 | -0.002 | 0.001 | -0.004 |
| | 1.66 | 0.60 | 0.66 | 1.64 | -0.64 | 1.21 | 0.85 | -1.07 | 0.51 | -1.41 |
| | 56.16 | 56.00 | 50.67 | 49.32 | 38.03 | 53.42 | 50.68 | 45.21 | 42.47 | 48.61 |
| $\beta_2$ | 0.048 | 0.038$^{3}$ | 0.042$^{2}$ | -0.013 | 0.054 | 0.007 | 0.051$^{2}$ | 0.068$^{1}$ | 0.067$^{1}$ | 0.033 |
| | 0.97 | 1.69 | 2.50 | -0.90 | 1.22 | 0.29 | 2.02 | 3.94 | 2.91 | 1.51 |
| | 42.47 | 50.67 | 60.00 | 47.95 | 61.97 | 57.53 | 65.75 | 63.01 | 60.27 | 54.17 |
| $\beta_{2lag}$ | 0.014 | -0.019 | 0.003 | -0.035$^{3}$ | 0.044 | -0.005 | 0.075$^{1}$ | 0.093$^{1}$ | 0.085$^{1}$ | 0.076$^{1}$ |
| | 0.40 | -0.73 | 0.20 | -1.86 | 1.31 | -0.16 | 2.86 | 4.41 | 3.53 | 3.45 |
| | 47.95 | 40.00 | 46.67 | 46.58 | 54.93 | 46.58 | 58.90 | 68.49 | 63.01 | 61.11 |
| $\beta_2 + \beta_{2lag}$ | 0.062 | 0.019 | 0.045$^{3}$ | -0.048$^{3}$ | 0.098 | 0.001 | 0.126$^{1}$ | 0.161$^{1}$ | 0.152$^{1}$ | 0.109$^{1}$ |
| | 0.87 | 0.51 | 1.74 | -1.82 | 1.60 | 0.03 | 3.01 | 4.85 | 3.76 | 2.90 |
| | 45.21 | 45.33 | 53.33 | 47.26 | 58.45 | 52.05 | 62.33 | 65.75 | 61.64 | 57.64 |
| $\beta_3$ | 0.263$^{2}$ | 0.271$^{1}$ | 0.443$^{1}$ | 0.342$^{1}$ | 0.477$^{2}$ | 0.530$^{1}$ | 0.603$^{1}$ | 0.519$^{1}$ | 0.464$^{1}$ | 0.308$^{1}$ |
| | 2.25 | 2.73 | 6.37 | 4.55 | 2.71 | 6.55 | 7.47 | 11.36 | 7.36 | 5.18 |
| | 56.16 | 66.67 | 80.00 | 71.23 | 71.83 | 80.82 | 86.30 | 90.41 | 82.19 | 76.39 |
| $\beta_{3lag}$ | 0.014 | -0.085 | 0.012 | 0.044 | 0.320$^{3}$ | -0.063 | -0.103$^{2}$ | -0.021 | 0.077$^{3}$ | 0.203$^{1}$ |
| | 0.09 | -0.76 | 0.19 | 0.59 | 1.74 | -1.05 | -2.23 | -0.56 | 1.87 | 4.34 |
| | 49.32 | 48.00 | 44.00 | 50.68 | 57.75 | 45.21 | 34.25 | 54.79 | 54.79 | 70.83 |
| $\beta_3 + \beta_{3lag}$ | 0.277 | 0.186 | 0.454$^{1}$ | 0.386$^{1}$ | 0.797$^{2}$ | 0.467$^{1}$ | 0.500$^{1}$ | 0.498$^{1}$ | 0.541$^{1}$ | 0.511$^{1}$ |
| | 1.18 | 1.03 | 4.04 | 3.05 | 2.80 | 4.50 | 5.23 | 8.23 | 6.49 | 5.81 |
| | 52.74 | 57.33 | 62.00 | 60.96 | 64.79 | 63.01 | 60.27 | 72.60 | 68.49 | 73.61 |
| $\beta_4$ | 3.077$^{1}$ | 3.414$^{1}$ | 2.349$^{1}$ | -0.099 | -0.730 | 3.219$^{1}$ | 3.663$^{1}$ | 1.900$^{1}$ | 0.059 | -1.023$^{1}$ |
| | 7.06 | 13.60 | 8.27 | -0.37 | -1.43 | 10.71 | 14.21 | 9.92 | 0.25 | -4.19 |
| | 73.97 | 88.00 | 88.00 | 50.68 | 40.85 | 90.41 | 95.89 | 90.41 | 46.58 | 23.61 |
| $\beta_5$ | 0.270$^{1}$ | 0.251$^{1}$ | 0.246$^{2}$ | 0.106 | 0.097 | 0.302$^{1}$ | 0.000 | 0.122$^{2}$ | 0.117$^{3}$ | 0.058 |
| | 3.42 | 3.10 | 2.56 | 1.20 | 1.70 | 3.50 | -0.01 | 2.45 | 1.85 | 0.74 |
| | 63.01 | 61.33 | 54.67 | 47.95 | 54.93 | 73.97 | 52.05 | 50.68 | 45.21 | 56.94 |
| $\beta_6$ | -0.194 | 1.616$^{3}$ | 0.921 | 1.502$^{2}$ | -0.585 | -2.272$^{1}$ | -0.452 | -0.556 | -0.358 | -0.961 |
| | -0.13 | 1.91 | 1.55 | 2.26 | -0.31 | -2.77 | -0.69 | -1.51 | -0.69 | -1.34 |
| | 47.95 | 58.67 | 61.33 | 67.12 | 39.44 | 41.10 | 45.21 | 46.58 | 56.16 | 45.83 |
| $\beta_7$ | 4.921$^{3}$ | 5.868$^{1}$ | 2.928$^{1}$ | 1.388 | 0.708 | 0.244 | 2.323$^{2}$ | 1.284$^{2}$ | -0.003 | -0.707 |
| | 2.00 | 5.07 | 4.30 | 1.22 | 0.21 | 0.20 | 2.60 | 2.63 | -0.01 | -0.61 |
| | 50.68 | 61.33 | 69.33 | 47.95 | 36.62 | 53.42 | 60.27 | 61.64 | 52.05 | 44.44 |
| $intercept$ | 5.046$^{1}$ | 1.751$^{2}$ | 1.619$^{2}$ | 1.713$^{2}$ | 4.758$^{1}$ | 5.731$^{1}$ | 3.751$^{1}$ | 3.282$^{1}$ | 2.690$^{1}$ | 4.596$^{1}$ |
| | 3.65 | 2.66 | 2.63 | 2.61 | 3.20 | 7.26 | 8.10 | 8.55 | 5.69 | 6.66 |
| | 67.12 | 62.67 | 69.33 | 56.16 | 69.01 | 87.67 | 83.56 | 89.04 | 73.97 | 79.17 |
| $adj\ R^2$ | 9.04 | 6.4 | 7.33 | 2.15 | 3.81 | 8.7 | 8.29 | 5.71 | 2.91 | 3.96 |
| $N$ | 24 | 62 | 70 | 63 | 20 | 67 | 70 | 70 | 70 | 64 |

**Table A14 (Continued)**
**Liquidity Comovement between Call Options and their Underlying Stock Market (Percentage Spread)**

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| $\beta_1$ | -0.004 | -0.004 | -0.001 | 0.002 | 0.002 | 0.002 | -0.001 | 0.000 | 0.004 | 0.000 |
| | -1.04 | -1.01 | -0.23 | 0.73 | 0.63 | 1.08 | -0.66 | -0.10 | 1.55 | -0.16 |
| | 49.32 | 39.73 | 42.47 | 48.65 | 48.61 | 51.32 | 42.11 | 51.32 | 55.26 | 43.24 |
| $\beta_2$ | 0.089[2] | 0.031 | -0.011 | 0.048[3] | -0.009 | 0.064[1] | 0.099[1] | 0.077[1] | 0.064[1] | 0.028[1] |
| | 2.24 | 0.88 | -0.53 | 1.69 | -0.32 | 5.18 | 5.34 | 6.60 | 3.66 | 3.01 |
| | 60.27 | 57.53 | 50.68 | 59.46 | 56.94 | 71.05 | 77.63 | 71.05 | 71.05 | 67.57 |
| $\beta_{2lag}$ | -0.004 | -0.065 | -0.055[2] | -0.026 | -0.001 | -0.011 | 0.027[3] | 0.016 | 0.017 | 0.000 |
| | -0.10 | -1.23 | -2.34 | -0.88 | -0.04 | -0.77 | 1.78 | 1.33 | 1.17 | 0.04 |
| | 45.21 | 43.84 | 39.73 | 52.70 | 51.39 | 48.68 | 59.21 | 52.63 | 64.47 | 45.95 |
| $\beta_2 + \beta_{2lag}$ | 0.085 | -0.034 | -0.066[3] | 0.023 | -0.010 | 0.053[2] | 0.126[1] | 0.092[1] | 0.081[1] | 0.028[2] |
| | 1.26 | -0.47 | -1.71 | 0.45 | -0.20 | 2.62 | 5.11 | 5.07 | 2.90 | 2.05 |
| | 52.74 | 50.68 | 45.21 | 56.08 | 54.17 | 59.87 | 68.42 | 61.84 | 67.76 | 56.76 |
| $\beta_3$ | 0.376[1] | 0.559[1] | 0.506[1] | 0.486[1] | 0.427[1] | 0.651[1] | 0.686[1] | 0.600[1] | 0.566[1] | 0.492[1] |
| | 4.27 | 5.72 | 6.98 | 6.85 | 6.78 | 8.82 | 7.70 | 10.31 | 9.12 | 12.21 |
| | 68.49 | 76.71 | 75.34 | 81.08 | 76.39 | 90.79 | 84.21 | 88.16 | 86.84 | 91.89 |
| $\beta_{3lag}$ | -0.196[1] | -0.125[2] | -0.140[1] | -0.001 | 0.022 | -0.086[1] | -0.060[3] | -0.048 | 0.093 | 0.106[1] |
| | -3.47 | -2.07 | -4.14 | -0.02 | 0.51 | -2.75 | -1.71 | -1.63 | 1.24 | 2.84 |
| | 36.99 | 35.62 | 30.14 | 45.95 | 51.39 | 40.79 | 42.11 | 44.74 | 47.37 | 58.11 |
| $\beta_3 + \beta_{3lag}$ | 0.180[3] | 0.434[1] | 0.366[1] | 0.484[1] | 0.449[1] | 0.565[1] | 0.626[1] | 0.551[1] | 0.659[1] | 0.598[1] |
| | 1.74 | 3.53 | 4.22 | 5.31 | 5.15 | 7.50 | 6.71 | 9.05 | 5.86 | 9.88 |
| | 52.74 | 56.16 | 52.74 | 63.51 | 63.89 | 65.79 | 63.16 | 66.45 | 67.11 | 75.00 |
| $\beta_4$ | 3.732[1] | 3.340[1] | 1.725 | 0.334 | -0.711[1] | 1.944[1] | 1.457[1] | 1.175[1] | 0.664[1] | -0.457[1] |
| | 11.89 | 9.57 | 8.86 | 1.54 | -3.19 | 12.71 | 7.50 | 7.97 | 4.41 | -3.41 |
| | 93.15 | 91.78 | 89.04 | 55.41 | 37.50 | 92.11 | 80.26 | 77.63 | 67.11 | 36.49 |
| $\beta_5$ | 0.289[1] | 0.079 | 0.084[3] | -0.101 | 0.201[1] | 0.162[1] | 0.113[2] | 0.112[1] | 0.063[3] | 0.103[1] |
| | 2.84 | 0.73 | 1.92 | -1.34 | 2.80 | 4.49 | 2.43 | 2.93 | 1.93 | 3.28 |
| | 58.90 | 54.79 | 52.05 | 41.89 | 62.50 | 75.00 | 56.58 | 61.84 | 53.95 | 59.46 |
| $\beta_6$ | 0.820 | -1.035 | -0.897 | -0.365 | -0.521 | 0.136 | -0.448 | 0.041 | -0.475 | -1.336[1] |
| | 0.64 | -0.84 | -1.37 | -0.52 | -0.83 | 0.34 | -0.75 | 0.14 | -1.25 | -4.44 |
| | 58.90 | 50.68 | 41.10 | 51.35 | 45.83 | 55.26 | 46.05 | 48.68 | 36.84 | 32.43 |
| $\beta_7$ | 4.102[1] | 3.321[2] | 1.057 | 0.260 | -0.839 | 2.687[1] | 4.433[1] | 2.664[1] | 1.878[1] | -0.403[1] |
| | 2.92 | 2.65 | 1.36 | 0.36 | -0.84 | 4.18 | 4.65 | 5.91 | 3.49 | -0.89 |
| | 61.64 | 68.49 | 64.38 | 56.76 | 47.22 | 65.79 | 68.42 | 72.37 | 61.84 | 32.43 |
| *intercept* | 2.839[2] | 3.923[1] | 3.783[1] | 4.113[1] | 3.636[1] | 3.025[1] | 2.802[1] | 2.537[1] | 2.714[1] | 3.911[1] |
| | 2.52 | 3.56 | 5.43 | 6.10 | 6.28 | 7.66 | 4.59 | 8.79 | 8.28 | 12.10 |
| | 72.60 | 71.23 | 82.19 | 81.08 | 80.56 | 84.21 | 75.00 | 88.16 | 86.84 | 94.59 |
| $adj\ R^2$ | 8.92 | 7.63 | 5.78 | 2.28 | 5.71 | 6.23 | 4.19 | 4.11 | 2.8 | 4.11 |
| $N$ | 65 | 68 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A14 (Continued)
## Liquidity Comovement between Call Options and their Underlying Stock Market (Percentage Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.001 | 0.003 | -0.003 | -0.002 | -0.001 | 0.002 | 0.000 | -0.002 | -0.002 | -0.003$^{3}$ |
| | 0.22 | 1.01 | -1.55 | -1.11 | -0.87 | 0.53 | 0.12 | -0.70 | -0.85 | -1.91 |
| | 48.68 | 51.32 | 42.11 | 50.00 | 44.00 | 42.86 | 40.91 | 50.00 | 31.82 | 40.91 |
| $\beta_2$ | 0.067$^{1}$ | 0.102$^{1}$ | 0.071$^{1}$ | 0.062$^{1}$ | 0.030$^{1}$ | 0.037$^{2}$ | 0.057$^{3}$ | 0.038$^{2}$ | 0.051$^{3}$ | 0.022 |
| | 4.00 | 5.25 | 5.04 | 3.44 | 2.95 | 2.18 | 2.08 | 2.82 | 1.79 | 1.70 |
| | 63.16 | 71.05 | 68.42 | 63.16 | 62.67 | 61.90 | 63.64 | 72.73 | 59.09 | 59.09 |
| $\beta_{2lag}$ | 0.003 | 0.013 | 0.008 | -0.001 | -0.011 | 0.035$^{3}$ | 0.062$^{2}$ | 0.024 | 0.080$^{1}$ | 0.041$^{1}$ |
| | 0.15 | 0.62 | 0.70 | -0.06 | -1.04 | 1.90 | 2.35 | 1.30 | 3.79 | 3.53 |
| | 46.05 | 53.95 | 44.74 | 43.42 | 48.00 | 61.90 | 72.73 | 63.64 | 77.27 | 68.18 |
| $\beta_2 + \beta_{2lag}$ | 0.070$^{1}$ | 0.115$^{1}$ | 0.079$^{1}$ | 0.061$^{3}$ | 0.020 | 0.072$^{2}$ | 0.119$^{2}$ | 0.062$^{2}$ | 0.131$^{1}$ | 0.063$^{1}$ |
| | 2.69 | 3.46 | 4.04 | 1.92 | 1.27 | 2.78 | 2.51 | 2.89 | 3.10 | 3.25 |
| | 54.61 | 62.50 | 56.58 | 53.29 | 55.33 | 61.90 | 68.18 | 68.18 | 68.18 | 63.64 |
| $\beta_3$ | 0.749$^{1}$ | 0.841$^{1}$ | 0.813$^{1}$ | 0.661$^{1}$ | 0.472$^{1}$ | 0.250$^{1}$ | 0.169$^{3}$ | 0.094 | 0.171$^{3}$ | 0.062 |
| | 8.56 | 8.67 | 10.15 | 8.82 | 8.29 | 3.76 | 1.97 | 1.11 | 2.07 | 1.02 |
| | 86.84 | 86.84 | 89.47 | 80.26 | 81.33 | 80.95 | 72.73 | 50.00 | 63.64 | 59.09 |
| $\beta_{3lag}$ | -0.002 | 0.123$^{2}$ | 0.060$^{3}$ | 0.096$^{2}$ | 0.102$^{1}$ | 0.038 | 0.088 | 0.034 | 0.091 | 0.031 |
| | -0.07 | 2.57 | 1.98 | 2.15 | 4.04 | 0.53 | 1.31 | 0.48 | 1.48 | 0.59 |
| | 51.32 | 55.26 | 52.63 | 63.16 | 62.67 | 57.14 | 50.00 | 50.00 | 68.18 | 45.45 |
| $\beta_3 + \beta_{3lag}$ | 0.746$^{1}$ | 0.964$^{1}$ | 0.873$^{1}$ | 0.757$^{1}$ | 0.574$^{1}$ | 0.288$^{2}$ | 0.257$^{2}$ | 0.128 | 0.261$^{2}$ | 0.093 |
| | 8.40 | 8.92 | 10.20 | 8.66 | 9.40 | 2.56 | 2.19 | 0.92 | 2.17 | 0.97 |
| | 69.08 | 71.05 | 71.05 | 71.71 | 72.00 | 69.05 | 61.36 | 50.00 | 65.91 | 52.27 |
| $\beta_4$ | 1.749$^{1}$ | 0.754$^{1}$ | 0.904$^{1}$ | 0.362$^{1}$ | -0.479$^{1}$ | 1.221$^{2}$ | 0.735 | 0.410 | 0.275 | -0.342 |
| | 8.91 | 3.58 | 6.56 | 2.53 | -3.97 | 2.23 | 1.29 | 1.59 | 1.07 | -1.61 |
| | 81.58 | 64.47 | 73.68 | 63.16 | 32.00 | 66.67 | 54.55 | 54.55 | 50.00 | 36.36 |
| $\beta_5$ | 0.090$^{1}$ | 0.085$^{2}$ | 0.016 | 0.043 | 0.082$^{1}$ | 0.075 | -0.029 | -0.038 | 0.031 | 0.061 |
| | 3.20 | 2.02 | 0.63 | 1.17 | 2.96 | 1.58 | -0.58 | -1.30 | 0.48 | 1.50 |
| | 65.79 | 57.89 | 46.05 | 53.95 | 65.33 | 52.38 | 50.00 | 45.45 | 63.64 | 59.09 |
| $\beta_6$ | 0.643$^{3}$ | 0.271 | 0.279 | -0.591 | -0.454 | 0.873$^{3}$ | 0.302 | 0.305 | 0.217 | 0.135 |
| | 1.74 | 0.42 | 0.73 | -1.35 | -1.07 | 1.86 | 0.37 | 0.74 | 0.22 | 0.28 |
| | 60.53 | 57.89 | 55.26 | 40.79 | 41.33 | 57.14 | 54.55 | 54.55 | 63.64 | 54.55 |
| $\beta_7$ | 4.033$^{1}$ | 4.048$^{1}$ | 3.223$^{1}$ | 2.016$^{1}$ | 0.518 | 5.077$^{1}$ | 3.438$^{2}$ | 2.596$^{1}$ | 2.008 | 1.447$^{3}$ |
| | 6.91 | 5.30 | 7.54 | 3.19 | 1.19 | 6.40 | 2.49 | 3.70 | 1.68 | 1.81 |
| | 71.05 | 67.11 | 77.63 | 63.16 | 53.33 | 90.48 | 68.18 | 68.18 | 59.09 | 68.18 |
| $intercept$ | 2.546$^{1}$ | 2.656$^{1}$ | 2.933$^{1}$ | 2.972$^{1}$ | 3.224$^{1}$ | 1.161$^{2}$ | 1.477 | 1.937$^{1}$ | 2.078$^{3}$ | 2.485$^{1}$ |
| | 6.96 | 4.85 | 7.99 | 5.98 | 8.34 | 2.75 | 1.63 | 5.70 | 2.09 | 3.89 |
| | 81.58 | 76.32 | 84.21 | 84.21 | 84.00 | 76.19 | 68.18 | 77.27 | 63.64 | 90.91 |
| $adj\ R^2$ | 4.87 | 4.06 | 3.79 | 2.95 | 2.61 | 2.28 | 1.7 | 1.07 | 0.84 | 1.39 |
| $N$ | 68 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A15

## Liquidity Comovement between Put Options and their Underlying Stock Market (Percentage Spread)

This table presents the results of liquidity comovement between put options and their underlying stock market. Option liquidity is measured by the percentage bid-ask spread (option spread as a percentage of stock price). For each stock in its maturity and moneyness portfolio, all put options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL_{m,t}^{res} + \beta_{3lag,i}DOSL_{m,t-1}^{res} + \beta_4\, r_{i,t} + \beta_5\, r^2{}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, $r^2{}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 years respectively, $DOSL_{m,t}^{res}$ and $DOSL_{m,t-1}^{res}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call options, put options and all options markets. This table reports, for each parameter, three stacked values: average coefficient, t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of $N$ have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0138 | -0.0123$^{2}$ | -0.0015 | -0.0075$^{3}$ | 0.0007 | -0.0033 | -0.0004 | 0.0025 | 0.0010 | 0.0036 |
| | 1.07 | -2.52 | -0.58 | -1.95 | 0.08 | -0.70 | -0.16 | 1.04 | 0.38 | 1.33 |
| | 56.94 | 26.03 | 45.33 | 37.33 | 58.33 | 41.10 | 45.21 | 47.95 | 46.58 | 52.78 |
| $\beta_2$ | -0.0482 | 0.0245 | 0.0570$^{1}$ | 0.0423$^{2}$ | -0.0007 | 0.0839$^{2}$ | 0.0630 | 0.0742$^{1}$ | 0.0479$^{2}$ | -0.0216 |
| | -0.54 | 0.71 | 3.70 | 2.20 | -0.02 | 2.26 | 2.44 | 3.84 | 2.25 | -0.90 |
| | 55.56 | 56.16 | 66.67 | 58.67 | 56.94 | 63.01 | 57.53 | 68.49 | 61.64 | 41.67 |
| $\beta_{2lag}$ | -0.1158 | -0.0334 | -0.0028 | 0.0007 | 0.0223 | 0.0634$^{3}$ | 0.1135$^{1}$ | 0.1236$^{1}$ | 0.0979$^{1}$ | 0.0654$^{1}$ |
| | -1.18 | -1.14 | -0.17 | 0.03 | 0.88 | 1.71 | 4.16 | 4.14 | 4.08 | 3.72 |
| | 44.44 | 34.24 | 48.00 | 52.00 | 48.61 | 56.16 | 73.97 | 73.97 | 64.38 | 59.72 |
| $\beta_2 + \beta_{2lag}$ | -0.1640 | -0.0088 | 0.0542$^{3}$ | 0.0429 | 0.0217 | 0.1473$^{2}$ | 0.1766$^{1}$ | 0.1978$^{1}$ | 0.1458$^{1}$ | 0.0438 |
| | -0.93 | -0.18 | 1.98 | 1.31 | 0.55 | 2.34 | 3.78 | 5.01 | 3.71 | 1.26 |
| | 50.00 | 45.20 | 57.33 | 55.33 | 52.77 | 59.58 | 65.75 | 71.23 | 63.01 | 50.69 |
| $\beta_3$ | 0.9900$^{1}$ | 0.6284$^{1}$ | 0.5785$^{1}$ | 0.3702$^{1}$ | 0.1699 | 0.5560$^{1}$ | 0.6523$^{1}$ | 0.7280$^{1}$ | 0.5741$^{1}$ | 0.3652$^{1}$ |
| | 5.24 | 6.00 | 9.46 | 5.28 | 1.46 | 5.69 | 11.75 | 16.45 | 11.94 | 8.86 |
| | 62.50 | 80.82 | 82.66 | 69.33 | 70.83 | 78.08 | 94.52 | 98.63 | 94.52 | 90.27 |
| $\beta_{3lag}$ | 0.0548 | 0.0918 | 0.0234 | -0.0387 | -0.0649 | 0.1174$^{3}$ | 0.1273$^{2}$ | 0.0504 | -0.0269 | 0.0006 |
| | 0.19 | 0.74 | 0.41 | -0.51 | -0.52 | 1.71 | 2.62 | 0.88 | -0.66 | 0.01 |
| | 50.00 | 56.16 | 52.00 | 46.66 | 52.77 | 61.64 | 57.53 | 54.79 | 43.83 | 52.77 |
| $\beta_3 + \beta_{3lag}$ | 1.0448$^{2}$ | 0.7202$^{1}$ | 0.6019$^{1}$ | 0.3316$^{1}$ | 0.1050 | 0.6734$^{1}$ | 0.7796 | 0.7785$^{1}$ | 0.5472$^{1}$ | 0.3658$^{1}$ |
| | 2.67 | 4.08 | 6.68 | 2.83 | 0.53 | 5.11 | 10.53 | 12.11 | 8.47 | 6.30 |
| | 56.25 | 68.49 | 67.33 | 58.00 | 61.80 | 69.86 | 76.02 | 76.71 | 69.17 | 71.52 |
| $\beta_4$ | -5.6295$^{1}$ | -5.6765$^{1}$ | -3.8808$^{1}$ | -2.0746$^{1}$ | -1.3026$^{1}$ | -4.8878 | -4.4220$^{1}$ | -3.1580$^{1}$ | -1.2401$^{1}$ | -0.6874$^{1}$ |
| | -6.54 | -15.75 | -12.60 | -7.28 | -2.87 | -16.21 | -16.46 | -14.89 | -5.70 | -3.70 |
| | 15.27 | 2.73 | 4.00 | 16.00 | 31.94 | 1.36 | 0.00 | 2.73 | 20.54 | 29.16 |
| $\beta_5$ | 0.2952$^{2}$ | 0.1554 | 0.1207 | -0.0232 | 0.2046$^{3}$ | 0.3649$^{1}$ | 0.1232$^{2}$ | 0.1116 | -0.0673$^{3}$ | 0.1744$^{1}$ |
| | 2.16 | 1.28 | 1.19 | -0.37 | 1.88 | 3.88 | 2.07 | 2.38 | -1.86 | 2.65 |
| | 47.22 | 49.31 | 53.33 | 50.66 | 65.27 | 68.49 | 57.53 | 57.53 | 41.09 | 63.88 |
| $\beta_6$ | 1.4281 | 1.8249 | 0.5470 | 1.3890 | 1.0414 | -0.8633 | -0.7255 | -0.6865 | -1.3758$^{1}$ | -1.1024$^{3}$ |
| | 0.63 | 1.27 | 0.92 | 1.44 | 1.14 | -0.66 | -1.21 | -1.41 | -2.71 | -1.98 |
| | 52.77 | 50.68 | 54.66 | 52.00 | 62.50 | 52.05 | 45.20 | 52.05 | 35.61 | 48.61 |
| $\beta_7$ | 2.3783 | 4.1060$^{2}$ | 2.9688$^{1}$ | 1.8705$^{3}$ | 5.0368$^{2}$ | 1.3170 | 2.8987$^{1}$ | 1.5399$^{2}$ | -0.1474 | -1.0147 |
| | 0.53 | 2.58 | 4.23 | 1.85 | 2.63 | 0.77 | 2.94 | 2.51 | -0.24 | -1.05 |
| | 33.33 | 56.16 | 61.33 | 60.00 | 51.38 | 53.42 | 64.38 | 61.64 | 50.68 | 51.38 |
| $intercept$ | 5.7061$^{1}$ | 2.7606$^{2}$ | 2.3129$^{1}$ | 2.3825$^{1}$ | 2.3130$^{1}$ | 5.9556$^{1}$ | 3.5898$^{1}$ | 3.5524$^{1}$ | 3.8390$^{1}$ | 3.7275$^{1}$ |
| | 3.18 | 2.32 | 3.99 | 3.90 | 2.84 | 5.48 | 5.78 | 7.32 | 7.12 | 6.29 |
| | 68.05 | 76.71 | 66.66 | 73.33 | 58.33 | 75.34 | 73.97 | 89.04 | 84.93 | 75.00 |
| $adj\ R^2$ | 28.48 | 18.81 | 16.32 | 5.36 | 5.12 | 21.3 | 13.2 | 13.46 | 6.02 | 5.23 |
| $N$ | 15 | 43 | 70 | 68 | 35 | 59 | 70 | 70 | 70 | 70 |

## Table A15 (Continued)
## Liquidity Comovement between Put Options and their Underlying Stock Market (Percentage Spread)

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0029 | -0.0026 | -0.0039 | -0.0049 | -0.0028 | -0.0002 | -0.0004 | 0.0013 | -0.0018 | 0.0011 |
| | -1.06 | -0.65 | -1.74 | -1.24 | -0.91 | -0.13 | -0.15 | 0.73 | -0.91 | 0.69 |
| | 46.58 | 36.99 | 45.21 | 39.73 | 30.56 | 49.33 | 44.00 | 52.63 | 40.79 | 50.00 |
| $\beta_2$ | 0.0754[3] | 0.0135 | 0.0294 | 0.0591[3] | 0.0360[3] | 0.0514[1] | 0.0732[1] | 0.0609[1] | 0.0758[1] | 0.0586[1] |
| | 1.80 | 0.42 | 1.11 | 1.95 | 1.72 | 3.77 | 3.85 | 4.85 | 4.79 | 5.29 |
| | 52.05 | 56.16 | 54.79 | 65.75 | 59.72 | 60.00 | 68.00 | 75.00 | 72.37 | 67.11 |
| $\beta_{2lag}$ | -0.0347 | -0.0484 | -0.0143 | 0.0429 | 0.0060 | 0.0073 | 0.0627[1] | 0.0198[3] | 0.0078 | 0.0282[1] |
| | -0.92 | -1.37 | -0.66 | 1.63 | 0.28 | 0.47 | 3.31 | 1.72 | 0.56 | 2.67 |
| | 49.32 | 41.10 | 46.58 | 58.90 | 52.78 | 49.33 | 64.00 | 59.21 | 53.95 | 52.63 |
| $\beta_2 + \beta_{2lag}$ | 0.0407 | -0.0349 | 0.0151 | 0.1021[2] | 0.0420 | 0.0587[2] | 0.1359[1] | 0.0807[1] | 0.0836[1] | 0.0868[1] |
| | 0.59 | -0.60 | 0.37 | 2.36 | 1.18 | 2.36 | 4.37 | 4.53 | 3.73 | 4.80 |
| | 50.68 | 48.63 | 50.68 | 62.33 | 56.25 | 54.67 | 66.00 | 67.11 | 63.16 | 59.87 |
| $\beta_3$ | 0.8173[1] | 0.7007[1] | 0.6429[1] | 0.4245[1] | 0.4668[1] | 0.6777[1] | 0.7651[1] | 0.6737[1] | 0.5883[1] | 0.4990[1] |
| | 5.42 | 8.98 | 10.17 | 6.39 | 10.59 | 11.15 | 12.09 | 13.71 | 11.43 | 14.57 |
| | 75.34 | 86.30 | 95.89 | 79.45 | 88.89 | 93.33 | 93.33 | 93.42 | 89.47 | 92.11 |
| $\beta_{3lag}$ | 0.1144 | -0.117[2] | -0.0444 | -0.0588 | -0.073[2] | 0.0126 | -0.0084 | 0.0003 | -0.0098 | 0.0218 |
| | 1.68 | -2.55 | -1.30 | -1.39 | -2.10 | 0.37 | -0.20 | 0.01 | -0.41 | 0.76 |
| | 49.32 | 35.62 | 39.73 | 43.84 | 37.50 | 48.00 | 46.67 | 46.05 | 38.16 | 44.74 |
| $\beta_3 + \beta_{3lag}$ | 0.9317[1] | 0.5837[1] | 0.5985[1] | 0.3657[1] | 0.3936[1] | 0.6902[1] | 0.7567[1] | 0.6740[1] | 0.5785[1] | 0.5207[1] |
| | 5.38 | 6.21 | 7.43 | 4.09 | 6.37 | 10.51 | 11.08 | 13.73 | 10.65 | 11.01 |
| | 62.33 | 60.96 | 67.81 | 61.64 | 63.19 | 70.67 | 70.00 | 69.74 | 63.82 | 68.42 |
| $\beta_4$ | -4.1776[1] | -4.0836[1] | -2.6601[1] | -1.5253[1] | -0.7613[1] | -3.1034[1] | -2.612[1] | -2.1700[1] | -1.4916[1] | -0.9813[1] |
| | -13.84 | -16.31 | -15.96 | -6.10 | -3.74 | -19.34 | -14.55 | -13.65 | -9.26 | -7.92 |
| | 5.48 | 4.11 | 6.85 | 17.81 | 26.39 | 1.33 | 1.33 | 1.32 | 6.58 | 13.16 |
| $\beta_5$ | 0.4391[1] | -0.0624 | 0.0232 | 0.0437 | 0.0820 | 0.1917[1] | 0.0835[2] | 0.1288[1] | 0.1095[1] | 0.1082[1] |
| | 3.47 | -1.12 | 0.62 | 0.72 | 1.58 | 4.01 | 2.42 | 3.85 | 3.29 | 3.76 |
| | 82.19 | 54.79 | 61.64 | 47.95 | 65.28 | 69.33 | 64.00 | 67.11 | 64.47 | 71.05 |
| $\beta_6$ | -1.3222 | -1.1871 | -1.3742[2] | -1.0306 | -0.4170 | -1.0613[2] | 0.8924[2] | 0.1889 | -0.7007 | -0.4415 |
| | -1.22 | -1.65 | -2.59 | -1.52 | -0.59 | -2.33 | 2.09 | 0.61 | -1.54 | -1.23 |
| | 43.84 | 38.36 | 45.21 | 47.95 | 52.78 | 33.33 | 61.33 | 46.05 | 44.74 | 39.47 |
| $\beta_7$ | 2.4133 | 1.5648[3] | 1.1357[3] | 0.6033 | 0.0386 | 2.3099[1] | 4.2530[1] | 2.8314[1] | 1.1992[2] | 0.4948 |
| | 1.57 | 1.84 | 1.69 | 0.83 | 0.05 | 3.46 | 6.17 | 6.18 | 2.08 | 1.28 |
| | 56.16 | 53.42 | 64.38 | 53.42 | 48.61 | 65.33 | 72.00 | 65.79 | 57.89 | 52.63 |
| $intercept$ | 5.1984[1] | 5.2720[1] | 4.2119[1] | 3.4952[1] | 3.9299[1] | 4.3749[1] | 2.8267[1] | 2.9904[1] | 3.4459[1] | 3.3928[1] |
| | 5.57 | 8.58 | 8.44 | 5.43 | 5.64 | 10.67 | 7.62 | 10.44 | 9.03 | 11.25 |
| | 75.34 | 86.30 | 93.15 | 76.71 | 84.72 | 90.67 | 85.33 | 89.47 | 86.84 | 89.47 |
| $adj\ R^2$ | 16.72 | 10.49 | 11.11 | 5.85 | 7.29 | 10.96 | 7.56 | 6.93 | 4.75 | 5.88 |
| $N$ | 58 | 68 | 70 | 69 | 70 | 70 | 70 | 70 | 70 | 70 |

## Table A15 (Continued)
## Liquidity Comovement between Put Options and their Underlying Stock Market (Percentage Spread)

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0007 | -0.0031 | -0.0010 | 0.0007 | 0.0000 | -0.0026 | 0.0051[3] | -0.0005 | 0.0011 | 0.0018 |
| | -0.20 | -1.17 | -0.58 | 0.19 | -0.02 | -1.53 | 1.76 | -0.29 | 0.62 | 0.79 |
| | 42.67 | 44.74 | 51.32 | 50.00 | 43.42 | 40.91 | 68.18 | 54.55 | 40.91 | 61.90 |
| $\beta_2$ | 0.0106 | 0.0372[3] | 0.0534[1] | 0.0550[1] | 0.0193 | 0.0388[2] | 0.0127 | 0.0234 | 0.0304 | 0.0315 |
| | 0.66 | 1.79 | 4.44 | 3.16 | 1.62 | 2.11 | 0.52 | 1.17 | 1.45 | 1.39 |
| | 57.33 | 63.16 | 67.11 | 59.21 | 53.95 | 72.73 | 50.00 | 54.55 | 63.64 | 66.67 |
| $\beta_{2lag}$ | -0.0175 | 0.0245 | 0.0068 | 0.0149 | -0.0025 | 0.0837[1] | 0.0975[1] | 0.0087 | 0.0969[1] | 0.0358[2] |
| | -0.76 | 0.86 | 0.46 | 0.71 | -0.16 | 4.96 | 4.58 | 0.32 | 3.48 | 2.10 |
| | 48.00 | 51.32 | 51.32 | 52.63 | 52.63 | 90.91 | 77.27 | 50.00 | 72.73 | 66.67 |
| $\beta_2 + \beta_{2lag}$ | -0.0069 | 0.0617 | 0.0602[1] | 0.0700[2] | 0.0167 | 0.1225[1] | 0.1102[1] | 0.0321 | 0.1273[1] | 0.0673[2] |
| | -0.20 | 1.46 | 3.21 | 2.51 | 0.74 | 4.26 | 3.11 | 0.81 | 3.39 | 2.15 |
| | 52.67 | 57.24 | 59.21 | 55.92 | 53.29 | 81.82 | 63.64 | 52.27 | 68.18 | 66.67 |
| $\beta_3$ | 0.9209[1] | 0.8977[1] | 0.8451[1] | 0.7994[1] | 0.5749[1] | 0.3921[1] | 0.2857[1] | 0.3334[1] | 0.2511[1] | 0.1019 |
| | 10.26 | 9.73 | 10.90 | 8.76 | 9.98 | 5.25 | 4.25 | 6.78 | 5.07 | 1.07 |
| | 90.67 | 88.16 | 89.47 | 84.21 | 92.11 | 90.91 | 86.36 | 86.36 | 81.82 | 71.43 |
| $\beta_{3lag}$ | 0.1333[1] | 0.1308[1] | 0.1358[1] | 0.1591[1] | 0.0467 | 0.0435 | 0.0523 | 0.0461 | 0.0048 | 0.0101 |
| | 3.70 | 3.13 | 4.34 | 3.34 | 1.44 | 1.37 | 1.09 | 1.73 | 0.08 | 0.24 |
| | 62.67 | 60.53 | 65.79 | 57.89 | 56.58 | 72.73 | 54.55 | 63.64 | 50.00 | 57.14 |
| $\beta_3 + \beta_{3lag}$ | 1.0542[1] | 1.0285[1] | 0.9809[1] | 0.9585[1] | 0.6216[1] | 0.4357[1] | 0.3379[1] | 0.3795[1] | 0.2558[1] | 0.1120 |
| | 10.76 | 9.46 | 10.89 | 8.38 | 9.18 | 4.77 | 3.49 | 5.80 | 3.47 | 0.91 |
| | 76.67 | 74.34 | 77.63 | 71.05 | 74.34 | 81.82 | 70.45 | 75.00 | 65.91 | 64.29 |
| $\beta_4$ | -2.7013[1] | -2.0918[1] | -1.8403[1] | -1.1195[1] | -0.8917[1] | -2.5482[1] | -2.3388[1] | -1.9738[1] | -1.865[1] | -1.6973[1] |
| | -13.96 | -8.80 | -9.28 | -5.15 | -6.23 | -10.50 | -7.18 | -7.33 | -7.96 | -7.23 |
| | 5.33 | 10.53 | 14.47 | 17.11 | 23.68 | 0.00 | 0.00 | 0.00 | 4.55 | 0.00 |
| $\beta_5$ | 0.1818[1] | 0.1256[1] | 0.1128[1] | 0.0937[2] | 0.0758[1] | 0.0473 | 0.0040 | 0.0258 | 0.0648[3] | 0.0324 |
| | 4.00 | 3.10 | 3.65 | 2.62 | 2.82 | 1.04 | 0.10 | 0.77 | 1.78 | 1.39 |
| | 74.67 | 65.79 | 65.79 | 64.47 | 56.58 | 72.73 | 59.09 | 63.64 | 63.64 | 66.67 |
| $\beta_6$ | 0.1390 | 1.6606[1] | 0.3508 | 0.3882 | 0.6063 | -0.2904 | -0.0775 | 0.7414 | -0.6405 | 1.3448[3] |
| | 0.25 | 2.93 | 0.81 | 0.72 | 1.54 | -0.45 | -0.07 | 1.39 | -0.69 | 2.08 |
| | 58.67 | 57.89 | 51.32 | 56.58 | 56.58 | 68.18 | 59.09 | 68.18 | 45.45 | 61.90 |
| $\beta_7$ | 4.1308[1] | 5.2051[1] | 3.9336[1] | 2.9317[1] | 2.2388[1] | 5.267[1]5 | 2.4188 | 3.3350[1] | 1.3326 | 3.7235[1] |
| | 6.30 | 6.18 | 7.14 | 4.57 | 5.12 | 4.95 | 1.47 | 3.93 | 1.60 | 5.14 |
| | 74.67 | 72.37 | 75.00 | 69.74 | 61.84 | 81.82 | 63.64 | 68.18 | 54.55 | 85.71 |
| $intercept$ | 3.4940[1] | 2.4325[1] | 2.9682[1] | 2.7641[1] | 2.8012[1] | 1.9851[1] | 1.9632[3] | 1.3970[1] | 2.3519[1] | 1.5031[1] |
| | 6.94 | 5.28 | 7.28 | 6.91 | 8.04 | 3.47 | 1.89 | 2.96 | 3.01 | 4.24 |
| | 82.67 | 71.05 | 84.21 | 82.89 | 82.89 | 90.91 | 63.64 | 77.27 | 68.18 | 90.48 |
| $adj\ R^2$ | 9.24 | 6.79 | 5.98 | 5.08 | 4.47 | 8.57 | 4.39 | 4.05 | 2.41 | 2.16 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

**Table A16**
**Liquidity Comovement between All Options and their Underlying Stock Market (Percentage Spread)**

This table presents the results of liquidity comovement between all (calls and puts combined) options and their underlying stock market. Option liquidity is measured by the percentage bid-ask spread (option spread as a percentage of stock price). For each stock in its maturity and moneyness portfolio, all (calls and puts combined) options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL_{m,t}^{res} + \beta_{3lag,i}DOSL_{m,t-1}^{res} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \beta_7 D_{2,t} + \varepsilon_{i,t}$ . $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ and $D_{2,t}$ are dummy variables for 2009 and 2010 years respectively, $DOSL_{m,t}^{res}$ and $DOSL_{m,t-1}^{res}$are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of options across all stocks. Residual of stock market is separately calculated for call option, put options and all options markets. This table reports, for each parameter, three stacked values: average coefficient, t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of $N$ have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Moreover, significance of coefficient is indicated by superscripts 1, 2, and 3 at 1%, 5% and 10% significance levels respectively.

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0000 | -0.0009 | -0.0007 | 0.0013 | -0.0029 | 0.0014 | 0.0005 | 0.0007 | 0.0019 | 0.0028 |
| | 0.00 | -0.27 | -0.27 | 0.54 | -0.53 | 0.51 | 0.25 | 0.37 | 0.85 | 1.09 |
| | 58.11 | 46.67 | 45.33 | 48.00 | 50.00 | 49.32 | 52.05 | 49.32 | 50.68 | 47.22 |
| $\beta_2$ | 0.1135 | 0.0386$^{2}$ | 0.0526$^{1}$ | 0.0243$^{3}$ | 0.0399 | 0.0202 | 0.0624$^{1}$ | 0.0776$^{1}$ | 0.0648$^{1}$ | -0.0042 |
| | 1.52 | 2.18 | 3.54 | 1.92 | 1.45 | 0.85 | 3.40 | 4.80 | 3.30 | -0.25 |
| | 54.05 | 58.67 | 66.67 | 62.67 | 62.50 | 60.27 | 61.64 | 73.97 | 69.86 | 45.83 |
| $\beta_{2lag}$ | -0.0443 | -0.0357$^{3}$ | -0.0029 | -0.0070 | 0.0275 | 0.0190 | 0.0883$^{1}$ | 0.0906$^{1}$ | 0.0896$^{1}$ | 0.0621$^{1}$ |
| | -1.18 | -1.94 | -0.20 | -0.49 | 1.18 | 0.67 | 4.05 | 3.21 | 4.44 | 3.63 |
| | 39.19 | 37.33 | 48.00 | 46.67 | 56.94 | 52.05 | 69.86 | 71.23 | 64.38 | 52.78 |
| $\beta_2 + \beta_{2lag}$ | 0.0692 | 0.0029 | 0.0496$^{3}$ | 0.0173 | 0.0674 | 0.0392 | 0.1507$^{1}$ | 0.1682$^{1}$ | 0.1544$^{1}$ | 0.0579$^{2}$ |
| | 0.68 | 0.10 | 1.95 | 0.78 | 1.68 | 0.89 | 4.28 | 4.59 | 4.61 | 2.14 |
| | 46.62 | 48.00 | 57.33 | 54.67 | 59.72 | 56.16 | 65.75 | 72.60 | 67.12 | 49.31 |
| $\beta_3 + \beta_{3lag}$ | 0.9047$^{2}$ | 0.4798$^{1}$ | 0.5543$^{1}$ | 0.3125$^{1}$ | 0.5076$^{1}$ | 0.5845$^{1}$ | 0.6594$^{1}$ | 0.6606$^{1}$ | 0.5554$^{1}$ | 0.4472$^{1}$ |
| | 2.58 | 3.06 | 4.86 | 3.20 | 2.94 | 5.89 | 9.61 | 11.06 | 8.03 | 7.55 |
| | 56.08 | 59.33 | 62.00 | 56.00 | 68.06 | 66.44 | 68.49 | 73.29 | 71.92 | 75.69 |
| $\beta_4$ | -0.4289 | -0.2544 | -0.6498$^{2}$ | -1.0170$^{1}$ | -0.8971$^{1}$ | -0.0569 | -0.0878 | -0.6941$^{1}$ | -0.6946$^{1}$ | -0.6961$^{1}$ |
| | -1.05 | -1.05 | -2.29 | -6.91 | -3.81 | -0.22 | -0.51 | -4.99 | -3.96 | -4.39 |
| | 41.89 | 45.33 | 28.00 | 13.33 | 33.33 | 42.47 | 45.21 | 20.55 | 23.29 | 20.83 |
| $\beta_5$ | 0.6187$^{1}$ | 0.5783$^{1}$ | 0.2764$^{2}$ | 0.0189 | 0.1367$^{2}$ | 0.6631$^{1}$ | 0.3513$^{1}$ | 0.1212$^{1}$ | -0.0014 | 0.1103$^{1}$ |
| | 4.68 | 5.83 | 2.46 | 0.29 | 2.33 | 7.71 | 6.72 | 2.66 | -0.04 | 2.82 |
| | 82.43 | 88.00 | 61.33 | 40.00 | 62.50 | 97.26 | 91.78 | 56.16 | 36.99 | 62.50 |
| $\beta_3$ | 0.6803$^{1}$ | 0.4681$^{1}$ | 0.5367$^{1}$ | 0.3255$^{1}$ | 0.3219$^{1}$ | 0.5815$^{1}$ | 0.6749$^{1}$ | 0.6376$^{1}$ | 0.5283$^{1}$ | 0.3468$^{1}$ |
| | 4.34 | 5.12 | 7.71 | 5.33 | 2.81 | 6.80 | 12.03 | 14.92 | 9.75 | 8.86 |
| | 66.22 | 68.00 | 81.33 | 64.00 | 77.78 | 82.19 | 95.89 | 98.63 | 91.78 | 88.89 |
| $\beta_{3lag}$ | 0.2244 | 0.0117 | 0.0176 | -0.0130 | 0.1857$^{3}$ | 0.0031 | -0.0155 | 0.0230 | 0.0272 | 0.1004$^{1}$ |
| | 0.91 | 0.12 | 0.26 | -0.22 | 1.95 | 0.07 | -0.35 | 0.55 | 0.76 | 3.35 |
| | 45.95 | 50.67 | 42.67 | 48.00 | 58.33 | 50.68 | 41.10 | 47.95 | 52.05 | 62.50 |
| $\beta_6$ | -0.1702 | 0.2933 | 0.7267 | 0.9951$^{3}$ | 1.7367 | -2.4758$^{1}$ | -1.0517$^{3}$ | -0.8982$^{3}$ | -0.7929$^{3}$ | -0.7908 |
| | -0.11 | 0.37 | 1.31 | 1.69 | 1.18 | -2.86 | -1.94 | -1.81 | -1.87 | -1.64 |
| | 44.59 | 52.00 | 58.67 | 56.00 | 54.17 | 36.99 | 45.21 | 47.95 | 39.73 | 40.28 |
| $\beta_7$ | 1.8626 | 3.8882$^{1}$ | 3.1773$^{1}$ | 0.8296 | 3.5057$^{2}$ | -0.0584 | 3.2795$^{1}$ | 1.1631$^{3}$ | -0.1786 | -0.0192 |
| | 0.69 | 2.97 | 4.84 | 0.90 | 2.27 | -0.05 | 3.74 | 1.88 | -0.34 | -0.03 |
| | 45.95 | 57.33 | 70.67 | 53.33 | 48.61 | 50.68 | 60.27 | 65.75 | 47.95 | 51.39 |
| $intercept$ | 6.8545$^{1}$ | 3.8024$^{1}$ | 1.8029$^{1}$ | 1.8544$^{1}$ | 2.8390$^{1}$ | 6.8398$^{1}$ | 4.3165$^{1}$ | 3.6492$^{1}$ | 3.2369$^{1}$ | 3.7601$^{1}$ |
| | 4.86 | 5.56 | 3.00 | 3.83 | 3.86 | 9.08 | 9.46 | 7.48 | 7.78 | 7.69 |
| | 77.03 | 74.67 | 66.67 | 65.33 | 66.67 | 91.78 | 86.30 | 90.41 | 82.19 | 83.33 |
| $adj\ R^2$ | 10.47 | 6.49 | 6.64 | 1.78 | 5.11 | 10.27 | 5.21 | 5.71 | 4.52 | 4.27 |
| $N$ | 34 | 70 | 70 | 70 | 40 | 70 | 70 | 70 | 70 | 70 |

## Table A16 (Continued)
## Liquidity Comovement between All Options and their Underlying Stock Market (Percentage Spread)

| Maturity | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | -0.0045 | -0.0044 | -0.0022 | -0.0002 | -0.0010 | 0.0012 | -0.0006 | 0.0010 | 0.0017 | 0.0011 |
| | -1.47 | -1.53 | -1.18 | -0.10 | -0.35 | 0.84 | -0.30 | 0.71 | 1.01 | 0.86 |
| | 43.84 | 43.84 | 42.47 | 40.54 | 38.89 | 47.37 | 53.95 | 53.95 | 51.32 | 48.68 |
| $\beta_2$ | 0.1025$^{1}$ | 0.0106 | 0.0093 | 0.0472$^{3}$ | 0.0159 | 0.0548$^{1}$ | 0.0873$^{1}$ | 0.0744$^{1}$ | 0.0683$^{1}$ | 0.0413$^{1}$ |
| | 3.24 | 0.35 | 0.38 | 1.67 | 0.70 | 4.51 | 5.87 | 7.12 | 5.42 | 4.53 |
| | 60.27 | 52.05 | 54.79 | 59.46 | 61.11 | 69.74 | 75.00 | 77.63 | 75.00 | 68.42 |
| $\beta_{2lag}$ | -0.018 | -0.067$^{2}$ | -0.0361 | 0.0114 | -0.0038 | -0.0056 | 0.033$^{2}$ | 0.0128 | 0.0046 | 0.0159$^{3}$ |
| | -0.58 | -2.25 | -1.65 | 0.53 | -0.19 | -0.43 | 2.40 | 1.21 | 0.38 | 1.99 |
| | 45.21 | 39.73 | 45.21 | 56.76 | 54.17 | 46.05 | 57.89 | 53.95 | 55.26 | 52.63 |
| $\beta_2 + \beta_{2lag}$ | 0.0844 | -0.0593 | -0.0268 | 0.0586 | 0.0121 | 0.0492$^{2}$ | 0.1203$^{1}$ | 0.0873$^{1}$ | 0.0729$^{1}$ | 0.0572$^{1}$ |
| | 1.55 | -1.13 | -0.65 | 1.34 | 0.32 | 2.40 | 5.49 | 5.47 | 3.42 | 4.10 |
| | 52.74 | 45.89 | 50.00 | 58.11 | 57.64 | 57.89 | 66.45 | 65.79 | 65.13 | 60.53 |
| $\beta_3$ | 0.5534$^{1}$ | 0.6606$^{1}$ | 0.6440$^{1}$ | 0.5122$^{1}$ | 0.4665$^{1}$ | 0.6962$^{1}$ | 0.7686$^{1}$ | 0.6854$^{1}$ | 0.5926$^{1}$ | 0.5028$^{1}$ |
| | 5.38 | 8.47 | 9.96 | 8.47 | 10.00 | 10.20 | 10.52 | 12.61 | 10.46 | 14.50 |
| | 72.60 | 90.41 | 94.52 | 85.14 | 88.89 | 93.42 | 89.47 | 96.05 | 88.16 | 94.74 |
| $\beta_{3lag}$ | -0.133$^{1}$ | -0.175$^{1}$ | -0.085$^{1}$ | -0.0256 | -0.0014 | -0.060 | -0.0518 | -0.0269 | 0.0233 | 0.0781$^{2}$ |
| | -2.76 | -4.70 | -2.78 | -0.72 | -0.04 | -2.28 | -1.59 | -0.95 | 0.64 | 2.45 |
| | 32.88 | 26.03 | 30.14 | 41.89 | 48.61 | 35.53 | 40.79 | 44.74 | 46.05 | 52.63 |
| $\beta_3 + \beta_{3lag}$ | 0.4203$^{1}$ | 0.4855$^{1}$ | 0.5586$^{1}$ | 0.4866$^{1}$ | 0.4651$^{1}$ | 0.6363$^{1}$ | 0.7169$^{1}$ | 0.6585$^{1}$ | 0.6159$^{1}$ | 0.5808$^{1}$ |
| | 3.74 | 5.57 | 7.16 | 6.21 | 6.78 | 9.36 | 9.62 | 12.30 | 9.01 | 11.85 |
| | 52.74 | 58.22 | 62.33 | 63.51 | 68.75 | 64.47 | 65.13 | 70.39 | 67.11 | 73.68 |
| $\beta_4$ | 0.0556 | -0.398$^{3}$ | -0.466$^{1}$ | -0.473$^{1}$ | -0.6374$^{1}$ | -0.425$^{1}$ | -0.5755$^{1}$ | -0.5121$^{1}$ | -0.3516$^{1}$ | -0.7619$^{1}$ |
| | 0.21 | -1.97 | -2.88 | -2.54 | -4.67 | -3.50 | -4.34 | -4.62 | -2.70 | -8.24 |
| | 49.32 | 28.77 | 21.92 | 29.73 | 20.83 | 26.32 | 21.05 | 26.32 | 28.95 | 14.47 |
| $\beta_5$ | 0.6674$^{1}$ | 0.2209$^{1}$ | 0.0651$^{3}$ | -0.0974$^{1}$ | 0.1240$^{1}$ | 0.3157$^{1}$ | 0.1577$^{1}$ | 0.1273$^{1}$ | 0.0633$^{1}$ | 0.1007$^{1}$ |
| | 7.46 | 3.30 | 1.77 | -2.02 | 2.97 | 7.11 | 4.36 | 3.88 | 2.40 | 3.65 |
| | 94.52 | 80.82 | 53.42 | 39.19 | 68.06 | 89.47 | 68.42 | 65.79 | 61.84 | 63.16 |
| $\beta_6$ | -1.7586$^{2}$ | -1.6978$^{3}$ | -1.5266$^{2}$ | -0.986~ | -1.021~ | -1.258$^{1}$ | -0.0285 | -0.0786 | -0.6525$^{2}$ | -1.1384$^{1}$ |
| | -2.22 | -1.94 | -2.44 | -1.68 | -1.94 | -2.88 | -0.07 | -0.28 | -2.07 | -4.16 |
| | 41.10 | 41.10 | 36.99 | 48.65 | 51.39 | 35.53 | 44.74 | 46.05 | 36.84 | 34.21 |
| $\beta_7$ | 2.4739$^{2}$ | 2.5622$^{2}$ | 1.2182 | 0.1114 | -0.4026 | 1.9488$^{1}$ | 4.7559$^{1}$ | 2.6705$^{1}$ | 1.5947$^{1}$ | 0.0023 |
| | 2.15 | 2.62 | 1.59 | 0.19 | -0.64 | 2.96 | 5.86 | 5.83 | 3.48 | 0.01 |
| | 54.79 | 67.12 | 64.38 | 47.30 | 52.78 | 53.95 | 75.00 | 71.05 | 60.53 | 43.42 |
| $intercept$ | 5.6334$^{1}$ | 5.4913$^{1}$ | 4.3136$^{1}$ | 4.1683$^{1}$ | 4.5962$^{1}$ | 4.5946$^{1}$ | 2.8730$^{1}$ | 2.9961$^{1}$ | 3.1393$^{1}$ | 3.7880$^{1}$ |
| | 7.49 | 6.90 | 6.73 | 7.39 | 8.55 | 10.65 | 7.79 | 10.86 | 11.86 | 12.94 |
| | 87.67 | 84.93 | 90.41 | 86.49 | 91.67 | 93.42 | 84.21 | 90.79 | 92.11 | 92.11 |
| $adj\ R^2$ | 9.07 | 5.96 | 7.59 | 4.9 | 7.25 | 7.87 | 4.46 | 5.3 | 3.58 | 6.27 |
| $N$ | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

**Table A16 (Continued)**
**Liquidity Comovement between All Options and their Underlying Stock Market (Percentage Spread)**

| Maturity | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0016 | -0.0005 | -0.0018 | -0.0002 | 0.0008 | -0.0002 | 0.0024 | -0.0007 | -0.0001 | -0.0008 |
| | 0.46 | -0.22 | -1.12 | -0.11 | 0.46 | -0.10 | 0.82 | -0.39 | -0.05 | -0.54 |
| | 46.05 | 43.42 | 46.05 | 47.37 | 44.74 | 40.91 | 63.64 | 45.45 | 45.45 | 45.45 |
| $\beta_2$ | 0.0388[2] | 0.0719[1] | 0.0660[1] | 0.0693[1] | 0.0279[1] | 0.0297[2] | 0.0445 | 0.0390[1] | 0.0541[2] | 0.0239[3] |
| | 2.44 | 4.29 | 5.74 | 4.62 | 2.93 | 2.18 | 2.81 | 3.12 | 2.60 | 2.06 |
| | 61.84 | 68.42 | 73.68 | 69.74 | 64.47 | 77.27 | 77.27 | 72.73 | 72.73 | 54.55 |
| $\beta_{2lag}$ | -0.0219 | 0.0150 | 0.0062 | -0.0003 | -0.0140 | 0.0577[1] | 0.0723[1] | 0.0184 | 0.0701[1] | 0.0207[3] |
| | -0.94 | 0.67 | 0.51 | -0.02 | -1.45 | 4.18 | 4.78 | 0.91 | 3.50 | 2.01 |
| | 44.74 | 53.95 | 46.05 | 50.00 | 44.74 | 90.91 | 86.36 | 50.00 | 72.73 | 77.27 |
| $\beta_2 + \beta_{2lag}$ | 0.0169 | 0.0868[2] | 0.0722[1] | 0.0690[1] | 0.0139 | 0.0874[1] | 0.1168[1] | 0.0574[2] | 0.1242[1] | 0.0446[2] |
| | 0.51 | 2.61 | 3.90 | 2.75 | 0.89 | 3.92 | 4.37 | 2.18 | 3.30 | 2.49 |
| | 53.29 | 61.18 | 59.87 | 59.87 | 54.61 | 84.09 | 81.82 | 61.36 | 72.73 | 65.91 |
| $\beta_3$ | 0.9452[1] | 0.9196[1] | 0.8981[1] | 0.7924[1] | 0.5530[1] | 0.3280[1] | 0.2388[1] | 0.2062[1] | 0.2153[1] | 0.0690 |
| | 9.65 | 9.62 | 10.75 | 9.73 | 9.86 | 5.91 | 4.04 | 3.58 | 3.74 | 1.12 |
| | 93.42 | 89.47 | 90.79 | 84.21 | 88.16 | 90.91 | 81.82 | 77.27 | 81.82 | 68.18 |
| $\beta_{3lag}$ | 0.0974[1] | 0.1291[1] | 0.1275[1] | 0.1400[1] | 0.0835[1] | 0.0082 | 0.0171 | 0.0191 | 0.0311 | 0.0349 |
| | 2.85 | 3.51 | 3.82 | 3.53 | 2.88 | 0.24 | 0.38 | 0.56 | 0.68 | 1.02 |
| | 61.84 | 65.79 | 64.47 | 64.47 | 64.47 | 68.18 | 59.09 | 40.91 | 72.73 | 59.09 |
| $\beta_3 + \beta_{3lag}$ | 1.0426[1] | 1.0488[1] | 1.0256[1] | 0.9324[1] | 0.6365[1] | 0.3363[1] | 0.2560[2] | 0.2253[2] | 0.2464[2] | 0.1039 |
| | 9.75 | 9.67 | 10.47 | 9.92 | 10.05 | 5.83 | 2.80 | 2.74 | 2.79 | 1.18 |
| | 77.63 | 77.63 | 77.63 | 74.34 | 76.32 | 79.55 | 70.45 | 59.09 | 77.27 | 63.64 |
| $\beta_4$ | -0.6192[1] | -0.6631[1] | -0.4961[1] | -0.3148[2] | -0.6780[1] | -0.9193[1] | -1.054[1] | -0.8213[1] | -0.7813[1] | -0.9676[1] |
| | -4.49 | -4.17 | -3.71 | -2.24 | -6.97 | -5.24 | -6.49 | -7.15 | -6.60 | -8.96 |
| | 30.26 | 23.68 | 32.89 | 28.95 | 21.05 | 9.09 | 4.55 | 4.55 | 9.09 | 4.55 |
| $\beta_5$ | 0.2907[1] | 0.1747[1] | 0.0833[1] | 0.0346 | 0.0404[2] | 0.1778[1] | 0.0075 | 0.0060 | 0.0478 | 0.0276 |
| | 7.21 | 4.61 | 3.16 | 1.08 | 2.25 | 2.94 | 0.19 | 0.20 | 1.02 | 1.01 |
| | 90.79 | 75.00 | 61.84 | 55.26 | 61.84 | 81.82 | 45.45 | 45.45 | 54.55 | 54.55 |
| $\beta_6$ | -0.2941 | 0.5450 | 0.2360 | -0.2934 | -0.2037 | 0.4734 | 0.4038 | 0.6885 | -0.1493 | 0.7540[2] |
| | -0.65 | 1.17 | 0.60 | -0.75 | -0.63 | 0.99 | 0.53 | 1.64 | -0.27 | 2.12 |
| | 47.37 | 52.63 | 52.63 | 52.63 | 46.05 | 72.73 | 63.64 | 59.09 | 45.45 | 50.00 |
| $\beta_7$ | 3.6525[1] | 4.4620[1] | 3.6168[1] | 2.3016[1] | 1.2768[1] | 5.7356[1] | 3.5525[1] | 3.1646[1] | 1.9004[1] | 2.9960[1] |
| | 6.23 | 6.47 | 7.99 | 4.21 | 3.91 | 6.77 | 2.81 | 4.50 | 2.41 | 4.71 |
| | 72.37 | 75.00 | 76.32 | 64.47 | 59.21 | 86.36 | 68.18 | 72.73 | 63.64 | 81.82 |
| $intercept$ | 3.8531[1] | 2.8166[1] | 2.9935[1] | 2.9656[1] | 3.2767[1] | 1.5458[1] | 1.3486[1] | 1.4354[1] | 2.0477[1] | 1.7300[1] |
| | 8.92 | 7.84 | 8.67 | 8.33 | 11.30 | 3.53 | 2.20 | 4.21 | 3.19 | 4.32 |
| | 88.16 | 84.21 | 90.79 | 86.84 | 89.47 | 81.82 | 77.27 | 72.73 | 72.73 | 77.27 |
| $adj\ R^2$ | 7.06 | 5 | 5.21 | 4.15 | 4.49 | 5.46 | 1.95 | 1.66 | 1.44 | 1.75 |
| $N$ | 69 | 69 | 69 | 69 | 69 | 19 | 19 | 19 | 19 | 19 |

## Table A17 (a)
## Size Effects in Liquidity Comovement between Call Options and Underlying Stock Market (Proportional Spreads)

This table reports regression results for size quartile portfolios. We estimate time-series market model regressions for each stock in maturity and moneyness portfolios, and then we group the results in quartiles by firm size. Firm size is based on time-series average of market capitalization for a stock over entire sample from 22 February 2008 to 31 December 2010. We calculate the cross-sectional average of regression coefficients across stocks within each quartile. Due to the panel nature of options, we report results for liquidity comovement between options and their underlying stock market. We use proportional bid-ask spread (option bid-ask spread as a percentage of option bid-ask midpoint) as a measure of option liquidity. We also report the difference in coefficients of options market liquidity for small and big firms and the t-static. Table A17(a), Table A17(b), and Table A17(c) reports results for Call, Put, and All (calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B – S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05-1.10** | 12 | 0.0672 | 0.0604 | -0.0271 | 0.1301 | 18 | 0.063** |
| | | | 0.95 | 0.83 | -0.51 | 1.52 | | 2.12 |
| | **0.95-1.05** | 17 | 0.1125*** | 0.1208** | 0.1198*** | 0.1287 | 18 | 0.016 |
| | | | 3.32 | 2.18 | 2.54 | 1.64 | | 0.78 |
| | **0.90-0.95** | 15 | -0.0156 | -0.0007 | 0.0135 | -0.0570 | 18 | -0.041 |
| | | | -0.30 | -0.01 | 0.21 | -0.61 | | -1.52 |
| 31-60 | **1.05-1.10** | 17 | 0.2612*** | 0.0879 | 0.1323 | 0.1963*** | 18 | -0.065** |
| | | | 2.50 | 1.27 | 1.30 | 3.27 | | -2.27 |
| | **0.95-1.05** | 17 | 0.2188*** | 0.1608** | 0.3940*** | 0.1453*** | 18 | -0.074*** |
| | | | 2.53 | 1.99 | 4.49 | 2.96 | | -3.12 |
| | **0.90-0.95** | 17 | 0.1442 | 0.2454** | 0.3220*** | 0.1459** | 18 | 0.002 |
| | | | 1.25 | 2.20 | 3.15 | 2.08 | | 0.05 |
| 61-91 | **1.05-1.10** | 16 | -0.1304 | 0.0524 | 0.1377 | 0.1200 | 18 | 0.250*** |
| | | | -0.79 | 0.38 | 1.07 | 1.51 | | 5.74 |
| | **0.95-1.05** | 17 | -0.0421 | -0.0278 | 0.0725 | 0.1385* | 18 | 0.181*** |
| | | | -0.36 | -0.43 | 0.95 | 1.87 | | 5.48 |
| | **0.90-0.95** | 17 | 0.1545 | -0.0016 | 0.0037 | 0.1218* | 18 | -0.033 |
| | | | 0.94 | -0.01 | 0.04 | 1.75 | | -0.77 |
| 92-182 | **1.05-1.10** | 17 | 0.2082*** | 0.1320*** | 0.0508 | 0.1689*** | 18 | -0.039*** |
| | | | 4.10 | 2.89 | 0.94 | 4.64 | | -2.64 |
| | **0.95-1.05** | 17 | 0.1260*** | 0.0833*** | 0.1315*** | 0.1717*** | 18 | 0.046*** |
| | | | 2.84 | 2.88 | 4.34 | 3.28 | | 2.78 |
| | **0.90-0.95** | 17 | 0.1043 | 0.0991*** | 0.1514*** | 0.0297 | 18 | -0.075*** |
| | | | 1.26 | 3.27 | 4.06 | 0.41 | | -2.84 |
| 183-273 | **1.05-1.10** | 16 | 0.0911 | 0.1625** | 0.0843 | 0.1544*** | 18 | 0.063*** |
| | | | 1.42 | 2.12 | 1.27 | 3.24 | | 3.28 |
| | **0.95-1.05** | 16 | 0.0533 | 0.0862** | 0.1047*** | 0.1016*** | 18 | 0.048*** |
| | | | 1.09 | 2.00 | 3.29 | 2.83 | | 3.31 |
| | **0.90-0.95** | 16 | -0.0164 | 0.1473 | 0.1052*** | 0.0613 | 18 | 0.078*** |
| | | | -0.48 | 1.31 | 5.02 | 1.03 | | 4.57 |

**Table A17 (b)**
**Size Effects in Liquidity Comovement between Put Options and Underlying Stock Market (Proportional Spreads)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05-1.10** | 7 | -0.1415 | 0.0533 | -0.0159 | -0.0223 | 18 | 0.119*** |
| | | | -1.32 | 0.64 | -0.27 | -0.30 | | 3.18 |
| | **0.95-1.05** | 17 | 0.0423 | -0.0211 | 0.0477 | -0.0013 | 19 | -0.044* |
| | | | 0.81 | -0.27 | 1.17 | -0.01 | | -1.78 |
| | **0.90-0.95** | 16 | 0.0165 | -0.2121* | 0.0277 | -0.0106 | 19 | -0.027 |
| | | | 0.21 | -1.74 | 0.34 | -0.08 | | -0.74 |
| 31-60 | **1.05-1.10** | 17 | 0.0794 | 0.2183*** | 0.1811** | 0.1300 | 19 | 0.051 |
| | | | 0.76 | 2.40 | 2.01 | 1.48 | | 1.58 |
| | **0.95-1.05** | 17 | 0.0904 | 0.2384*** | 0.2924*** | 0.1327*** | 19 | 0.042 |
| | | | 0.64 | 4.13 | 4.87 | 3.84 | | 1.27 |
| | **0.90-0.95** | 17 | 0.2209 | 0.1055 | 0.1768** | 0.1728*** | 19 | -0.048 |
| | | | 1.48 | 1.21 | 2.30 | 3.23 | | -1.31 |
| 61-91 | **1.05-1.10** | 16 | 0.0320 | -0.0601 | -0.0680 | 0.0464 | 19 | 0.014 |
| | | | 0.21 | -0.63 | -0.53 | 0.47 | | 0.34 |
| | **0.95-1.05** | 17 | 0.0635 | -0.0279 | 0.2165** | 0.1687*** | 19 | 0.105*** |
| | | | 0.56 | -0.33 | 2.38 | 3.01 | | 3.62 |
| | **0.90-0.95** | 16 | -0.0706 | 0.3060*** | 0.2514*** | 0.2364*** | 19 | 0.307*** |
| | | | -0.78 | 2.60 | 2.42 | 4.24 | | 12.29 |
| 92-182 | **1.05-1.10** | 17 | 0.2637*** | 0.1513** | 0.0870** | 0.1201** | 19 | -0.144*** |
| | | | 3.06 | 2.02 | 2.18 | 2.23 | | -6.06 |
| | **0.95-1.05** | 17 | 0.1129*** | 0.1408*** | 0.1096*** | 0.0868* | 19 | -0.026* |
| | | | 2.54 | 3.74 | 3.83 | 1.86 | | -1.72 |
| | **0.90-0.95** | 17 | 0.0748 | 0.0686 | 0.1064* | 0.1264*** | 19 | 0.052*** |
| | | | 1.60 | 1.64 | 1.97 | 3.16 | | 3.57 |
| 183-273 | **1.05-1.10** | 16 | 0.0574 | 0.0905 | 0.1217** | 0.0721 | 19 | 0.015 |
| | | | 0.54 | 1.12 | 2.20 | 0.82 | | 0.45 |
| | **0.95-1.05** | 16 | 0.0557 | 0.0921* | 0.0942** | 0.0391 | 19 | -0.017 |
| | | | 1.04 | 1.94 | 2.36 | 1.25 | | -1.14 |
| | **0.90-0.95** | 16 | 0.0468 | 0.1224 | -0.0110 | 0.1069** | 19 | 0.060*** |
| | | | 0.63 | 1.53 | -0.17 | 2.21 | | 2.87 |

**Table A17 (c)**
**Size Effects in Liquidity Comovement between All Options and their Underlying Stock Market (Proportional Spread)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05-1.10** | 17 | 0.0434 | 0.0670 | 0.0718 | 0.0893 | 18 | 0.046** |
| | | | 0.73 | 1.48 | 1.35 | 1.34 | | 2.14 |
| | **0.95-1.05** | 17 | 0.1223*** | 0.0864 | 0.1076*** | 0.0776 | 18 | -0.045** |
| | | | 3.85 | 1.49 | 2.43 | 0.98 | | -2.16 |
| | **0.90-0.95** | 17 | 0.0140 | -0.0793 | -0.0124 | 0.0353 | 18 | 0.021 |
| | | | 0.18 | -0.82 | -0.15 | 0.44 | | 0.79 |
| 31-60 | **1.05-1.10** | 17 | 0.2418*** | 0.2117*** | 0.2182*** | 0.1384*** | 18 | -0.103*** |
| | | | 3.01 | 3.25 | 2.71 | 2.22 | | -4.27 |
| | **0.95-1.05** | 17 | 0.1153 | 0.2177*** | 0.3498*** | 0.1525*** | 18 | 0.037 |
| | | | 0.92 | 3.65 | 5.10 | 3.77 | | 1.19 |
| | **0.90-0.95** | 17 | 0.1389 | 0.2222*** | 0.2732*** | 0.1536*** | 18 | 0.015 |
| | | | 1.17 | 2.47 | 4.08 | 2.84 | | 0.47 |
| 61-91 | **1.05-1.10** | 17 | -0.0396 | -0.0320 | 0.0812 | 0.1009 | 18 | 0.141*** |
| | | | -0.27 | -0.39 | 1.00 | 1.24 | | 3.51 |
| | **0.95-1.05** | 17 | 0.1040 | -0.0033 | 0.1729*** | 0.2131*** | 18 | 0.109*** |
| | | | 0.74 | -0.06 | 2.59 | 2.65 | | 2.85 |
| | **0.90-0.95** | 17 | 0.0172 | 0.2820*** | 0.1504** | 0.2584*** | 18 | 0.241*** |
| | | | 0.13 | 3.20 | 2.16 | 4.73 | | 7.29 |
| 92-182 | **1.05-1.10** | 17 | 0.2707*** | 0.1576*** | 0.1335*** | 0.1769*** | 18 | -0.094*** |
| | | | 4.11 | 3.54 | 2.65 | 4.37 | | -5.11 |
| | **0.95-1.05** | 17 | 0.1383*** | 0.1640*** | 0.1676*** | 0.1349*** | 18 | -0.003 |
| | | | 3.71 | 4.10 | 5.36 | 2.80 | | -0.23 |
| | **0.90-0.95** | 17 | 0.1173** | 0.0857*** | 0.1588*** | 0.0708 | 18 | -0.046** |
| | | | 2.34 | 3.88 | 4.87 | 1.09 | | -2.36 |
| 183-273 | **1.05-1.10** | 16 | 0.1187 | 0.1261 | 0.1477*** | 0.1581*** | 18 | 0.039 |
| | | | 1.29 | 1.69 | 3.08 | 2.46 | | 1.46 |
| | **0.95-1.05** | 16 | 0.1337** | 0.0927* | 0.1637*** | 0.0796*** | 18 | -0.054*** |
| | | | 2.37 | 1.88 | 5.83 | 2.47 | | -3.49 |
| | **0.90-0.95** | 16 | 0.0553 | 0.1149 | 0.0931* | 0.0864 | 18 | 0.031 |
| | | | 0.87 | 1.43 | 1.85 | 1.61 | | 1.55 |

**Table A18 (a)**

**Size Effects in Liquidity Comovement between Call Options and their Underlying Stock Market (Percentage Spread)**

This table reports regression results for size quartile portfolios. We estimate time-series market model regressions for each stock in maturity and moneyness portfolio, and then we group the results in quartiles by firm size. Firm size is based on time-series average of market capitalization for a stock over entire sample from 22 February 2008 to 31 December 2010. We calculate the cross-sectional average of regression coefficients across stocks within each quartile. Due to the panel nature of options, we report results for liquidity comovement between options and their underlying stock market. We use percentage bid-ask spread (option bid-ask spread as a percentage of underlying stock price) as a measure of option liquidity. We also report the difference in coefficients of options market liquidity for small and big firms and the t-static. Table A18(a), Table A18(b), and Table A18(c) reports results for Call, Put, and All (calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B – S |
|---|---|---|---|---|---|---|---|---|
| **Upto 30** | **1.05-1.10** | 12 | 0.0560 | 0.0159 | -0.0687 | 0.0801 | 18 | 0.024 |
| | | | 0.74 | 0.21 | -1.51 | 0.87 | | 0.75 |
| | **0.95-1.05** | 17 | 0.0523 | 0.0196 | 0.0330 | 0.0742 | 18 | 0.022 |
| | | | 1.58 | 0.37 | 0.73 | 1.06 | | 1.17 |
| | **0.90-0.95** | 15 | 0.0279 | -0.0520 | -0.0533 | -0.1033* | 18 | -0.131*** |
| | | | 0.95 | -0.90 | -1.02 | -1.70 | | -7.63 |
| **31-60** | **1.05-1.10** | 17 | 0.2313** | 0.0423 | 0.0877 | 0.1435** | 18 | -0.088*** |
| | | | 2.20 | 0.65 | 0.93 | 2.28 | | -3.02 |
| | **0.95-1.05** | 17 | 0.1492* | 0.1168* | 0.2753*** | 0.0980** | 18 | -0.051** |
| | | | 1.86 | 1.90 | 4.02 | 1.99 | | -2.29 |
| | **0.90-0.95** | 17 | 0.0862 | 0.1480** | 0.2566*** | 0.1141* | 18 | 0.028 |
| | | | 0.90 | 2.32 | 2.62 | 1.95 | | 1.04 |
| **61-91** | **1.05-1.10** | 16 | -0.2756 | -0.0549 | 0.1047 | 0.0687 | 18 | 0.344*** |
| | | | -1.34 | -0.45 | 0.66 | 0.84 | | 6.57 |
| | **0.95-1.05** | 17 | -0.1716 | -0.1232** | -0.0111 | 0.0329 | 18 | 0.205*** |
| | | | -1.41 | -2.10 | -0.21 | 0.60 | | 6.49 |
| | **0.90-0.95** | 17 | 0.0203 | -0.0718 | 0.0194 | 0.1178* | 18 | 0.098** |
| | | | 0.13 | -0.71 | 0.33 | 1.85 | | 2.39 |
| **92-182** | **1.05-1.10** | 17 | 0.1962*** | 0.1036** | 0.0681 | 0.1372*** | 18 | -0.059*** |
| | | | 3.80 | 2.28 | 1.17 | 3.63 | | -3.87 |
| | **0.95-1.05** | 17 | 0.0993** | 0.0533** | 0.0905*** | 0.1245*** | 18 | 0.025 |
| | | | 2.22 | 2.26 | 3.07 | 2.82 | | 1.67 |
| | **0.90-0.95** | 17 | 0.1324** | 0.0737*** | 0.1162*** | 0.0052 | 18 | -0.127*** |
| | | | 2.09 | 2.94 | 3.24 | 0.06 | | -5.20 |
| **183-273** | **1.05-1.10** | 16 | 0.0643 | 0.1535* | 0.0880 | 0.1501*** | 18 | 0.086*** |
| | | | 0.89 | 1.90 | 1.36 | 3.06 | | 4.08 |
| | **0.95-1.05** | 16 | 0.0655 | 0.0786* | 0.0892*** | 0.0823*** | 18 | 0.017 |
| | | | 1.29 | 1.67 | 3.21 | 2.46 | | 1.15 |
| | **0.90-0.95** | 16 | -0.0171 | 0.1282 | 0.0876*** | 0.0392 | 18 | 0.056*** |
| | | | -0.41 | 1.29 | 3.77 | 0.62 | | 3.03 |

**Table A18 (b)**
**Size Effects in Liquidity Comovement between Call Options and Stock Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | **1.05 - 1.10** | 7 | -0.2210** | 0.0931 | 0.0120 | 0.0123 | 18 | 0.233*** |
| | | | -2.00 | 0.70 | 0.21 | 0.17 | | 6.22 |
| | **0.95 - 1.05** | 17 | 0.0636* | 0.0530 | 0.0518 | 0.0489 | 19 | -0.015 |
| | | | 1.73 | 0.99 | 1.56 | 0.62 | | -0.70 |
| | **0.90 - 0.95** | 16 | 0.1235** | -0.0119 | 0.0264 | 0.0360 | 19 | -0.088*** |
| | | | 2.03 | -0.18 | 0.49 | 0.48 | | -3.75 |
| 31-60 | **1.05 - 1.10** | 17 | 0.1362 | 0.1992** | 0.1894* | 0.1810* | 19 | 0.045 |
| | | | 1.22 | 2.52 | 1.99 | 1.96 | | 1.32 |
| | **0.95 - 1.05** | 17 | 0.1135 | 0.2094*** | 0.3196*** | 0.1538*** | 19 | 0.040 |
| | | | 0.85 | 4.32 | 5.34 | 3.64 | | 1.25 |
| | **0.90 - 0.95** | 17 | 0.1841 | 0.0953** | 0.1485** | 0.1543*** | 19 | -0.030 |
| | | | 1.44 | 2.03 | 2.23 | 2.68 | | -0.92 |
| 61-91 | **1.05 - 1.10** | 16 | 0.0245 | -0.0777 | -0.1626 | 0.0655 | 19 | 0.041 |
| | | | 0.16 | -0.92 | -1.34 | 0.66 | | 0.95 |
| | **0.95 - 1.05** | 17 | -0.0131 | -0.1386 | 0.0477 | 0.1487*** | 19 | 0.162*** |
| | | | -0.15 | -1.41 | 0.73 | 2.47 | | 6.45 |
| | **0.90 - 0.95** | 16 | -0.0798 | 0.1261* | 0.1196 | 0.2180*** | 19 | 0.298*** |
| | | | -0.99 | 1.80 | 1.03 | 3.42 | | 12.17 |
| 92-182 | **1.05 - 1.10** | 17 | 0.2271*** | 0.1440*** | 0.0686* | 0.1073** | 19 | -0.120*** |
| | | | 2.59 | 2.22 | 1.95 | 2.13 | | -5.09 |
| | **0.95 - 1.05** | 17 | 0.0511 | 0.1076*** | 0.0630** | 0.0990** | 19 | 0.048*** |
| | | | 1.54 | 3.33 | 2.32 | 2.18 | | 3.57 |
| | **0.90 - 0.95** | 17 | 0.0204 | 0.0672* | 0.1044** | 0.1362*** | 19 | 0.116*** |
| | | | 0.42 | 1.81 | 2.25 | 3.02 | | 7.43 |
| 183-273 | **1.05 - 1.10** | 16 | 0.0294 | 0.0553 | 0.0930 | 0.0665 | 19 | 0.037 |
| | | | 0.31 | 0.59 | 1.46 | 0.76 | | 1.20 |
| | **0.95 - 1.05** | 16 | 0.0613 | 0.0731* | 0.0835** | 0.0270 | 19 | -0.034*** |
| | | | 1.41 | 1.69 | 2.42 | 0.86 | | -2.71 |
| | **0.90 - 0.95** | 16 | 0.0670 | 0.1162* | -0.0022 | 0.0956** | 19 | 0.029* |
| | | | 1.07 | 1.68 | -0.04 | 2.86 | | 1.72 |

**Table A18 (c)**
**Size Effects in Liquidity Comovement between All Options and Stock Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(S) | (S) | 2 | 3 | (B) | N(B) | B - S |
|---|---|---|---|---|---|---|---|---|
| **Upto 30** | **1.05-1.10** | 17 | -0.0143 | 0.0042 | 0.0043 | 0.0164 | 18 | 0.031 |
| | | | -0.30 | 0.08 | 0.10 | 0.20 | | 1.34 |
| | **0.95-1.05** | 17 | 0.0650** | 0.0339 | 0.0385 | 0.0611 | 18 | -0.004 |
| | | | 2.22 | 0.63 | 0.98 | 0.84 | | -0.21 |
| | **0.90-0.95** | 17 | 0.0545 | 0.0191 | -0.0053 | 0.0032 | 18 | -0.051*** |
| | | | 1.32 | 0.53 | -0.12 | 0.06 | | -3.17 |
| **31-60** | **1.05-1.10** | 17 | 0.1932** | 0.1382*** | 0.1403* | 0.1328** | 18 | -0.060*** |
| | | | 2.34 | 2.50 | 1.77 | 2.03 | | -2.40 |
| | **0.95-1.05** | 17 | 0.0747 | 0.1773*** | 0.2879*** | 0.1279*** | 18 | 0.053* |
| | | | 0.62 | 3.84 | 5.00 | 3.19 | | 1.77 |
| | **0.90-0.95** | 17 | 0.1069 | 0.1133*** | 0.2484*** | 0.1442*** | 18 | 0.037 |
| | | | 1.07 | 2.59 | 4.51 | 2.48 | | 1.36 |
| **61-91** | **1.05-1.10** | 17 | -0.2252 | -0.1044 | -0.0266 | 0.1072 | 18 | 0.332*** |
| | | | -1.38 | -1.44 | -0.34 | 1.43 | | 7.80 |
| | **0.95-1.05** | 17 | -0.1169 | -0.1344* | 0.0222 | 0.1107** | 18 | 0.228*** |
| | | | -0.94 | -1.89 | 0.43 | 1.91 | | 7.00 |
| | **0.90-0.95** | 17 | -0.0463 | 0.0328 | 0.0574 | 0.1834*** | 18 | 0.230*** |
| | | | -0.36 | 0.38 | 1.01 | 2.99 | | 6.77 |
| **92-182** | **1.05-1.10** | 17 | 0.1848*** | 0.1015*** | 0.0623 | 0.1354*** | 18 | -0.049*** |
| | | | 3.37 | 2.66 | 1.41 | 3.92 | | -3.21 |
| | **0.95-1.05** | 17 | 0.0691** | 0.0884*** | 0.0838*** | 0.1069** | 18 | 0.038*** |
| | | | 2.19 | 3.63 | 3.72 | 2.35 | | 2.84 |
| | **0.90-0.95** | 17 | 0.0900** | 0.0573** | 0.0951*** | 0.0492 | 18 | -0.041** |
| | | | 2.24 | 2.14 | 3.71 | 0.75 | | -2.20 |
| **183-273** | **1.05-1.10** | 16 | 0.0594 | 0.0572 | 0.0897** | 0.1364** | 18 | 0.077*** |
| | | | 0.74 | 0.69 | 2.10 | 2.23 | | 3.17 |
| | **0.95-1.05** | 16 | 0.0975* | 0.0550 | 0.1057*** | 0.0326 | 18 | -0.065*** |
| | | | 1.96 | 1.27 | 4.38 | 1.11 | | -4.70 |
| | **0.90-0.95** | 16 | 0.0643 | 0.1009 | 0.0707** | 0.0413 | 18 | -0.023 |
| | | | 1.05 | 1.62 | 2.04 | 0.95 | | -1.27 |

**Table A19 (a)**

**Volatility Effects in Liquidity Comovement between Call Options and their Underlying Stock Market (Proportional Spread)**

In this table, we report regression results for volatility quartile portfolios. We estimate time-series market model regressions for each stock in maturity and moneyness portfolio, and then we group the results in quartiles by average implied volatility of a stock. Implied volatility is calculated by inverting the Black-Scholes option pricing formula. Implied volatility assigned to stock is calculated as a time-series average of implied volatility of options for the entire sample period from 22 February 2008 to 31 December 2010. We compute results based on the stocks in volatility quartiles by calculating the cross-sectional average of regression coefficients across stocks within each quartile portfolio. Due to the panel nature of options, we report results for liquidity comovement between options and their underlying stock market. We use proportional bid-ask spread (option bid-ask spread as a percentage of option bid-ask midpoint) as a measure of option liquidity. We also report the difference in coefficients of options market liquidity for small and big firms and the t-statistic. Table A19(a), Table A19(b) and Table A19(c) reports results of Call, Put and All (calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05- 1.10 | 14 | -0.0895 | 0.0082 | 0.0711 | 0.2337** | 15 | 0.323*** |
| | | | -1.52 | 0.15 | 1.46 | 2.31 | | 10.42 |
| | 0.95- 1.05 | 16 | 0.0173 | 0.0798 | 0.1417*** | 0.2285*** | 18 | 0.211*** |
| | | | 0.42 | 1.58 | 3.60 | 3.10 | | 10.11 |
| | 0.90-0.95 | 14 | -0.1301 | -0.0333 | 0.0479 | 0.0292 | 15 | 0.159*** |
| | | | -1.51 | -0.45 | 1.09 | 0.27 | | 4.32 |
| 31-60 | 1.05-1.10 | 16 | 0.1720* | 0.1974** | 0.2687*** | 0.0354 | 18 | -0.137*** |
| | | | 1.91 | 2.05 | 3.47 | 0.46 | | -4.79 |
| | 0.95-1.05 | 16 | 0.3069*** | 0.3554*** | 0.2225*** | 0.0543 | 18 | -0.253*** |
| | | | 2.78 | 5.52 | 3.20 | 0.97 | | -8.56 |
| | 0.90-0.95 | 16 | 0.2459* | 0.3162*** | 0.2140** | 0.0928 | 18 | -0.153*** |
| | | | 1.83 | 3.30 | 2.24 | 1.26 | | -4.17 |
| 61-91 | 1.05-1.10 | 16 | -0.0354 | 0.0498 | -0.0673 | 0.2492* | 17 | 0.285*** |
| | | | -0.37 | 0.39 | -0.45 | 1.95 | | 7.20 |
| | 0.95-1.05 | 16 | -0.0174 | 0.1646*** | 0.0011 | 0.0038 | 18 | 0.021 |
| | | | -0.20 | 3.18 | 0.01 | 0.05 | | 0.72 |
| | 0.90-0.95 | 16 | -0.2141 | 0.3458*** | 0.0913 | 0.0374 | 18 | 0.251*** |
| | | | -1.60 | 3.70 | 1.07 | 0.36 | | 6.13 |
| 92-182 | 1.05-1.10 | 16 | 0.0670 | 0.0809* | 0.2326*** | 0.1596*** | 18 | 0.093*** |
| | | | 1.19 | 1.80 | 4.78 | 4.58 | | 5.85 |
| | 0.95-1.05 | 16 | 0.1029*** | 0.1002*** | 0.1648*** | 0.1408*** | 18 | 0.038*** |
| | | | 3.06 | 2.78 | 4.91 | 2.61 | | 2.42 |
| | 0.90-0.95 | 16 | 0.0578 | 0.1437*** | 0.1803*** | -0.0043 | 18 | -0.062*** |
| | | | 1.46 | 4.85 | 2.88 | -0.05 | | -2.81 |
| 183-273 | 1.05-1.10 | 16 | 0.1836*** | 0.1628*** | 0.0942 | 0.0619 | 18 | -0.122*** |
| | | | 3.00 | 2.73 | 1.53 | 0.87 | | -5.33 |
| | 0.95-1.05 | 16 | 0.0913** | 0.0573* | 0.1158*** | 0.0841** | 18 | -0.007 |
| | | | 2.32 | 1.82 | 2.53 | 2.09 | | -0.52 |
| | 0.90-0.95 | 16 | 0.1356 | 0.0801* | 0.0441 | 0.0507 | 18 | -0.085*** |
| | | | 1.13 | 1.70 | 1.14 | 1.16 | | -2.80 |

**Table A19 (b)**

**Volatility Effects in Liquidity Comovement between Put Options and their Underlying Stock Market (Proportional Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| **Upto 30** | 1.05-1.10 | 6 | -0.1347 | 0.0128 | -0.1042 | .0699 | 14 | 0.205*** |
| | | | -0.96 | 0.19 | -1.39 | 1.01 | | 4.44 |
| | 0.95-1.05 | 17 | 0.0065 | -0.0235 | 0.0851*** | -0.0062 | 19 | -0.013 |
| | | | 0.14 | -0.36 | 2.64 | -0.06 | | -0.47 |
| | 0.90-0.95 | 17 | -0.0225 | -0.2237* | 0.0272 | 0.0361 | 17 | 0.059 |
| | | | -0.23 | -1.85 | 0.39 | 0.28 | | 1.48 |
| **31-60** | 1.05-1.10 | 17 | 0.2369*** | 0.0861 | 0.1096 | 0.1701* | 19 | -0.067** |
| | | | 2.48 | 0.87 | 1.19 | 1.94 | | -2.19 |
| | 0.95-1.05 | 17 | 0.2108*** | 0.2403*** | 0.1622 | 0.1437*** | 19 | -0.067*** |
| | | | 4.33 | 3.37 | 1.27 | 2.50 | | -3.76 |
| | 0.90-0.95 | 17 | 0.1540 | 0.0796 | 0.3426*** | 0.0937 | 19 | -0.060* |
| | | | 1.35 | 1.23 | 2.99 | 1.43 | | -1.97 |
| **61-91** | 1.05-1.10 | 17 | -0.1311 | 0.0076 | 0.0365 | 0.0427 | 17 | 0.174*** |
| | | | -1.24 | 0.05 | 0.27 | 0.58 | | 5.55 |
| | 0.95-1.05 | 17 | 0.1346** | 0.0990 | 0.0645 | 0.1292 | 19 | -0.005 |
| | | | 2.16 | 1.04 | 0.60 | 1.51 | | -0.21 |
| | 0.90-0.95 | 17 | 0.2754*** | 0.2473*** | -0.0343 | 0.2676*** | 18 | -0.008 |
| | | | 3.10 | 2.56 | -0.42 | 2.49 | | -0.23 |
| **92-182** | 1.05-1.10 | 17 | 0.1588** | 0.0518 | 0.3070*** | 0.0927** | 19 | -0.066*** |
| | | | 2.37 | 0.86 | 4.02 | 1.99 | | -3.47 |
| | 0.95-1.05 | 17 | 0.1213*** | 0.0913*** | 0.1298*** | 0.1035** | 19 | -0.018 |
| | | | 4.35 | 2.72 | 3.15 | 2.02 | | -1.27 |
| | 0.90-0.95 | 17 | 0.0944*** | 0.0575 | 0.1484*** | 0.0764 | 19 | -0.018 |
| | | | 2.53 | 0.97 | 3.98 | 1.65 | | -1.28 |
| **183-273** | 1.05-1.10 | 17 | 0.1209 | 0.0532 | 0.2076** | -0.0285 | 19 | -0.149*** |
| | | | 1.24 | 1.20 | 2.27 | -0.36 | | -5.06 |
| | 0.95-1.05 | 17 | 0.0641** | 0.0518 | 0.0901 | 0.0711* | 19 | 0.007 |
| | | | 2.14 | 1.22 | 1.55 | 1.84 | | 0.60 |
| | 0.90-0.95 | 17 | 0.1151 | 0.0490 | 0.1058 | 0.0071 | 19 | -0.108*** |
| | | | 1.33 | 1.35 | 1.38 | 0.12 | | -4.42 |

**Table A19 (c)**
**Volatility Effects in Liquidity Comovement between All Options and their Underlying Stock Market (Proportional Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| **Upto 30** | 1.05-1.10 | 17 | 0.0094 | 0.0223 | 0.0276 | 0.1984*** | 19 | 0.189*** |
| | | | 0.14 | 0.53 | 0.51 | 4.13 | | 9.74 |
| | 0.95-1.05 | 17 | 0.0513 | 0.0007 | 0.1387*** | 0.1914*** | 19 | 0.140*** |
| | | | 1.29 | 0.01 | 5.80 | 2.49 | | 6.73 |
| | 0.90-0.95 | 17 | -0.0954 | -0.1061 | 0.0927 | 0.0606 | 19 | 0.156*** |
| | | | -1.08 | -1.06 | 1.28 | 0.88 | | 5.92 |
| **31-60** | 1.05-1.10 | 17 | 0.2759*** | 0.1340* | 0.2522*** | 0.1511** | 19 | -0.125*** |
| | | | 3.87 | 1.88 | 3.67 | 2.04 | | -5.14 |
| | 0.95-1.05 | 17 | 0.3009*** | 0.3126*** | 0.1282 | 0.1102*** | 19 | -0.191*** |
| | | | 3.97 | 5.25 | 1.06 | 2.56 | | -9.40 |
| | 0.90-0.95 | 17 | 0.2398** | 0.1789*** | 0.2563*** | 0.1235* | 19 | -0.116*** |
| | | | 2.18 | 3.05 | 2.60 | 1.88 | | -3.91 |
| **61-91** | 1.05-1.10 | 17 | 0.0119 | 0.0518 | -0.0026 | 0.0539 | 19 | 0.042 |
| | | | 0.13 | 0.73 | -0.02 | 0.64 | | 1.42 |
| | 0.95-1.05 | 17 | 0.1035* | 0.1697** | 0.1043 | 0.1180 | 19 | 0.015 |
| | | | 1.93 | 2.09 | 0.79 | 1.33 | | 0.59 |
| | 0.90-0.95 | 17 | 0.2063** | 0.2392*** | 0.0962 | 0.1703** | 19 | -0.036 |
| | | | 2.34 | 2.69 | 0.86 | 2.28 | | -1.33 |
| **92-182** | 1.05-1.10 | 17 | 0.1699*** | 0.0882*** | 0.3207*** | 0.1595*** | 19 | -0.010 |
| | | | 2.73 | 2.85 | 5.25 | 4.86 | | -0.64 |
| | 0.95-1.05 | 17 | 0.1773*** | 0.1268*** | 0.1774*** | 0.1263*** | 19 | -0.051*** |
| | | | 4.61 | 4.11 | 4.29 | 2.86 | | -3.68 |
| | 0.90-0.95 | 17 | 0.1113*** | 0.1155*** | 0.1835*** | 0.0321 | 19 | -0.079*** |
| | | | 2.94 | 3.77 | 5.86 | 0.50 | | -4.47 |
| **183-273** | 1.05-1.10 | 17 | 0.2481*** | 0.0980** | 0.1925** | 0.0308 | 19 | -0.217*** |
| | | | 3.56 | 2.09 | 2.18 | 0.51 | | -10.01 |
| | 0.95-1.05 | 17 | 0.1148*** | 0.1064*** | 0.1639*** | 0.0901** | 19 | -0.025** |
| | | | 3.74 | 2.60 | 2.81 | 2.39 | | -2.14 |
| | 0.90-0.95 | 17 | 0.1596*** | 0.0835*** | 0.1127 | 0.0070 | 19 | -0.153*** |
| | | | 1.96 | 2.65 | 1.67 | 0.13 | | -6.67 |

**Table A20 (a)**

**Volatility Effects in Liquidity Comovement between Call Options and their Underlying Stock Market (Percentage Spread)**

This table reports regression results for volatility quartile portfolios. We estimate time-series market model regressions for each stock in maturity and moneyness portfolio, and then we group the results in quartiles by average implied volatility of a stock. Implied volatility is calculated by inverting the Black-Scholes option pricing formula. Implied volatility assigned to stock is calculated as a time-series average of implied volatility of options for entire sample period from 22 February 2008 to 31 December 2010. We compute results based on the stocks in volatility quartiles by calculating the cross-sectional average of regression coefficients across stocks within each quartile. Due to the panel nature of options, we report results for liquidity comovement between options and their underlying stock market. We use percentage bid-ask spread (option bid-ask spread as a percentage of underlying stock price) as a measure of option liquidity. We also report the difference in coefficients of options market liquidity for small and big firms and the t-static. Table A20(a), Table A20(b) and Table A20(c) report results of Call, Put and All (calls and puts combined) options respectively.

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05-1.10 | 14 | -0.1529** | -0.0021 | 0.0354 | 0.1838* | 15 | 0.337*** |
| | | | -2.20 | -0.04 | 0.67 | 1.85 | | 10.50 |
| | 0.95-1.05 | 16 | -0.0113 | -0.0064 | 0.0936*** | 0.0924 | 18 | 0.104*** |
| | | | -0.27 | -0.13 | 2.46 | 1.32 | | 5.16 |
| | 0.90-0.95 | 14 | -0.1083 | -0.0923* | 0.0357 | -0.0447 | 15 | 0.064*** |
| | | | -1.65 | -1.98 | 1.64 | -0.63 | | 2.50 |
| 31-60 | 1.05-1.10 | 16 | 0.1051 | 0.1575 | 0.2381*** | -0.0039 | 18 | -0.109*** |
| | | | 1.31 | 1.53 | 3.12 | -0.06 | | -4.29 |
| | 0.95-1.05 | 16 | 0.1599* | 0.2675*** | 0.1798*** | 0.0400 | 18 | -0.120*** |
| | | | 1.78 | 4.61 | 3.06 | 0.78 | | -4.85 |
| | 0.90-0.95 | 16 | 0.1213 | 0.2679*** | 0.1664** | 0.0554 | 18 | -0.066** |
| | | | 1.42 | 3.29 | 2.13 | 0.71 | | -2.35 |
| 61-91 | 1.05-1.10 | 16 | -0.0568 | -0.0430 | -0.1990 | 0.1702 | 17 | 0.227*** |
| | | | -0.50 | -0.29 | -1.07 | 1.49 | | 5.71 |
| | 0.95-1.05 | 16 | -0.0799 | 0.0125 | -0.1211 | -0.0696 | 18 | 0.010 |
| | | | -1.26 | 0.26 | -1.15 | -0.97 | | 0.44 |
| | 0.90-0.95 | 16 | -0.1463 | 0.2000*** | 0.0182 | 0.0106 | 18 | 0.157*** |
| | | | -1.37 | 3.22 | 0.15 | 0.11 | | 4.50 |
| 92-182 | 1.05-1.10 | 16 | 0.0478 | 0.0766 | 0.2190*** | 0.1424*** | 18 | 0.095*** |
| | | | 0.99 | 1.37 | 4.35 | 4.33 | | 6.73 |
| | 0.95-1.05 | 16 | 0.0679** | 0.0653* | 0.1331*** | 0.0966** | 18 | 0.029** |
| | | | 2.33 | 1.88 | 3.94 | 2.13 | | 2.16 |
| | 0.90-0.95 | 16 | 0.0364 | 0.1064*** | 0.1891*** | -0.0165 | 18 | -0.053** |
| | | | 0.90 | 3.67 | 4.06 | -0.20 | | -2.37 |
| 183-273 | 1.05-1.10 | 16 | 0.1707*** | 0.1783*** | 0.1065* | 0.0135 | 18 | -0.157*** |
| | | | 2.80 | 3.01 | 1.70 | 0.18 | | -6.55 |
| | 0.95-1.05 | 16 | 0.0823*** | 0.0458 | 0.1438*** | 0.0438 | 18 | -0.039*** |
| | | | 2.42 | 1.30 | 3.20 | 1.13 | | -3.06 |
| | 0.90-0.95 | 16 | 0.1230 | 0.0725 | 0.0617 | -0.0069 | 18 | -0.130*** |
| | | | 1.11 | 1.52 | 1.52 | -0.17 | | -4.66 |

**Table A20 (b)**
**Volatility Effects in Liquidity Comovement between Put Options and their Underlying Stock Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05-1.10 | 6 | -0.1760 | -0.0035 | -0.1233 | 0.1653* | 14 | 0.341*** |
| | | | -1.64 | -0.05 | -1.58 | 1.82 | | 7.29 |
| | 0.95-1.05 | 17 | -0.0078 | 0.0198 | 0.1133*** | 0.0826 | 19 | 0.090*** |
| | | | -0.21 | 0.38 | 3.88 | 1.03 | | 4.28 |
| | 0.90-0.95 | 17 | -0.0652 | -0.0307 | 0.1280** | 0.1304 | 17 | 0.196*** |
| | | | -1.19 | -0.67 | 2.21 | 1.54 | | 7.98 |
| 31-60 | 1.05-1.10 | 17 | 0.2772*** | 0.1071 | 0.1832** | 0.1387 | 19 | -0.138*** |
| | | | 2.76 | 1.05 | 2.00 | 1.64 | | -4.49 |
| | 0.95-1.05 | 17 | 0.2703*** | 0.2599*** | 0.1979* | 0.0806 | 19 | -0.190*** |
| | | | 5.29 | 3.72 | 1.74 | 1.33 | | -10.10 |
| | 0.90-0.95 | 17 | 0.1077 | 0.0950 | 0.3045*** | 0.0723 | 19 | -0.035 |
| | | | 1.17 | 1.65 | 3.21 | 1.37 | | -1.43 |
| 61-91 | 1.05-1.10 | 17 | -0.2260** | 0.0124 | 0.0542 | 0.0175 | 17 | 0.244*** |
| | | | -2.33 | 0.09 | 0.39 | 0.25 | | 8.36 |
| | 0.95-1.05 | 17 | -0.0271 | 0.0159 | -0.0168 | 0.0825 | 19 | 0.110*** |
| | | | -0.42 | 0.19 | -0.21 | 0.89 | | 4.05 |
| | 0.90-0.95 | 17 | 0.0773 | 0.1189 | -0.0567 | 0.2692*** | 18 | 0.192*** |
| | | | 0.97 | 1.55 | -0.82 | 2.65 | | 6.18 |
| 92-182 | 1.05-1.10 | 17 | 0.1402** | 0.0627 | 0.2848*** | 0.0526 | 19 | -0.088*** |
| | | | 2.36 | 1.14 | 3.84 | 1.17 | | -5.02 |
| | 0.95-1.05 | 17 | 0.0785*** | 0.0709** | 0.0938*** | 0.0785* | 19 | 0.000 |
| | | | 2.72 | 2.10 | 2.68 | 1.80 | | 0.00 |
| | 0.90-0.95 | 17 | 0.0725** | 0.0653 | 0.1237*** | 0.0710 | 19 | -0.001 |
| | | | 1.99 | 1.18 | 3.31 | 1.40 | | -0.10 |
| 183-273 | 1.05-1.10 | 17 | 0.1035 | 0.0386 | 0.1800** | -0.0623 | 19 | -0.166*** |
| | | | 1.05 | 0.64 | 2.34 | -0.71 | | -5.32 |
| | 0.95-1.05 | 17 | 0.0449 | 0.0285 | 0.0861* | 0.0775*** | 19 | 0.033*** |
| | | | 1.50 | 0.70 | 1.80 | 2.40 | | 3.12 |
| | 0.90-0.95 | 17 | 0.0570 | 0.0512 | 0.1015 | 0.0691 | 19 | 0.012 |
| | | | 0.79 | 1.47 | 1.57 | 1.45 | | 0.60 |

**Table A20 (c)**
**Volatility Effects in Liquidity Comovement between All Options and their Underlying Stock Market (Percentage Spread)**

| Maturity (days) | Moneyness | N(L) | (L) | 2 | 3 | (H) | N(H) | H - L |
|---|---|---|---|---|---|---|---|---|
| Upto 30 | 1.05-1.10 | 17 | -0.0858 | -0.0133 | 0.0089 | 0.0913 | 19 | 0.177*** |
| | | | -1.34 | -0.31 | 0.19 | 1.34 | | 8.02 |
| | 0.95-1.05 | 17 | -0.0045 | 0.0044 | 0.0929*** | 0.0999 | 19 | 0.104*** |
| | | | -0.10 | 0.09 | 4.73 | 1.41 | | 5.27 |
| | 0.90-0.95 | 17 | -0.0842* | -0.0289 | 0.1188*** | 0.0587 | 19 | 0.143*** |
| | | | -1.94 | -0.90 | 3.40 | 1.20 | | 9.23 |
| 31-60 | 1.05-1.10 | 17 | 0.2047*** | 0.0632 | 0.2421*** | 0.0989 | 19 | -0.106*** |
| | | | 3.55 | 0.85 | 3.55 | 1.32 | | -4.70 |
| | 0.95-1.05 | 17 | 0.2342*** | 0.2489*** | 0.1219 | 0.0782* | 19 | -0.156*** |
| | | | 3.50 | 4.76 | 1.08 | 1.75 | | -8.31 |
| | 0.90-0.95 | 17 | 0.1362** | 0.1863*** | 0.2192*** | 0.0843 | 19 | -0.052*** |
| | | | 2.14 | 3.43 | 2.64 | 1.28 | | -2.41 |
| 61-91 | 1.05-1.10 | 17 | -0.0399 | -0.0603 | -0.1466 | 0.0024 | 19 | 0.042 |
| | | | -0.49 | -0.75 | -0.87 | 0.03 | | 1.64 |
| | 0.95-1.05 | 17 | -0.0443 | 0.0202 | -0.1013 | 0.0133 | 19 | 0.058*** |
| | | | -0.81 | 0.34 | -0.85 | 0.16 | | 2.42 |
| | 0.90-0.95 | 17 | -0.0010 | 0.1225** | -0.0604 | 0.1614** | 19 | 0.162*** |
| | | | -0.01 | 2.30 | -0.50 | 2.21 | | 6.13 |
| 92-182 | 1.05-1.10 | 17 | 0.1022** | 0.0602* | 0.2339*** | 0.0888*** | 19 | -0.013 |
| | | | 2.02 | 1.95 | 4.50 | 2.90 | | -0.97 |
| | 0.95-1.05 | 17 | 0.0860*** | 0.0623** | 0.1142*** | 0.0866** | 19 | 0.001 |
| | | | 3.29 | 2.20 | 3.56 | 2.22 | | 0.06 |
| | 0.90-0.95 | 17 | 0.0577* | 0.0521* | 0.1670*** | 0.0209 | 19 | -0.037** |
| | | | 1.72 | 1.75 | 5.61 | 0.35 | | -2.26 |
| 183-273 | 1.05-1.10 | 17 | 0.1764*** | 0.0844* | 0.1302* | -0.0276 | 19 | -0.204*** |
| | | | 2.84 | 1.70 | 1.80 | -0.38 | | -9.02 |
| | 0.95-1.05 | 17 | 0.0619** | 0.0375 | 0.1367*** | 0.0582* | 19 | -0.004 |
| | | | 2.30 | 1.05 | 2.73 | 1.76 | | -0.36 |
| | 0.90-0.95 | 17 | 0.0959 | 0.0472 | 0.1332** | 0.0103 | 19 | -0.086*** |
| | | | 1.37 | 1.67 | 2.32 | 0.29 | | -4.68 |

## Table A21 All Options Liquidity, Information Asymmetry and Inventory Risk

Table A21 reports regression results for information asymmetry and inventory risk in the all options market. We estimate the time-series multivariate regression model $DOL_{i,t} = \gamma_{0,i} + \gamma_{1,i}DSL_{i,t} + \gamma_{2,i}DT_{i,t} + \gamma_{3,i}DOI_{i,t} + \gamma_{4,i}DV_{i,t} + \gamma_{4lag,i}DV_{i,t-1} + \gamma_{5,i}DSV_{i,t}^{res} + \gamma_{5lag,i}DSV_{i,t-1}^{res} + \gamma_6\, r_{i,t} + \gamma_7\, {r^2}_{i,t} + \gamma_8\, D_{1,t} + \gamma_9\, D_{2,t} + \varepsilon_{i,t}$ for all options on each stock and we report stacked values of the cross-sectional average of the coefficient across stocks and t-statistic. $D$ stands for percentage change, $SL$ for underlying stock liquidity, $T$ for number of distinct options on a stock traded, $OI$ for open interest, $V$ for option volume, $SV^{res}$ for residual from projection of stock market volume on options market volume, $r$ for return on stock, $r^2$ proxies for instantaneous volatility on stock, $D_1$ for year dummy for 2009, and $D_2$ for year dummy for 2010. Superscripts 1,2 and 3 indicate significance at 10%, 5% and 1% levels respectively. Liquidity of an option is measured as the percentage option bid-ask spread (option bid-ask spread as a percentage of underlying stock price.)

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\gamma_1$ | -0.002 | 0.000 | -0.003 | 0.001 | 0.000 | -0.003 | -0.005$^{2}$ | -0.002 | -0.002 | 0.006 | -0.008$^{1}$ | -0.005 | -0.008$^{2}$ | -0.006 | -0.001 |
| | -0.37 | 0.00 | -0.52 | 0.28 | -0.02 | -0.87 | -2.03 | -0.67 | -0.77 | 1.57 | -1.88 | -0.92 | -2.03 | -1.52 | -0.22 |
| $\gamma_2$ | 0.049 | -0.245$^{3}$ | 0.064 | -0.093 | -0.068 | -0.214$^{1}$ | -0.412$^{3}$ | -0.138$^{1}$ | -0.057 | -0.114$^{1}$ | -0.166$^{1}$ | -0.292$^{3}$ | 0.272$^{3}$ | 0.286$^{3}$ | 0.120$^{3}$ |
| | 0.26 | -2.84 | 1.18 | -1.47 | -0.92 | -1.78 | -4.79 | -1.79 | -0.93 | -1.96 | -1.81 | -2.67 | 3.45 | 2.99 | 3.83 |
| $\gamma_3$ | -0.198$^{3}$ | -0.104$^{1}$ | -0.023 | -0.010 | 0.014 | -0.061 | -0.041 | -0.004 | -0.012 | -0.003 | -0.013 | -0.041 | 0.022$^{3}$ | 0.009$^{3}$ | -0.002 |
| | -2.18 | -1.96 | -1.52 | -0.55 | 0.39 | -1.30 | -1.01 | -0.36 | -0.83 | -0.22 | -0.21 | -1.02 | 2.65 | 2.84 | -0.09 |
| $\gamma_4$ | 0.002$^{1}$ | 0.004$^{3}$ | 0.003$^{2}$ | 0.001 | 0.001 | 0.001 | 0.001$^{3}$ | 0.001 | 0.001$^{3}$ | 0.000 | 0.002$^{1}$ | 0.000 | 0.002$^{2}$ | 0.002$^{2}$ | 0.001 |
| | 1.70 | 2.49 | 2.31 | 1.02 | 0.61 | 0.80 | 2.81 | 1.61 | 2.78 | 0.60 | 1.86 | -0.43 | 2.06 | 2.17 | 0.52 |
| $\gamma_{4lag}$ | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | -0.001 | -0.001 | 0.001 | 0.002$^{1}$ | 0.002 |
| | 0.70 | 0.65 | 0.68 | -0.76 | 0.20 | 0.22 | -0.98 | -0.16 | -1.35 | 1.28 | -0.99 | -1.01 | 0.80 | 1.72 | 1.52 |
| $\gamma_5$ | 0.004 | 0.043$^{3}$ | 0.040$^{3}$ | 0.022$^{3}$ | -0.002 | 0.051$^{3}$ | 0.051$^{3}$ | 0.032$^{3}$ | 0.036$^{3}$ | 0.025$^{3}$ | 0.045$^{3}$ | 0.038$^{3}$ | 0.015$^{1}$ | -0.002 | 0.004 |
| | 0.18 | 3.24 | 3.03 | 2.65 | -0.13 | 3.54 | 6.58 | 4.63 | 3.95 | 3.18 | 4.52 | 4.08 | 1.79 | -0.29 | 0.53 |
| $\gamma_{5lag}$ | -0.019$^{1}$ | -0.008 | 0.000 | -0.013 | -0.002 | 0.016 | 0.004 | -0.003 | -0.007 | -0.005 | 0.012$^{1}$ | -0.007 | -0.020 | -0.006 | -0.002 |
| | -1.76 | -0.64 | 0.04 | -1.45 | -0.10 | 1.53 | 0.54 | -0.50 | -1.03 | -0.69 | 1.70 | -0.84 | -1.68 | -0.71 | -0.22 |
| $\gamma_6$ | -0.259 | -0.118 | -0.555 | -1.432$^{3}$ | -0.734$^{3}$ | 0.312 | -0.023 | -0.647$^{3}$ | -0.577$^{3}$ | -0.658$^{3}$ | -0.040 | -0.489$^{2}$ | -0.597$^{1}$ | -0.932$^{3}$ | -0.856$^{3}$ |
| | -0.58 | -0.43 | -1.06 | -6.60 | -2.70 | 0.86 | -0.07 | -3.02 | -2.38 | -3.21 | -0.11 | -2.20 | -1.95 | -2.46 | -2.75 |
| $\gamma_7$ | 0.669$^{3}$ | 0.510$^{3}$ | 0.250$^{1}$ | 0.055 | 0.282$^{3}$ | 0.818$^{3}$ | 0.402$^{3}$ | 0.088 | -0.003 | 0.283$^{2}$ | 0.582$^{3}$ | 0.273$^{2}$ | -0.148 | -0.251$^{2}$ | 0.130 |
| | 3.22 | 4.64 | 1.87 | 0.47 | 2.77 | 3.78 | 3.99 | 1.18 | -0.04 | 2.02 | 3.88 | 2.04 | -1.26 | -2.11 | 1.63 |
| $\gamma_8$ | -1.371 | -0.937 | -1.807 | 0.295 | -0.213 | -0.893 | -1.524 | -1.762$^{1}$ | -1.885$^{1}$ | -1.505 | -3.360$^{3}$ | -1.030 | -2.914 | -2.802 | -2.603$^{2}$ |
| | -1.16 | -0.96 | -0.73 | 0.34 | -0.11 | -0.68 | -1.34 | -1.96 | -1.77 | -1.67 | -2.62 | -1.03 | -1.36 | -1.31 | -2.12 |
| $\gamma_9$ | 3.859$^{1}$ | 3.689$^{2}$ | 0.166 | -0.092 | 1.339 | 2.465 | 3.378$^{2}$ | 1.230 | -0.214 | -0.335 | 1.872 | 4.763$^{3}$ | 0.485 | -1.291 | -2.140 |
| | 1.89 | 2.23 | 0.07 | -0.07 | 0.58 | 1.41 | 2.30 | 1.08 | -0.18 | -0.21 | 0.92 | 3.36 | 0.21 | -0.55 | -1.37 |
| $\gamma_0$ | 6.514$^{3}$ | 4.426$^{3}$ | 5.322$^{2}$ | 3.716$^{3}$ | 5.050$^{3}$ | 6.274$^{3}$ | 5.041$^{3}$ | 4.923$^{3}$ | 4.520$^{3}$ | 4.813$^{3}$ | 7.661$^{3}$ | 4.109$^{3}$ | 6.663$^{3}$ | 6.587$^{3}$ | 6.624$^{3}$ |
| | 4.50 | 4.66 | 2.14 | 3.81 | 4.04 | 5.59 | 4.39 | 4.84 | 4.56 | 4.99 | 5.94 | 4.58 | 3.02 | 2.85 | 4.80 |
| $N$ | 24 | 39 | 40 | 38 | 27 | 44 | 50 | 51 | 51 | 50 | 39 | 39 | 47 | 46 | 47 |
| $adjR^2$ | 20.85 | 15.17 | 21.66 | 14.97 | 13.09 | 16.55 | 11.82 | 22.21 | 17.50 | 17.36 | 13.44 | 8.95 | 44.54 | 30.37 | 24.92 |

## Table A21 (Continued)

| Maturity | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\gamma_1$ | 0.001 | -0.006$^{3}$ | -0.004$^{2}$ | 0.003 | 0.001 | 0.001 | -0.005 | -0.005 | -0.002 | 0.000 | 0.001 | 0.002 | 0.002 | 0.004 | 0.001 |
| | 0.44 | -2.34 | -2.08 | 0.63 | 0.39 | 0.35 | -1.51 | -1.65 | -0.78 | -0.15 | 0.41 | 0.64 | 0.36 | 1.63 | 0.36 |
| $\gamma_2$ | -0.147$^{3}$ | -0.269$^{3}$ | 0.097$^{1}$ | 0.239$^{3}$ | 0.164$^{3}$ | -0.497$^{3}$ | -0.365$^{3}$ | 0.030 | -0.152$^{2}$ | 0.046 | -0.225$^{3}$ | -0.339$^{3}$ | 0.317 | 0.189 | 0.278$^{2}$ |
| | -2.87 | -4.52 | 1.84 | 3.84 | 3.76 | -6.20 | -4.72 | 0.25 | -2.16 | 0.54 | -4.35 | -6.67 | 1.13 | 1.51 | 2.03 |
| $\gamma_3$ | -0.053$^{3}$ | -0.057$^{3}$ | 0.015 | 0.025$^{1}$ | 0.031$^{3}$ | -0.030 | -0.059$^{3}$ | 0.034$^{1}$ | 0.029$^{2}$ | 0.031$^{3}$ | -0.125$^{3}$ | -0.094$^{2}$ | 0.010$^{1}$ | 0.011 | 0.011$^{3}$ |
| | -2.80 | -3.55 | 0.94 | 1.75 | 3.48 | -1.21 | -2.89 | 1.93 | 2.22 | 3.05 | -3.79 | -2.25 | 1.84 | 1.52 | 3.44 |
| $\gamma_4$ | 0.001$^{3}$ | 0.001 | 0.001$^{2}$ | 0.001$^{3}$ | 0.001 | 0.001$^{1}$ | 0.000 | 0.001$^{3}$ | 0.001 | 0.002$^{2}$ | 0.001$^{3}$ | 0.001 | 0.004$^{1}$ | 0.002$^{1}$ | 0.005$^{2}$ |
| | 2.55 | 1.61 | 2.08 | 2.51 | 1.69 | 1.87 | -0.26 | 2.30 | 1.53 | 2.11 | 2.63 | 1.55 | 1.87 | 1.77 | 2.38 |
| $\gamma_{4lag}$ | 0.001 | 0.000 | 0.000 | 0.000 | -0.001$^{1}$ | -0.001 | -0.001 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001$^{1}$ | 0.002 | 0.000 | 0.002 |
| | 0.89 | 0.94 | -0.15 | -0.09 | -1.84 | -1.48 | -1.65 | -0.05 | 0.37 | 0.03 | 0.19 | -1.91 | 1.03 | 0.40 | 1.22 |
| $\gamma_5$ | 0.022$^{3}$ | 0.018$^{3}$ | 0.020$^{3}$ | 0.020$^{3}$ | 0.008 | 0.024$^{3}$ | 0.024$^{3}$ | 0.011$^{1}$ | 0.018$^{3}$ | 0.007 | 0.031$^{3}$ | 0.034$^{3}$ | 0.022$^{2}$ | 0.020$^{1}$ | 0.011 |
| | 3.20 | 2.84 | 3.08 | 2.86 | 1.50 | 3.72 | 3.23 | 1.75 | 2.67 | 0.89 | 4.28 | 5.16 | 2.20 | 1.88 | 1.28 |
| $\gamma_{5lag}$ | 0.004 | -0.004 | -0.013$^{2}$ | -0.015$^{2}$ | -0.009 | 0.000 | -0.001 | -0.013$^{2}$ | -0.005 | -0.004 | -0.001 | -0.008 | 0.023 | -0.019$^{2}$ | 0.012 |
| | 0.79 | -0.56 | -2.31 | -2.24 | -1.63 | 0.03 | -0.19 | -2.11 | -0.76 | -0.59 | -0.14 | -0.91 | 0.96 | -2.20 | 0.58 |
| $\gamma_6$ | -0.592$^{3}$ | -0.626$^{3}$ | -0.747$^{3}$ | -0.510$^{3}$ | -0.959$^{3}$ | -0.940$^{3}$ | -0.918$^{3}$ | -0.964$^{3}$ | -0.757$^{3}$ | -0.995$^{3}$ | -0.890$^{3}$ | -0.926$^{3}$ | -0.670$^{3}$ | -1.004$^{3}$ | -0.778$^{3}$ |
| | -3.75 | -3.96 | -5.30 | -2.62 | -6.01 | -4.74 | -5.50 | -4.64 | -4.19 | -5.87 | -4.79 | -5.95 | -2.51 | -6.35 | -3.82 |
| $\gamma_7$ | 0.281$^{3}$ | 0.094$^{1}$ | 0.143$^{3}$ | 0.018 | 0.074$^{1}$ | 0.292$^{3}$ | 0.150$^{3}$ | 0.077$^{1}$ | 0.028 | 0.054$^{1}$ | 0.138$^{3}$ | -0.043 | -0.083 | 0.019 | -0.042 |
| | 6.04 | 1.94 | 3.55 | 0.41 | 1.70 | 5.18 | 2.73 | 1.89 | 0.70 | 1.69 | 2.47 | -1.02 | -1.08 | 0.41 | -0.63 |
| $\gamma_8$ | -0.294 | 0.712 | -0.745 | -1.186 | -1.338 | -1.028 | -1.234 | -4.355 | -3.424 | -2.684 | 0.013 | 0.181 | -12.061 | -1.564 | -9.275 |
| | -0.50 | 1.35 | -0.62 | -0.43 | -0.64 | -0.95 | -0.67 | -1.69 | -1.55 | -0.93 | 0.03 | 0.23 | -1.06 | -1.68 | -0.94 |
| $\gamma_9$ | 2.967$^{3}$ | 6.046$^{3}$ | 2.579$^{2}$ | 1.444 | -0.237 | 3.100$^{3}$ | 2.753 | -0.758 | 0.516 | -2.088 | 5.641$^{3}$ | 3.370$^{3}$ | -10.892 | 0.569 | -9.148 |
| | 3.34 | 5.84 | 2.19 | 0.51 | -0.11 | 2.84 | 1.54 | -0.27 | 0.24 | -0.69 | 6.38 | 2.72 | -0.88 | 0.42 | -0.84 |
| $\gamma_0$ | 3.653$^{3}$ | 2.207$^{3}$ | 3.540$^{3}$ | 3.714 | 4.527$^{2}$ | 4.292$^{3}$ | 4.923$^{3}$ | 7.583$^{3}$ | 5.289$^{3}$ | 6.541$^{2}$ | 1.798$^{3}$ | 1.650$^{3}$ | 14.920 | 3.210$^{3}$ | 13.074 |
| | 6.91 | 4.46 | 3.61 | 1.32 | 2.08 | 4.57 | 2.71 | 2.78 | 2.49 | 2.26 | 4.23 | 2.65 | 1.19 | 3.81 | 1.19 |
| $N$ | 65 | 63 | 65 | 65 | 65 | 63 | 63 | 63 | 64 | 64 | 19 | 19 | 19 | 19 | 19 |
| $adjR^2$ | 12.56 | 7.99 | 28.68 | 29.26 | 32.61 | 13.81 | 11.02 | 32.64 | 28.90 | 32.83 | 9.65 | 12.35 | 49.10 | 51.09 | 43.09 |

## Table A22 Call Option Liquidity, Information Asymmetry and Inventory Risk

Table A22 reports regression results for information asymmetry and inventory risk in the call options market. We estimate the time-series multivariate regression model $DOL_{i,t} = \gamma_{0,i} + \gamma_{1,i}DSL_{i,t} + \gamma_{2,i}DT_{i,t} + \gamma_{3,i}DOI_{i,t} + \gamma_{4,i}DV_{i,t} + \gamma_{4lag,i}DV_{i,t-1} + \gamma_{5,i}DSV^{res}_{i,t} + \gamma_{5lag,i}DSV^{res}_{i,t-1} + \gamma_6\, r_{i,t} + \gamma_7\, r^2{}_{i,t} + \gamma_8\, D_{1,t} + \gamma_9\, D_{2,t} + \varepsilon_{i,t}$ for call options on each stock and we report stacked values of the cross-sectional average of the coefficient across stocks and t-statistic. $D$ stands for percentage change, $SL$ for underlying stock liquidity, $T$ for number of distinct options on a stock traded, $OI$ for open interest, $V$ for option volume, $SV^{res}$ for residual from projection of stock market volume on options market volume, $r$ for return on stock, $r^2$ proxies for instantaneous volatility on stock, $D_1$ for year dummy for 2009, and $D_2$ for year dummy for 2010. Superscripts 1, 2 and 3 indicate significance at 10%, 5% and 1% levels respectively. Liquidity of an option is measured as percentage option bid-ask spread (option bid-ask spread as a percentage of underlying stock price.)

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\gamma_1$ | 0.011 | 0.003 | -0.003 | 0.010 | 0.006 | 0.005 | -0.003 | -0.001 | 0.001 | -0.003 | 0.002 | -0.010 | -0.003 | 0.004 | 0.011 |
| | 1.15 | 0.43 | -0.44 | 1.19 | 0.64 | 1.23 | -0.67 | -0.34 | 0.22 | -0.57 | 0.69 | -1.36 | -0.65 | 0.56 | 1.24 |
| $\gamma_2$ | -0.146 | -0.283$^{2}$ | 0.008 | 0.004 | -0.024 | -0.403$^{3}$ | -0.275$^{3}$ | -0.065 | -0.020 | -0.023 | -0.342$^{3}$ | -0.125$^{2}$ | 0.218$^{2}$ | 0.189$^{2}$ | 0.110$^{3}$ |
| | -0.97 | -2.29 | 0.22 | 0.09 | -0.65 | -3.44 | -4.21 | -0.99 | -0.26 | -0.49 | -5.77 | -2.35 | 2.09 | 2.12 | 4.22 |
| $\gamma_3$ | 0.020 | -0.189$^{2}$ | 0.009 | 0.000 | -0.001 | 0.071$^{2}$ | -0.007 | -0.006 | 0.003 | -0.003 | 0.011 | -0.056 | 0.012$^{3}$ | -0.007 | 0.011 |
| | 0.23 | -2.19 | 0.71 | -0.06 | -0.08 | 2.02 | -0.17 | -0.40 | 0.13 | -0.22 | 0.39 | -1.36 | 2.74 | -0.42 | 1.36 |
| $\gamma_4$ | 0.001 | 0.000 | 0.002 | -0.001 | 0.001 | 0.003$^{2}$ | 0.001$^{1}$ | 0.001 | 0.000 | 0.000 | 0.001 | 0.002$^{2}$ | 0.001 | 0.003$^{1}$ | 0.001$^{2}$ |
| | 0.58 | -0.19 | 1.38 | -0.65 | 0.78 | 2.53 | 1.75 | 1.47 | 0.25 | 1.00 | 1.42 | 2.08 | 1.28 | 1.89 | 2.08 |
| $\gamma_{4lag}$ | 0.000 | 0.001 | 0.000 | -0.001 | -0.001 | 0.000 | -0.001 | -0.001$^{1}$ | 0.000 | 0.000 | 0.000 | 0.001 | 0.001$^{1}$ | 0.000 | 0.000 |
| | 0.03 | 0.81 | -0.73 | -1.30 | -0.87 | -1.11 | -0.85 | -1.72 | 0.69 | 0.10 | -0.03 | 0.85 | 1.75 | 0.36 | -0.50 |
| $\gamma_5$ | -0.009 | 0.037$^{2}$ | 0.022 | -0.001 | 0.024 | 0.063$^{3}$ | 0.041$^{3}$ | 0.038$^{3}$ | 0.039 | 0.011 | 0.047$^{3}$ | 0.027$^{2}$ | 0.030$^{3}$ | 0.030$^{2}$ | 0.006 |
| | -0.36 | 2.12 | 1.63 | -0.08 | 0.71 | 3.42 | 3.60 | 5.32 | 4.60 | 0.61 | 4.10 | 2.10 | 3.21 | 2.38 | 0.61 |
| $\gamma_{5lag}$ | -0.025 | -0.013 | -0.008 | -0.007 | 0.014 | 0.011 | 0.000 | -0.006 | -0.019 | -0.023 | 0.003 | -0.009 | -0.004 | -0.005 | -0.021$^{2}$ |
| | -1.61 | -0.75 | -0.48 | -0.51 | 0.52 | 0.90 | -0.03 | -0.69 | -1.47 | -1.35 | 0.35 | -0.83 | -0.41 | -0.31 | -2.12 |
| $\gamma_6$ | 2.805$^{3}$ | 4.145$^{3}$ | 2.914$^{3}$ | 0.019 | -0.583 | 3.174$^{3}$ | 3.441$^{3}$ | 2.256$^{3}$ | 0.525 | -1.024$^{3}$ | 3.759$^{3}$ | 3.362$^{3}$ | 1.909$^{3}$ | 0.082 | -0.449$^{1}$ |
| | 7.07 | 10.87 | 8.89 | 0.05 | -1.01 | 6.90 | 6.64 | 6.86 | 1.34 | -2.63 | 9.84 | 7.05 | 6.10 | 0.19 | -1.79 |
| $\gamma_7$ | 0.267$^{3}$ | 0.190 | 0.181$^{1}$ | 0.273 | 0.131$^{2}$ | 0.247 | 0.007 | -0.019 | -0.001 | 0.191 | 0.092 | 0.040 | -0.010 | -0.188 | 0.026 |
| | 2.73 | 1.41 | 1.84 | 1.68 | 2.11 | 1.15 | 0.05 | -0.18 | -0.01 | 0.94 | 1.25 | 0.23 | -0.10 | -1.55 | 0.34 |
| $\gamma_8$ | 1.040 | 1.139 | -2.369 | 0.612 | -4.262$^{2}$ | -1.322 | 0.702 | -0.471 | -0.818 | 1.217 | 1.251 | 1.596 | -1.961 | -3.355 | -3.953$^{2}$ |
| | 0.60 | 1.21 | -1.08 | 0.46 | -2.18 | -1.13 | 0.77 | -0.53 | -0.54 | 0.87 | 0.94 | 0.76 | -1.18 | -1.32 | -2.30 |
| $\gamma_9$ | 7.298$^{3}$ | 7.347$^{3}$ | 0.658 | 1.161 | -0.365 | 5.526$^{3}$ | 5.830$^{3}$ | 3.150$^{3}$ | 1.054 | 2.146 | 6.337$^{3}$ | 7.492$^{3}$ | 1.808 | -0.363 | -3.790$^{1}$ |
| | 3.07 | 3.62 | 0.28 | 0.60 | -0.09 | 2.95 | 3.73 | 2.96 | 0.62 | 1.28 | 3.92 | 2.96 | 1.09 | -0.14 | -1.78 |
| $\gamma_0$ | 3.728$^{2}$ | 2.961$^{3}$ | 5.230$^{2}$ | 4.613$^{3}$ | 6.752$^{3}$ | 3.700$^{3}$ | 2.740$^{3}$ | 3.987$^{3}$ | 3.009$^{2}$ | 3.944$^{3}$ | 2.978$^{3}$ | 0.874$^{3}$ | 4.539$^{3}$ | 5.831$^{2}$ | 8.114$^{3}$ |
| | 2.34 | 3.00 | 2.32 | 3.43 | 4.88 | 3.57 | 2.67 | 5.19 | 2.10 | 3.76 | 3.39 | 0.40 | 2.62 | 2.37 | 4.04 |
| $N$ | 21 | 25 | 32 | 26 | 18 | 31 | 40 | 40 | 38 | 28 | 27 | 30 | 35 | 34 | 28 |
| $adjR^2$ | 19.22 | 14.33 | 23.32 | 12.02 | 15.17 | 15.68 | 14.68 | 21.79 | 16.82 | 12.97 | 12.33 | 11.78 | 38.38 | 23.88 | 16.74 |

## Table A22 (Continued)

| Maturity<br>Moneyness | 4<br>DITM | 4<br>ITM | 4<br>ATM | 4<br>OTM | 4<br>DOTM | 5<br>DITM | 5<br>ITM | 5<br>ATM | 5<br>OTM | 5<br>DOTM | 6<br>DITM | 6<br>ITM | 6<br>ATM | 6<br>OTM | 6<br>DOTM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1$ | 0.001 | 0.0002 | -0.005[1] | 0.006 | 0.003 | -0.004 | 0.002 | -0.006 | -0.006[1] | 0.002 | 0.002 | 0.002 | 0.005 | 0.000 | 0.002 |
| | 0.24 | 0.06 | -1.83 | 1.63 | 0.97 | -1.11 | 0.39 | -1.62 | -1.69 | 0.49 | 0.77 | 0.53 | 1.24 | -0.14 | 0.76 |
| $\gamma_2$ | -0.152[3] | -0.123[2] | 0.082 | 0.072 | 0.103[3] | -0.296[3] | -0.152[2] | -0.042 | -0.044 | 0.135[2] | -0.204[3] | -0.102 | 0.071 | -0.065 | 0.140[3] |
| | -2.77 | -2.25 | 1.30 | 0.99 | 3.35 | -4.84 | -2.31 | -0.37 | -0.54 | 2.16 | -4.35 | -1.57 | 1.12 | -0.67 | 3.48 |
| $\gamma_3$ | -0.024 | -0.098[3] | -0.002 | 0.032 | 0.031 | 0.003 | -0.082[3] | 0.026[2] | 0.038[2] | 0.032[1] | -0.036[1] | -0.076[3] | -0.031 | -0.029 | 0.001 |
| | -1.04 | -4.77 | -0.09 | 1.10 | 1.37 | 0.10 | -3.60 | 2.00 | 2.21 | 1.73 | -1.76 | -2.43 | -1.35 | -1.00 | 0.15 |
| $\gamma_4$ | 0.001[2] | 0.000 | 0.001 | 0.000 | 0.001[1] | 0.001 | 0.001 | 0.001 | 0.000 | 0.002[2] | 0.001 | 0.001 | 0.001[3] | 0.001 | 0.001 |
| | 2.29 | 0.70 | 0.91 | 0.67 | 1.69 | 0.69 | 1.33 | 0.83 | 0.46 | 2.33 | 1.27 | 1.19 | 3.04 | 1.67 | 1.17 |
| $\gamma_{4lag}$ | -0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.001 | 0.001 | -0.001 | 0.000 | -0.001[1] | 0.0001 | 0.0001 | 0.001 |
| | -1.26 | 0.85 | -0.65 | -0.64 | -0.39 | -0.57 | -0.93 | 1.22 | 0.90 | -0.95 | 0.46 | -1.82 | 0.01 | 0.35 | 1.66 |
| $\gamma_5$ | 0.030[3] | 0.021[1] | 0.027[3] | 0.034[3] | 0.019[3] | 0.031[3] | 0.040[3] | 0.026[3] | 0.026[2] | 0.027[3] | 0.025[3] | 0.042[3] | 0.029[3] | 0.030[2] | 0.012 |
| | 3.54 | 1.87 | 2.55 | 3.01 | 3.08 | 2.73 | 3.28 | 2.55 | 2.08 | 3.27 | 2.51 | 3.72 | 3.10 | 2.00 | 1.05 |
| $\gamma_{5lag}$ | 0.003 | -0.008 | -0.012[1] | -0.012 | -0.009 | -0.003 | 0.000 | -0.014 | -0.021[3] | -0.015 | 0.000 | -0.007 | -0.002 | -0.010 | -0.014[2] |
| | 0.51 | -0.96 | -1.71 | -1.25 | -1.12 | -0.51 | 0.02 | -1.65 | -2.75 | -1.27 | 0.08 | -0.67 | -0.21 | -1.36 | -2.08 |
| $\gamma_6$ | 2.104[3] | 1.889[3] | 1.447[3] | 0.841[3] | -0.414 | 1.876[3] | 0.770[3] | 1.040[3] | 0.276 | -0.748[3] | 1.060[1] | 0.843 | 0.502[1] | 0.207 | -0.338 |
| | 9.67 | 5.49 | 5.37 | 2.99 | -1.44 | 6.67 | 2.49 | 3.78 | 1.12 | -2.91 | 1.96 | 1.62 | 1.83 | 0.64 | -1.60 |
| $\gamma_7$ | 0.125[2] | 0.098 | 0.143[2] | 0.017 | 0.113[1] | 0.193[3] | 0.080 | 0.007 | 0.245 | 0.058 | 0.073 | -0.073 | -0.057 | -0.044 | 0.036 |
| | 2.14 | 1.19 | 2.00 | 0.26 | 1.88 | 2.88 | 0.85 | 0.15 | 1.43 | 1.32 | 1.39 | -1.40 | -1.43 | -0.52 | 0.83 |
| $\gamma_8$ | -0.121 | 0.242 | -0.330 | -2.059 | -0.089 | 0.724 | -0.108 | -2.093 | -1.642[1] | -2.965[2] | 0.340 | -0.065 | -0.783 | -1.056 | 0.033 |
| | -0.20 | 0.34 | -0.19 | -0.99 | -0.04 | 0.99 | -0.15 | -1.15 | -1.87 | -1.93 | 0.88 | -0.09 | -0.68 | -0.90 | 0.07 |
| $\gamma_9$ | 3.573[3] | 7.240[3] | 3.941[2] | 1.957 | 0.639 | 6.180[3] | 5.826[3] | 1.671 | 3.119[3] | -1.790 | 4.910[3] | 3.168[2] | 0.720 | 1.408 | 1.433[1] |
| | 4.34 | 5.20 | 2.33 | 0.84 | 0.28 | 6.34 | 5.04 | 0.89 | 2.71 | -0.89 | 6.40 | 2.37 | 0.81 | 1.09 | 1.81 |
| $\gamma_0$ | 3.200[3] | 2.230[3] | 2.628 | 3.494 | 2.756 | 1.769[3] | 2.713[3] | 4.917[3] | 2.839[3] | 6.253[3] | 1.243[3] | 1.953[3] | 3.165[3] | 2.797[2] | 2.700[3] |
| | 5.17 | 3.32 | 1.44 | 1.57 | 1.21 | 2.84 | 4.10 | 2.61 | 3.81 | 3.55 | 3.61 | 2.42 | 3.86 | 2.38 | 4.10 |
| $N$ | 53 | 51 | 57 | 53 | 56 | 52 | 48 | 55 | 51 | 52 | 20 | 19 | 20 | 19 | 19 |
| $adjR^2$ | 11.33 | 10.15 | 20.78 | 23.66 | 25.45 | 10.38 | 9.83 | 27.19 | 29.80 | 27.64 | 10.69 | 13.74 | 29.65 | 41.19 | 35.46 |

## Table A23 Put Option Liquidity, Information Asymmetry and Inventory Risk

Table A23 reports regression results for information asymmetry and inventory risk in the put options market. We estimate the time-series multivariate regression model $DOL_{i,t} = \gamma_{0,i} + \gamma_{1,i}DSL_{i,t} + \gamma_{2,i}DT_{i,t} + \gamma_{3,i}DOI_{i,t} + \gamma_{4,i}DV_{i,t} + \gamma_{4lag,i}DV_{i,t-1} + \gamma_{5,i}DSV_{i,t}^{res} + \gamma_{5lag,i}DSV_{i,t-1}^{res} + \gamma_6\, r_{i,t} + \gamma_7\, r^2{}_{i,t} + \gamma_8\, D_{1,t} + \gamma_9\, D_{2,t} + \varepsilon_{i,t}$ for put options on each stock and we report stacked values of the cross-sectional average of the coefficient across stocks and t-statistic. $D$ stands for percentage change, $SL$ for underlying stock liquidity, $T$ for number of distinct options on a stock traded, $OI$ for open interest, $V$ for option volume, $SV^{res}$ for residual from projection of stock market volume on options market volume, $r$ for return on stock, $r^2$ proxies for instantaneous volatility on stock, $D_1$ for year dummy for 2009, and $D_2$ for year dummy for 2010. Superscripts 1,2 and 3 indicate significance at 10%, 5% and 1% levels respectively. Liquidity of an option is measured as percentage option bid-ask spread (option bid-ask spread as a percentage of underlying stock price.)

| Maturity | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM | DITM | ITM | ATM | OTM | DOTM |
| $\gamma_1$ | 0.014 | 0.000 | 0.001 | -0.005 | 0.001 | 0.001 | -0.007[1] | 0.003 | 0.006[1] | 0.004 | 0.000 | 0.003 | 0.001 | 0.003 | 0.002 |
| | 1.10 | 0.02 | 0.20 | -0.95 | 0.18 | 0.22 | -1.84 | 0.87 | 1.71 | 1.10 | 0.12 | 0.39 | 0.07 | 0.46 | 0.45 |
| $\gamma_2$ | -0.388[1] | -0.390[3] | 0.143[1] | -0.004 | 0.032 | -0.147 | -0.312[3] | -0.057 | -0.022 | 0.033 | -0.094 | -0.360[3] | 0.235[3] | 0.177 | 0.171[2] |
| | -1.86 | -2.41 | 1.90 | -0.05 | 0.67 | -1.67 | -3.29 | -0.63 | -0.37 | 0.78 | -0.79 | -2.64 | 2.48 | 1.55 | 2.15 |
| $\gamma_3$ | -0.037 | -0.039 | -0.028 | -0.010 | -0.012 | -0.124[3] | -0.045 | 0.024 | -0.042 | 0.007 | -0.077 | -0.120[3] | 0.019[3] | 0.001 | 0.010[3] |
| | -0.24 | -0.52 | -1.64 | -0.72 | -0.93 | -2.49 | -0.95 | 1.32 | -0.63 | 0.23 | -1.60 | -2.54 | 2.70 | 0.08 | 2.53 |
| $\gamma_4$ | 0.001 | 0.003[1] | 0.003[2] | 0.001 | 0.000 | 0.003 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001[1] |
| | 0.38 | 1.70 | 2.08 | 0.93 | 0.21 | 1.10 | 0.00 | -0.15 | 1.21 | 1.60 | -0.28 | 0.35 | 1.51 | 0.86 | 1.91 |
| $\gamma_{4lag}$ | 0.004 | 0.000 | -0.002[1] | -0.002[1] | -0.001 | 0.001 | 0.000 | -0.001[1] | -0.001 | -0.001[2] | -0.001[1] | -0.001 | -0.001[3] | -0.001 | 0.000 |
| | 0.90 | 0.00 | -1.73 | -1.83 | -1.24 | 1.58 | -0.15 | -1.92 | -0.70 | -2.13 | -1.86 | -0.99 | -2.43 | -1.44 | -0.01 |
| $\gamma_5$ | 0.039 | 0.042[3] | 0.043[3] | 0.028[1] | 0.002 | 0.052[3] | 0.061[3] | 0.045[3] | 0.045[3] | 0.024[2] | 0.035[3] | 0.035[3] | 0.036[3] | 0.025[2] | 0.013 |
| | 1.16 | 2.43 | 2.53 | 1.97 | 0.13 | 2.72 | 5.37 | 5.12 | 4.73 | 2.40 | 2.81 | 2.55 | 3.56 | 2.20 | 0.91 |
| $\gamma_{5lag}$ | 0.032 | -0.012 | 0.014 | -0.023 | 0.016 | -0.012 | 0.006 | 0.005 | 0.005 | 0.010 | 0.003 | -0.008 | -0.013 | 0.009 | 0.012 |
| | 0.88 | -0.80 | 1.09 | -1.53 | 1.01 | -0.87 | 0.59 | 0.56 | 0.73 | 1.10 | 0.29 | -0.71 | -1.11 | 1.00 | 1.27 |
| $\gamma_6$ | -6.033[3] | -5.751[3] | -5.308[3] | -2.699[3] | -1.563[3] | -5.374[3] | -5.317[3] | -3.665[3] | -1.355[3] | -0.826[3] | -5.050[3] | -4.847[3] | -3.051[3] | -2.191[3] | -1.300[3] |
| | -6.89 | -17.77 | -11.81 | -5.00 | -3.70 | -14.23 | -14.12 | -11.77 | -2.96 | -2.46 | -11.67 | -7.90 | -9.49 | -5.35 | -3.48 |
| $\gamma_7$ | 0.164 | 0.088 | -0.008 | -0.091 | 0.259[1] | 0.205[2] | 0.138 | 0.087 | -0.001 | 0.188[2] | 0.221[3] | 0.141 | -0.005 | 0.054 | 0.196[2] |
| | 1.14 | 0.96 | -0.06 | -0.80 | 1.87 | 2.28 | 1.04 | 0.96 | -0.02 | 2.00 | 3.00 | 1.54 | -0.05 | 0.48 | 2.13 |
| $\gamma_8$ | 0.516 | 0.958 | 0.032 | 2.251 | 1.924 | 0.006 | 0.107 | -2.381[2] | -4.791[1] | -0.478 | -1.223 | -2.583[3] | 1.684 | -2.288 | -1.373 |
| | 0.23 | 0.68 | 0.02 | 1.45 | 1.43 | 0.00 | 0.08 | -2.05 | -1.69 | -0.31 | -0.84 | -2.67 | 0.65 | -0.86 | -0.80 |
| $\gamma_9$ | 2.853 | 4.239[1] | 2.527 | 2.143 | 5.221[2] | 4.222[1] | 6.005[3] | 1.474 | -1.431 | 0.719 | 3.750[1] | 3.277[3] | 3.392 | -0.664 | -0.175 |
| | 0.55 | 1.98 | 1.56 | 1.40 | 2.22 | 1.84 | 4.68 | 1.33 | -0.53 | 0.48 | 1.69 | 2.65 | 1.48 | -0.28 | -0.08 |
| $\gamma_0$ | 5.762[3] | 3.183[3] | 4.737[3] | 3.619[3] | 2.496[2] | 5.648[3] | 3.301[3] | 5.065[3] | 7.014[2] | 4.216[3] | 6.080[3] | 5.076[3] | 2.790 | 6.174[3] | 5.112[3] |
| | 2.99 | 2.82 | 2.98 | 2.84 | 2.35 | 4.10 | 2.73 | 4.63 | 2.38 | 3.21 | 4.68 | 5.15 | 1.25 | 2.64 | 2.47 |
| $N$ | 14 | 24 | 34 | 28 | 23 | 25 | 32 | 40 | 39 | 32 | 26 | 28 | 35 | 34 | 32 |
| $adjR^2$ | 38.30 | 25.44 | 27.84 | 16.84 | 12.32 | 23.04 | 16.72 | 24.54 | 18.86 | 16.57 | 19.15 | 12.88 | 31.88 | 28.09 | 22.46 |

**Table A23 (Continued)**

| Maturity<br>Moneyness | 4<br>DITM | 4<br>ITM | 4<br>ATM | 4<br>OTM | 4<br>DOTM | 5<br>DITM | 5<br>ITM | 5<br>ATM | 5<br>OTM | 5<br>DOTM | 6<br>DITM | 6<br>ITM | 6<br>ATM | 6<br>OTM | 6<br>DOTM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1$ | -0.004[1] | -0.006 | -0.008[1] | -0.002 | 0.001 | -0.002 | -0.001 | -0.006 | -0.001 | -0.006 | 0.002 | 0.007[1] | 0.001 | 0.007 | 0.003 |
| | -1.82 | -1.42 | -2.11 | -0.49 | 0.34 | -0.38 | -0.11 | -1.25 | -0.11 | -1.60 | 0.53 | 1.90 | 0.38 | 1.45 | 0.61 |
| $\gamma_2$ | -0.232[3] | -0.214[3] | -0.058 | 0.034 | 0.279[3] | -0.465[3] | -0.426[3] | -0.124 | -0.103 | 0.044 | -0.250[3] | -0.319[3] | 0.563 | 0.169 | 0.484 |
| | -3.23 | -3.36 | -0.79 | 0.54 | 4.02 | -4.28 | -2.94 | -1.40 | -0.85 | 0.56 | -4.01 | -3.96 | 0.98 | 1.26 | 1.39 |
| $\gamma_3$ | -0.038[1] | -0.049[1] | -0.012 | -0.012 | 0.020 | -0.026 | -0.054[3] | -0.005 | 0.010 | 0.005 | -0.023 | -0.087[3] | 0.023 | 0.007 | 0.006 |
| | -1.93 | -1.88 | -0.43 | -0.58 | 1.04 | -0.95 | -2.41 | -0.19 | 0.24 | 0.33 | -0.71 | -2.48 | 0.98 | 0.68 | 0.60 |
| $\gamma_4$ | 0.000 | 0.001 | 0.001 | 0.002[3] | 0.001 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | 0.48 | 1.49 | 1.52 | 2.52 | 1.31 | -0.42 | 0.83 | -0.54 | 0.97 | 1.34 | 0.11 | 0.44 | 1.29 | -0.51 | 1.63 |
| $\gamma_{4lag}$ | -0.001 | 0.001 | -0.001 | 0.001 | -0.001 | 0.000 | -0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | -1.56 | 0.87 | -1.50 | 1.13 | -1.55 | -0.09 | -1.16 | -0.37 | 0.18 | 1.12 | -1.29 | -0.40 | 0.30 | -0.04 | 0.80 |
| $\gamma_5$ | 0.031[3] | 0.032[3] | 0.029[3] | 0.024[3] | 0.000 | 0.035[3] | 0.018 | 0.028[2] | 0.029[3] | 0.020[2] | 0.027[3] | 0.030[3] | 0.030[1] | 0.013 | 0.007 |
| | 2.76 | 3.89 | 2.89 | 2.54 | -0.03 | 3.20 | 1.59 | 2.02 | 3.05 | 2.01 | 4.35 | 3.05 | 1.93 | 1.50 | 0.88 |
| $\gamma_{5lag}$ | 0.007 | 0.007 | -0.003 | -0.015[2] | -0.009 | -0.007 | -0.004 | -0.006 | 0.003 | -0.006 | -0.006 | -0.010 | 0.006 | -0.009 | 0.015 |
| | 0.85 | 0.82 | -0.35 | -2.17 | -1.49 | -0.97 | -0.42 | -0.59 | 0.37 | -0.76 | -0.88 | -0.94 | 0.79 | -0.84 | 0.68 |
| $\gamma_6$ | -3.468[3] | -3.263[3] | -2.378[3] | -1.543[3] | -1.235[3] | -3.259[3] | -3.214[3] | -2.852[3] | -2.387[3] | -1.411[3] | -2.734[3] | -2.268[3] | -1.946[3] | -2.048[3] | -1.515[3] |
| | -14.87 | -11.43 | -9.21 | -6.12 | -4.66 | -10.64 | -9.54 | -9.83 | -7.33 | -5.10 | -10.50 | -6.59 | -5.24 | -8.23 | -5.10 |
| $\gamma_7$ | 0.163[3] | 0.008 | 0.117[2] | 0.166[3] | 0.164[3] | 0.179[3] | 0.147[1] | 0.056 | 0.086 | 0.166[3] | 0.003 | -0.067 | -0.048 | 0.091[1] | -0.008 |
| | 3.06 | 0.09 | 2.25 | 3.44 | 2.47 | 2.73 | 1.79 | 0.79 | 1.15 | 2.88 | 0.07 | -1.52 | -0.67 | 1.90 | -0.10 |
| $\gamma_8$ | -0.709 | 1.225 | 0.608 | -1.827 | -1.586 | 0.265 | 1.104 | -1.723 | -0.245 | 0.444 | -0.776 | -0.346 | -10.690 | -0.880 | -9.062 |
| | -0.63 | 1.40 | 0.59 | -1.33 | -1.51 | 0.24 | 0.86 | -1.26 | -0.16 | 0.39 | -1.26 | -0.31 | -0.97 | -0.87 | -0.87 |
| $\gamma_9$ | 4.304[3] | 6.206[3] | 4.817[3] | 0.834 | 0.442 | 5.471[3] | 5.615[3] | 3.943[3] | 4.674[3] | 2.326[1] | 5.345[3] | 2.509 | -9.336 | 0.607 | -7.903 |
| | 2.74 | 4.30 | 3.33 | 0.61 | 0.27 | 4.47 | 3.35 | 2.58 | 2.89 | 1.90 | 4.33 | 1.56 | -0.76 | 0.69 | -0.69 |
| $\gamma_0$ | 4.438[3] | 2.406[3] | 3.112[3] | 4.126[3] | 5.032[3] | 3.131[3] | 2.868[3] | 5.180[3] | 2.776[1] | 3.448[3] | 2.532[3] | 2.331[3] | 13.972 | 3.220[3] | 13.752 |
| | 3.94 | 2.52 | 3.25 | 3.34 | 4.46 | 3.38 | 2.53 | 3.81 | 1.82 | 3.40 | 4.39 | 2.10 | 1.16 | 4.06 | 1.16 |
| $N$ | 49 | 46 | 50 | 49 | 51 | 50 | 46 | 50 | 48 | 48 | 19 | 19 | 19 | 19 | 19 |
| $adjR^2$ | 15.91 | 10.88 | 20.15 | 23.72 | 30.05 | 16.74 | 15.55 | 27.02 | 26.92 | 30.19 | 11.81 | 8.92 | 35.48 | 37.22 | 38.95 |

**Table A24**

**Robustness Check: Liquidity Comovement of Call Options (Proportional Spread)**

This table presents the results of liquidity comovement between call options and their options market for the period from July 2009 to Dec 2010, excluding the crisis period. For each stock in its moneyness portfolio for maturity between 91 and 182 days, all options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ is a dummy variable for 2009, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of put options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0.0017 | -0.0007 | -0.0011 | 0.002 | -0.0001 |
| | 0.91 | -0.25 | -0.41 | 0.67 | -0.03 |
| | 52.63 | 44.74 | 51.32 | 48.68 | 45.95 |
| $\beta_2$ | 0.8458[1] | 0.8041[1] | 0.6844[1] | 0.5845[1] | 0.2828[1] |
| | 10.54 | 8.27 | 9.61 | 8.52 | 7.34 |
| | 88.16 | 86.84 | 86.84 | 90.79 | 82.43 |
| $\beta_{2lag}$ | -0.0592 | 0.029 | -0.0027 | 0.0622 | 0.033 |
| | -1.99 | 0.68 | -0.1 | 1.48 | 2.24 |
| | 42.11 | 53.95 | 50 | 61.84 | 58.11 |
| $\beta_2 + \beta_{2lag}$ | 0.7867[1] | 0.833[1] | 0.6817[1] | 0.6467[1] | 0.3157[1] |
| | 10.05 | 7.71 | 10.16 | 8.78 | 7.22 |
| | 65.13 | 70.39 | 68.42 | 76.32 | 70.27 |
| $\beta_3$ | -0.0202 | 0.0117 | -0.0055 | -0.0224 | -0.0548 |
| | -0.82 | 0.39 | -0.21 | -0.88 | -2.95 |
| | 40.79 | 48.68 | 47.37 | 40.79 | 40.54 |
| $\beta_{3lag}$ | 0.0268 | 0.073 | 0.053 | 0.0207 | 0.0024 |
| | 1.21 | 2.51 | 2.23 | 0.69 | 0.13 |
| | 48.68 | 56.58 | 56.58 | 57.89 | 50 |
| $\beta_3 + \beta_{3lag}$ | 0.0066 | 0.0847 | 0.0475 | -0.0017 | -0.0524 |
| | 0.18 | 1.72 | 1.07 | -0.03 | -1.72 |
| | 44.74 | 52.63 | 51.97 | 49.34 | 45.27 |
| $\beta_4$ | -0.5165 | -2.6306[1] | -4.7076[1] | -6.761[1] | -9.1676[1] |
| | -2.01 | -7.78 | -17.37 | -18.88 | -24.45 |
| | 34.21 | 13.16 | 0 | 0 | 0 |
| $\beta_5$ | 0.1741[2] | 0.0852 | 0.0397 | -0.0629 | 0.2699 |
| | 2.52 | 0.7 | 0.39 | -0.66 | 3.45 |
| | 63.16 | 51.32 | 52.63 | 43.42 | 70.27 |
| $\beta_6$ | -2.463[1] | -4.6284[1] | -2.8625[1] | -2.4507[1] | -1.2286[1] |
| | -4.74 | -6.08 | -6.86 | -4.93 | -3.96 |
| | 27.63 | 21.05 | 18.42 | 23.68 | 35.14 |
| $intercept$ | 4.8988[1] | 6.9967[1] | 5.4152[1] | 5.8836[1] | 5.3655[1] |
| | 10.86 | 9.73 | 12.71 | 13.38 | 14.72 |
| | 93.42 | 90.79 | 94.74 | 93.42 | 98.65 |
| $adj\ R^2$ | 5.46 | 7.56 | 11.36 | 14.31 | 29.84 |
| $N$ | 72 | 72 | 72 | 72 | 72 |

**Table A25**

**Robustness Check: Liquidity Comovement of Put Options (Proportional Spread)**

This table presents the results of liquidity comovement between put options and their options market for the period from July 2009 to Dec 2010, excluding the crisis period. For each stock in its moneyness portfolio for maturity between 91 and 182 days, all options are averaged at time t, and at stock level, we run the following time series market model: $DOL_{i,t} = \beta_{0,i} + \beta_{1,i}DSL_{i,t} + \beta_{2,i}DSL_{m,t} + \beta_{2lag,i}DSL_{m,t-1} + \beta_{3,i}DOSL^{res}_{m,t} + \beta_{3lag,i}DOSL^{res}_{m,t-1} + \beta_4\, r_{i,t} + \beta_5\, {r^2}_{i,t} + \beta_6 D_{1,t} + \varepsilon_{i,t}$. $DSL_{i,t}$ is the percentage change in a stock's liquidity, $DSL_{m,t}$ and $DSL_{m,t-1}$ are current and lagged percentage change in stock market liquidity, $r_{i,t}$ is stock return, ${r^2}_{i,t}$ is squared stock return as a proxy for instantaneous stock volatility, $D_{1,t}$ is a dummy variable for 2009, $DOSL^{res}_{m,t}$ and $DOSL^{res}_{m,t-1}$ are residual variables for the stock market liquidity obtained from regression $DSL_{m,t} = \delta_0 + \delta_1 DOL_{m,t} + \epsilon_t$, where $DOL_{m,t}$ is percentage change in options market liquidity. Options market liquidity is the average liquidity of put options across all stocks. Residual of stock market is separately calculated for call option, put option and all options markets. This table reports, for each parameter, three stacked values: t-stat, calculated using variance of respective coefficients within each portfolio, and their proportion of stocks with positive coefficients (e.g., if 50 then 50% of N have positive coefficients). $adj\ R^2$ is average adjusted $R^2$ of all regressions within a portfolio. $N$ is number of stocks in a portfolio. Options are divided into 30 bins (6 maturities x 5 moneyness). Superscripts 1, 2, and 3 indicate significance at the 1%, 5% and 10% levels, respectively.

| Maturity | 4 | 4 | 4 | 4 | 4 |
|---|---|---|---|---|---|
| Moneyness | DITM | ITM | ATM | OTM | DOTM |
| $\beta_1$ | 0 | -0.0003 | 0.0016 | -0.0052 | 0.0016 |
| | 0.00 | -0.08 | 0.51 | -1.73 | 0.73 |
| | 49.33 | 48 | 47.37 | 42.11 | 46.05 |
| $\beta_2$ | 0.7368[1] | 0.7581[1] | 0.567[1] | 0.4801[1] | 0.264[1] |
| | 8.14 | 7.42 | 7.08 | 5.94 | 6.32 |
| | 88 | 81.33 | 81.58 | 77.63 | 82.89 |
| $\beta_{2lag}$ | -0.0025 | -0.0161 | 0.0114 | 0.01 | 0.0151 |
| | -0.08 | -0.43 | 0.42 | 0.37 | 0.87 |
| | 49.33 | 50.67 | 48.68 | 44.74 | 48.68 |
| $\beta_2 + \beta_{2lag}$ | 0.7343[1] | 0.742[1] | 0.5784[1] | 0.49[1] | 0.2791[1] |
| | 8.13 | 7.86 | 7.94 | 6.21 | 6.31 |
| | 68.67 | 66 | 65.13 | 61.18 | 65.79 |
| $\beta_3$ | 0.0354 | 0.045 | -0.0117 | -0.0151 | -0.0442 |
| | 1.69 | 1.49 | -0.48 | -0.59 | -2.17 |
| | 49.33 | 46.67 | 50 | 48.68 | 44.74 |
| $\beta_{3lag}$ | 0.0266 | 0.1288[1] | 0.0321 | -0.0021 | -0.0244 |
| | 1.15 | 4.11 | 1.39 | -0.07 | -1.12 |
| | 53.33 | 62.67 | 51.32 | 44.74 | 39.47 |
| $\beta_3 + \beta_{3lag}$ | 0.062 | 0.1738[1] | 0.0204 | -0.0172 | -0.0686 |
| | 1.73 | 3.33 | 0.49 | -0.38 | -1.84 |
| | 51.33 | 54.67 | 50.66 | 46.71 | 42.11 |
| $\beta_4$ | 1.4018[1] | 2.5781[1] | 4.5782[1] | 6.6716[1] | 8.3711[1] |
| | 5.48 | 8.35 | 15.91 | 17.82 | 22.95 |
| | 78.67 | 89.33 | 96.05 | 97.37 | 97.37 |
| $\beta_5$ | 0.1006 | 0.2021 | 0.2314[1] | 0.3516[1] | 0.5656[1] |
| | 1.01 | 1.82 | 2.45 | 3.18 | 5.99 |
| | 50.67 | 56 | 69.74 | 67.11 | 84.21 |
| $\beta_6$ | -3.4383[1] | -3.173[1] | -2.9477[1] | -2.8994[1] | -1.8959[1] |
| | -7.11 | -5.54 | -7.37 | -6.38 | -6.39 |
| | 17.33 | 25.33 | 15.79 | 22.37 | 22.37 |
| $intercept$ | 5.933[1] | 6.7801[1] | 6.0355[1] | 5.6048[1] | 5.4581[1] |
| | 11.15 | 10.26 | 14.57 | 12.56 | 15.07 |
| | 96 | 90.67 | 94.74 | 96.05 | 94.74 |
| $adj\ R^2$ | 5.12 | 7.35 | 9.46 | 13.84 | 27.04 |
| $N$ | 72 | 72 | 72 | 72 | 72 |

### Table A26 List of Option Stocks

The following table shows the list of stocks for which options data is available. The columns named Data Years show that the availability of option data on stocks in year 2008, 2009, and 2010. Column 'FTSE 100' shows that which stocks are part of the FTSE 100 shares. Y indicates 'Yes' and N indicates 'No'. At the end of the table on the next page, total number of option stocks in each year and part of FTSE 100 index are shown.

| LIST OF OPTION STOCKS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Data Years | | | |
| | ISIN | SEDOL | LIFFE SYMBOL | COMPANY | 2008 | 2009 | 2010 | FTSE 100 |
| 1 | GB0006731235 | 673123 | ABR | ASSOCIATED BRIT.FDS.PLC. | Y | Y | Y | Y |
| 2 | GB0002634946 | 263494 | AER | BAE SYSTEMS PLC. | Y | Y | Y | Y |
| 3 | GB00B1XZS820 | B1XZS82 | AHA | ANGLO AMERICAN PLC. | Y | Y | Y | Y |
| 4 | GB0000595859 | | ARM | ARM HOLDINGS PLC. | Y | Y | Y | N |
| 5 | GB0000456144 | 45614 | ATT | ANTOFAGASTA PLC. | Y | Y | Y | Y |
| 6 | GB0009895292 | 989529 | AZA | ASTRAZENECA PLC. | Y | Y | Y | Y |
| 7 | GB0031348658 | 3134865 | BBL | BARCLAYS PLC. | Y | Y | Y | Y |
| 8 | GB0008762899 | 876289 | BGG | BG GROUP PLC. | Y | Y | Y | Y |
| 9 | GB0001367019 | 136701 | BLC | BRITISH LAND CO.PLC. | Y | Y | Y | Y |
| 10 | GB0000566504 | 56650 | BLT | BHP BILLITON PLC. | Y | Y | Y | Y |
| 11 | GB0007980591 | 798059 | BP | BP PLC. | Y | Y | Y | Y |
| 12 | GB00B19DVX61 | B19DVX6 | BRT | INVENSYS PLC. | Y | Y | Y | Y |
| 13 | GB0001411924 | 141192 | BSK | BRIT.SKY BCAST.GP.PLC. | Y | Y | Y | Y |
| 14 | GB0030913577 | 3091357 | BTG | BT GROUP PLC. | Y | Y | Y | Y |
| 15 | GB00B5KKT968 | B5KKT96 | CCT | CABLE & WRLS.COMMS.PLC. | N | N | Y | Y |
| 16 | GB0005331532 | 533153 | CPG | COMPASS GROUP PLC. | Y | Y | Y | Y |
| 17 | GB00B033F229 | B033F22 | CTR | CENTRICA PLC. | Y | Y | Y | Y |
| 18 | GB0002162385 | 216238 | CUA | AVIVA PLC. | Y | Y | Y | Y |
| 19 | GB00B5SXPF57 | | ESR | ESSAR ENERGY PLC. | N | N | Y | N |
| 20 | GB00B1L8B624 | B1L8B62 | ETP | ENTERPRISE INNS PLC. | Y | Y | Y | Y |
| 21 | GB00B29BCK10 | B29BCK1 | EUN | EURASIAN NATRES.CORP.PLC | N | N | Y | Y |
| 22 | GB00B19NLV48 | B19NLV4 | EXP | EXPERIAN PLC. | Y | Y | Y | Y |
| 23 | GB0033986497 | 3398649 | GME | ITV PLC. | Y | Y | Y | Y |
| 24 | GB0002374006 | 237400 | GNS | DIAGEO PLC. | Y | Y | Y | Y |
| 25 | GB0009252882 | 925288 | GXO | GLAXOSMITHKLINE PLC. | Y | Y | Y | Y |
| 26 | GB0005405286 | 540528 | HSB | HSBC HOLDINGS PLC. | Y | Y | Y | Y |
| 27 | GB0033872168 | 3387216 | ICA | ICAP PLC. | Y | Y | Y | Y |
| 28 | GB00B1YW4409 | B1YW440 | III | 3I GROUP PLC. | Y | Y | Y | Y |
| 29 | GB0004544929 | 454492 | IMP | IMPERIAL TOBACCO GP.PLC. | Y | Y | Y | Y |
| 30 | GB0033195214 | 3319521 | KGF | KINGFISHER PLC. | Y | Y | Y | Y |
| 31 | GB00B0HZPV38 | B0HZPV3 | KZK | KAZAKHMYS PLC. | Y | Y | Y | Y |
| 32 | GB00B0ZSH635 | | LDB | LADBROKES PLC. | Y | Y | Y | N |
| 33 | GB00B16KPT44 | B16KPT4 | LFI | STANDARD LIFE PLC. | Y | Y | Y | Y |
| 34 | GB0005603997 | 560399 | LGE | LEGAL & GENERAL GP.PLC. | Y | Y | Y | Y |
| 35 | GB0031192486 | 3119248 | LNM | LONMIN PLC. | Y | Y | Y | Y |
| 36 | GB0031809436 | 3180943 | LS | LAND SECURITIES GP.PLC. | Y | Y | Y | Y |
| 37 | GB00B0SWJX34 | B0SWJX3 | LSE | LONDON STOCK EX.GP.PLC. | Y | Y | Y | Y |
| 38 | GB0031274896 | 3127489 | M+S | MARKS & SPENCER GP.PLC. | Y | Y | Y | Y |
| 39 | GB0006043169 | 604316 | MWR | MORRISON(WM)SPMKTS.PLC. | Y | Y | Y | Y |
| 40 | GB00B08SNH34 | B08SNH3 | NGG | NATIONAL GRID PLC. | Y | Y | Y | Y |

## Table A24 List of Option Stocks (Continued)

| LIST OF OPTION STOCKS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Data Years | | | |
| | ISIN | SEDOL | LIFFE SYMBOL | COMPANY | 2008 | 2009 | 2010 | FTSE 100 |
| 41 | GB0032089863 | 3208986 | NXT | NEXT PLC. | Y | Y | Y | Y |
| 42 | GB00B77J0862 | B77J086 | OMT | OLD MUTUAL PLC. | Y | Y | Y | Y |
| 43 | GB00B0H2K534 | B0H2K53 | PET | PETROFAC LTD. | N | N | Y | Y |
| 44 | GB0031215220 | 3121522 | POC | CARNIVAL PLC. | Y | Y | Y | Y |
| 45 | GB0007099541 | 709954 | PRU | PRUDENTIAL PLC. | Y | Y | Y | Y |
| 46 | GB0006776081 | 677608 | PSO | PEARSON PLC. | Y | Y | Y | Y |
| 47 | GB00B01C3S32 | B01C3S3 | RAR | RANDGOLD RESOURCES LTD. | N | Y | Y | Y |
| 48 | GB00B24CGK77 | B24CGK7 | RB | RECKITT BENCKISER GP.PLC | Y | Y | Y | Y |
| 49 | GB00B7T77214 | B7T7721 | RBS | ROYAL BK.OF SCTL.GP.PLC. | Y | Y | Y | Y |
| 50 | GB00B2B0DG97 | B2B0DG9 | REI | REED ELSEVIER PLC. | Y | Y | Y | Y |
| 51 | GB00B63H8491 | B63H849 | RR | ROLLS-ROYCE HOLDINGS PLC | Y | Y | Y | Y |
| 52 | GB00B082RF11 | B082RF1 | RTO | RENTOKIL INITIAL PLC. | Y | Y | Y | Y |
| 53 | GB0007188757 | 718875 | RTZ | RIO TINTO PLC. | Y | Y | Y | Y |
| 54 | GB0006616899 | 661689 | RYL | RSA INSURANCE GROUP PLC. | Y | Y | Y | Y |
| 55 | GB0004835483 | 483548 | SAB | SABMILLER PLC. | Y | Y | Y | Y |
| 56 | GB00B019KW72 | B019KW7 | SAN | SAINSBURY (J) PLC. | Y | Y | Y | Y |
| 57 | GB0004082847 | 408284 | SCB | STD.CHARTERED PLC. | Y | Y | Y | Y |
| 58 | GB0008021650 | 802165 | SGE | THE SAGE GROUP PLC. | Y | Y | Y | Y |
| 59 | GB00B03MLX29 | B03MLX2 | SHA | ROYAL DUTCH SHELL | Y | Y | Y | Y |
| 60 | GB00B03MM408 | B03MM40 | SHL | ROYAL DUTCH SHELL PLC. | Y | Y | Y | Y |
| 61 | JE00B2QKY057 | B2QKY05 | SHP | SHIRE PLC. | Y | Y | Y | Y |
| 62 | GB0009223206 | 922320 | SNP | SMITH & NEPHEW PLC. | Y | Y | Y | Y |
| 63 | GB0007908733 | 790873 | SSE | SSE PLC. | Y | Y | Y | Y |
| 64 | GB00B1FH8J72 | B1FH8J7 | SVT | SEVERN TRENT PLC. | N | Y | Y | Y |
| 65 | GB0002875804 | 287580 | TAB | BRITISH AMER.TOB.PLC. | Y | Y | Y | Y |
| 66 | GB0008754136 | 875413 | TAT | TATE & LYLE PLC. | Y | Y | Y | Y |
| 67 | GB0008847096 | 884709 | TCO | TESCO PLC. | Y | Y | Y | Y |
| 68 | GB0001500809 | 150080 | TLO | TULLOW OIL PLC. | Y | Y | Y | Y |
| 69 | GB0008706128 | 870612 | TSB | LLOYDS BANKING GP.PLC. | Y | Y | Y | Y |
| 70 | GB00B10RZP78 | B10RZP7 | ULV | UNILEVER PLC. | Y | Y | Y | Y |
| 71 | GB00B39J2M42 | B39J2M4 | UUL | UNITED UTILITIES GP.PLC. | Y | Y | Y | Y |
| 72 | GB00B16GWD56 | B16GWD5 | VOD | VODAFONE GROUP PLC. | Y | Y | Y | Y |
| 73 | GB0033277061 | 3327706 | VRS | VEDANTA RESOURCES PLC. | Y | Y | Y | Y |
| 74 | GB0031698896 | | WHL | WILLIAM HILL PLC. | Y | Y | Y | N |
| 75 | JE00B3DMTY01 | B3DMTY0 | WPP | WPP PLC. | Y | Y | Y | Y |
| 76 | GB00B1KJJ408 | B1KJJ40 | WTB | WHITBREAD PLC. | Y | Y | Y | Y |
| 77 | GB0031411001 | 3141100 | XST | XSTRATA PLC. | Y | Y | Y | Y |
| | | | | ***TOTAL OPTION STOCKS*** | **71** | **73** | **77** | |
| | | | | ***TOTAL STOCKS IN FTSE 100*** | **68** | **70** | **73** | |
| | | | | ***STOCKS NOT IN FTSE 100 (%)*** | **4.23%** | **4.11%** | **5.19%** | |

# B. APPENDIX TO CHAPTER 5

## Table B1 Call Option Return Sensitivity to Call Options Market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for call option portfolios. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, call options market expected illiquidity $(eliq_{cm})$ and call options market unexpected illiquidity $(ueliq_{cm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{cm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | T | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 6.228*** | 10.96 | 0.388** | 2.46 | -0.670*** | -2.64 | -4.622 | -1.32 | 236 | 68.7 | 6.243*** | 11.46 | 0.237 | 1.49 | -0.678*** | -2.75 | 5.120*** | 2.83 | -20.48*** | -3.08 | 236 | 69.9 |
| 2 | 1 | 6.794*** | 16.64 | 0.282** | 2.34 | -1.199*** | -3.40 | -4.146 | -1.54 | 240 | 79.6 | 6.801*** | 16.97 | 0.236** | 2.01 | -1.199*** | -3.38 | 1.537 | 0.97 | -8.888 | -1.45 | 240 | 79.6 |
| 3 | 1 | 8.921*** | 13.46 | 0.380** | 2.00 | -1.945*** | -4.39 | -10.11** | -2.43 | 240 | 79.1 | 8.935*** | 13.62 | 0.294 | 1.57 | -1.946*** | -4.43 | 2.863 | 1.29 | -18.94** | -2.17 | 240 | 79.3 |
| 4 | 1 | 10.43*** | 9.93 | 0.397 | 1.45 | -1.712*** | -3.00 | -18.46*** | -3.06 | 240 | 69.2 | 10.47*** | 10.08 | 0.165 | 0.65 | -1.715*** | -3.12 | 7.775** | 2.39 | -42.45*** | -3.19 | 240 | 70.1 |
| 5 | 1 | 12.84*** | 10.57 | 0.180 | 0.47 | -1.086 | -1.28 | -16.93* | -1.89 | 238 | 57.1 | 12.86*** | 10.65 | 0.0688 | 0.18 | -1.086 | -1.27 | 3.794 | 0.87 | -28.68* | -1.65 | 238 | 57.3 |
| 1 | 2 | 4.733*** | 18.31 | 0.281*** | 3.27 | -0.436** | -2.33 | -4.157** | -2.28 | 357 | 75.7 | 4.762*** | 19.28 | 0.184** | 2.45 | -0.440** | -2.49 | 3.067*** | 3.29 | -13.54*** | -3.34 | 357 | 76.6 |
| 2 | 2 | 4.862*** | 13.18 | 0.327*** | 3.49 | -0.762*** | -3.21 | -6.116*** | -3.05 | 359 | 72.8 | 4.875*** | 13.42 | 0.294*** | 3.26 | -0.763*** | -3.23 | 1.028 | 1.00 | -9.251** | -2.22 | 359 | 72.9 |
| 3 | 2 | 5.728*** | 11.64 | 0.306** | 2.32 | -1.177*** | -4.68 | -7.493*** | -2.63 | 359 | 70.5 | 5.747*** | 11.76 | 0.258* | 1.95 | -1.179*** | -4.70 | 1.510 | 1.14 | -12.10** | -2.24 | 359 | 70.6 |
| 4 | 2 | 6.451*** | 9.97 | 0.520*** | 2.89 | -1.297*** | -3.86 | -16.03*** | -4.11 | 359 | 63.4 | 6.495*** | 10.12 | 0.409** | 2.29 | -1.301*** | -3.86 | 3.484** | 1.98 | -26.66*** | -3.61 | 359 | 63.8 |
| 5 | 2 | 7.843*** | 9.84 | 0.353 | 1.43 | -1.243*** | -2.60 | -15.09*** | -2.80 | 359 | 57.7 | 7.864*** | 9.90 | 0.301 | 1.26 | -1.244*** | -2.60 | 1.616 | 0.70 | -20.02** | -1.99 | 359 | 57.7 |
| 1 | 3 | 3.815*** | 10.51 | 0.238** | 2.42 | -0.447*** | -2.98 | -3.780* | -1.81 | 360 | 73.3 | 3.833*** | 10.89 | 0.164* | 1.82 | -0.460*** | -3.12 | 2.632*** | 3.08 | -12.01*** | -3.03 | 360 | 74.1 |
| 2 | 3 | 4.115*** | 10.13 | 0.232** | 2.21 | -0.674*** | -3.24 | -4.032* | -1.81 | 360 | 70.7 | 4.122*** | 10.30 | 0.201** | 2.05 | -0.680*** | -3.26 | 1.079 | 1.09 | -7.406* | -1.67 | 360 | 70.8 |
| 3 | 3 | 4.773*** | 10.68 | 0.208* | 1.71 | -0.766*** | -3.48 | -5.078** | -1.96 | 360 | 71.6 | 4.773*** | 10.70 | 0.211* | 1.85 | -0.765*** | -3.46 | -0.104 | -0.09 | -4.754 | -0.95 | 360 | 71.6 |
| 4 | 3 | 5.511*** | 10.59 | 0.217 | 1.51 | -0.837*** | -3.00 | -7.554** | -2.47 | 360 | 67.0 | 5.524*** | 10.75 | 0.163 | 1.21 | -0.847*** | -3.03 | 1.901 | 1.31 | -13.50** | -2.13 | 360 | 67.2 |
| 5 | 3 | 6.386*** | 9.71 | -0.00902 | -0.04 | -0.673* | -1.84 | -5.252 | -1.18 | 360 | 59.6 | 6.388*** | 9.74 | -0.0185 | -0.09 | -0.675* | -1.82 | 0.335 | 0.16 | -6.301 | -0.73 | 360 | 59.6 |
| 1 | 4 | 2.646*** | 9.17 | 0.247*** | 3.57 | -0.377*** | -4.17 | -4.525*** | -3.06 | 392 | 72.2 | 2.676*** | 9.54 | 0.171*** | 2.63 | -0.384*** | -4.33 | 2.560*** | 4.65 | -12.46*** | -4.85 | 392 | 73.7 |
| 2 | 4 | 3.242*** | 12.87 | 0.193*** | 2.94 | -0.547*** | -4.39 | -3.852*** | -2.74 | 392 | 75.3 | 3.257*** | 13.17 | 0.158** | 2.48 | -0.550*** | -4.40 | 1.212* | 1.96 | -7.609*** | -2.86 | 392 | 75.5 |
| 3 | 4 | 3.589*** | 13.11 | 0.148* | 1.91 | -0.721*** | -4.97 | -3.367** | -2.03 | 392 | 74.0 | 3.599*** | 13.24 | 0.122 | 1.62 | -0.724*** | -4.97 | 0.879 | 1.20 | -6.092* | -1.93 | 392 | 74.0 |
| 4 | 4 | 3.978*** | 12.07 | 0.180* | 1.95 | -0.756*** | -4.23 | -4.529** | -2.29 | 392 | 70.4 | 3.991*** | 12.22 | 0.148 | 1.64 | -0.759*** | -4.22 | 1.072 | 1.23 | -7.853** | -2.12 | 392 | 70.6 |
| 5 | 4 | 4.632*** | 11.99 | 0.113 | 0.96 | -0.762*** | -3.27 | -5.180** | -2.05 | 392 | 68.1 | 4.641*** | 12.08 | 0.0904 | 0.79 | -0.764*** | -3.26 | 0.776 | 0.69 | -7.584 | -1.57 | 392 | 68.1 |
| 1 | 5 | 2.710*** | 21.72 | 0.218*** | 5.33 | -0.272** | -2.57 | -3.802*** | -4.41 | 391 | 79.9 | 2.738*** | 24.10 | 0.137*** | 3.67 | -0.279*** | -2.92 | 2.775*** | 5.60 | -12.42*** | -6.41 | 391 | 82.0 |
| 2 | 5 | 2.388*** | 4.27 | 0.308** | 2.48 | -0.466*** | -4.54 | -6.359** | -2.39 | 392 | 52.8 | 2.405*** | 4.34 | 0.266** | 2.34 | -0.470*** | -4.50 | 1.419** | 2.17 | -10.76** | -2.56 | 392 | 53.2 |
| 3 | 5 | 2.915*** | 10.24 | 0.186*** | 2.65 | -0.553*** | -5.09 | -4.024*** | -2.68 | 392 | 74 | 2.924*** | 10.38 | 0.163** | 2.45 | -0.555*** | -5.08 | 0.756 | 1.34 | -6.366** | -2.39 | 392 | 74.1 |
| 4 | 5 | 3.164*** | 9.65 | 0.158* | 1.97 | -0.578*** | -4.42 | -4.046** | -2.34 | 392 | 70.6 | 3.159*** | 9.68 | 0.171** | 2.23 | -0.577*** | -4.42 | -0.417 | -0.62 | -2.755 | -0.88 | 392 | 70.6 |
| 5 | 5 | 3.837*** | 10.69 | 0.0972 | 0.90 | -0.637*** | -3.04 | -4.059* | -1.77 | 392 | 66.5 | 3.834*** | 10.69 | 0.106 | 1.07 | -0.636*** | -3.03 | -0.313 | -0.31 | -3.089 | -0.68 | 392 | 66.5 |
| 1 | 6 | 2.538*** | 19.17 | 0.211*** | 4.71 | -0.239** | -2.36 | -3.808*** | -4.08 | 364 | 74.6 | 2.558*** | 21.13 | 0.142*** | 3.17 | -0.240** | -2.54 | 2.271*** | 4.29 | -10.83*** | -5.56 | 364 | 76.2 |
| 2 | 6 | 2.659*** | 14.18 | 0.173*** | 3.16 | -0.578*** | -3.04 | -3.639*** | -3.22 | 368 | 68.9 | 2.661*** | 14.23 | 0.165*** | 3.04 | -0.579*** | -3.05 | 0.278 | 0.39 | -4.498* | -1.69 | 368 | 68.9 |
| 3 | 6 | 2.784*** | 8.57 | 0.229*** | 3.20 | -0.521** | -2.17 | -4.916*** | -3.28 | 372 | 67.2 | 2.783*** | 8.60 | 0.232*** | 3.47 | -0.520** | -2.17 | -0.0939 | -0.14 | -4.626 | -1.60 | 372 | 67.2 |
| 4 | 6 | 3.218*** | 18.94 | 0.114** | 2.20 | -0.542*** | -3.89 | -2.866*** | -2.60 | 365 | 75.5 | 3.221*** | 19.15 | 0.0967* | 1.76 | -0.546*** | -3.92 | 0.593 | 1.02 | -4.704** | -2.20 | 365 | 75.6 |
| 5 | 6 | 3.401*** | 10.63 | 0.0713 | 0.60 | -0.480 | -1.51 | -2.952 | -1.16 | 370 | 49.5 | 3.390*** | 10.52 | 0.109 | 0.98 | -0.477 | -1.51 | -1.234 | -0.90 | 0.848 | 0.15 | 370 | 49.7 |

## Table B2 Put Option Return Sensitivity to Put Options Market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for put option portfolios. Put option excess return is regressed on stock market excess return $(r_m - r_f)$, put options market expected illiquidity $(eliq_{pm})$ and put options market unexpected illiquidity $(ueliq_{pm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the put options market. The log volatility is the average implied volatility across all put options in the market. $ueliq_{pm}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | T | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | -5.430*** | -11.61 | -0.301 | -1.03 | -1.408*** | -3.72 | 9.453 | 1.38 | 234 | 62.4 | -5.432*** | -11.57 | -0.313 | -0.93 | -1.407*** | -3.71 | -0.283 | -0.13 | 10.79 | 0.76 | 234 | 62.4 |
| 2 | 1 | -6.918*** | -10.60 | 0.0818 | 0.43 | -0.796 | -1.58 | -0.200 | -0.04 | 240 | 72.4 | -6.934*** | -10.53 | -0.0739 | -0.40 | -0.811* | -1.66 | -3.665** | -2.01 | 17.12** | 1.99 | 240 | 72.9 |
| 3 | 1 | -9.277*** | -11.33 | -0.0297 | -0.11 | -1.583*** | -2.86 | -2.768 | -0.44 | 240 | 76.7 | -9.287*** | -11.27 | -0.128 | -0.48 | -1.593*** | -2.93 | -2.305 | -1.06 | 8.127 | 0.75 | 240 | 76.8 |
| 4 | 1 | -11.11*** | -10.46 | -0.244 | -0.72 | -1.700** | -2.22 | -3.755 | -0.46 | 240 | 73.1 | -11.12*** | -10.43 | -0.332 | -0.98 | -1.708** | -2.26 | -2.073 | -0.74 | 6.042 | 0.43 | 240 | 73.2 |
| 5 | 1 | -12.36*** | -10.72 | 0.318 | 0.82 | -0.757 | -0.94 | -20.57** | -2.31 | 240 | 66.5 | -12.39*** | -10.85 | 0.0318 | 0.08 | -0.785 | -1.00 | -6.750** | -2.01 | 11.33 | 0.67 | 240 | 67.0 |
| 1 | 2 | -4.997*** | -20.12 | 0.105 | 0.96 | -0.638*** | -3.36 | -0.953 | -0.38 | 359 | 76.9 | -4.995*** | -19.97 | 0.112 | 1.03 | -0.637*** | -3.34 | 0.169 | 0.16 | -1.751 | -0.35 | 359 | 76.9 |
| 2 | 2 | -5.650*** | -18.85 | 0.140 | 1.17 | -1.069*** | -4.30 | -2.409 | -0.87 | 359 | 78.6 | -5.675*** | -18.47 | 0.0657 | 0.55 | -1.075*** | -4.38 | -1.764 | -1.59 | 5.901 | 1.11 | 359 | 78.8 |
| 3 | 2 | -6.933*** | -15.05 | 0.0686 | 0.46 | -1.542*** | -4.61 | -3.232 | -0.91 | 359 | 77.8 | -6.961*** | -14.96 | -0.0128 | -0.09 | -1.550*** | -4.71 | -1.943 | -1.47 | 5.922 | 0.97 | 359 | 77.9 |
| 4 | 2 | -7.981*** | -13.44 | -0.0323 | -0.17 | -2.032*** | -4.86 | -3.777 | -0.84 | 359 | 74.4 | -8.003*** | -13.33 | -0.0975 | -0.56 | -2.038*** | -4.92 | -1.557 | -0.93 | 3.559 | 0.48 | 359 | 74.5 |
| 5 | 2 | -9.319*** | -12.37 | 0.254 | 1.12 | -1.821*** | -3.43 | -13.25** | -2.48 | 358 | 72.9 | -9.342*** | -12.30 | 0.162 | 0.75 | -1.834*** | -3.48 | -2.229 | -1.11 | -2.781 | -0.31 | 358 | 73.0 |
| 1 | 3 | -4.025*** | -13.86 | -0.0214 | -0.27 | -0.515** | -2.01 | 1.747 | 0.94 | 360 | 73.6 | -4.016*** | -13.96 | 0.0520 | 0.59 | -0.493** | -1.98 | 1.772 | 1.57 | -6.567 | -1.22 | 360 | 74.0 |
| 2 | 3 | -4.693*** | -16.77 | 0.00629 | 0.07 | -0.751*** | -3.28 | 0.428 | 0.20 | 360 | 79.5 | -4.696*** | -16.62 | -0.0161 | -0.17 | -0.758*** | -3.32 | -0.541 | -0.57 | 2.967 | 0.62 | 360 | 79.5 |
| 3 | 3 | -5.538*** | -15.57 | 0.00357 | 0.03 | -0.867*** | -3.54 | -1.056 | -0.38 | 360 | 79.4 | -5.538*** | -15.48 | 0.00607 | 0.05 | -0.866*** | -3.50 | 0.0604 | 0.06 | -1.340 | -0.27 | 360 | 79.4 |
| 4 | 3 | -6.400*** | -13.46 | 0.0552 | 0.39 | -1.080*** | -3.11 | -3.942 | -1.17 | 360 | 75.2 | -6.401*** | -13.43 | 0.0487 | 0.36 | -1.082*** | -3.09 | -0.155 | -0.12 | -3.214 | -0.54 | 360 | 75.2 |
| 5 | 3 | -7.103*** | -14.91 | -0.0344 | -0.24 | -0.972*** | -2.81 | -3.872 | -1.12 | 360 | 77.0 | -7.109*** | -14.88 | -0.0844 | -0.60 | -0.987*** | -2.86 | -1.207 | -0.85 | 1.793 | 0.28 | 360 | 77.0 |
| 1 | 4 | -2.923*** | -21.34 | -0.0216 | -0.50 | -0.348*** | -3.31 | 0.948 | 0.93 | 392 | 83.5 | -2.920*** | -21.09 | -0.0131 | -0.30 | -0.347*** | -3.30 | 0.209 | 0.45 | -0.0307 | -0.01 | 392 | 83.5 |
| 2 | 4 | -3.567*** | -19.36 | -0.0192 | -0.31 | -0.559*** | -3.87 | 0.102 | 0.07 | 392 | 81.4 | -3.574*** | -19.16 | -0.0426 | -0.68 | -0.563*** | -3.93 | -0.571 | -0.97 | 2.780 | 0.96 | 392 | 81.5 |
| 3 | 4 | -4.052*** | -17.87 | -0.0204 | -0.27 | -0.669*** | -3.91 | -0.288 | -0.16 | 392 | 78.5 | -4.061*** | -17.65 | -0.0495 | -0.67 | -0.674*** | -3.98 | -0.710 | -1.02 | 3.038 | 0.92 | 392 | 78.6 |
| 4 | 4 | -4.519*** | -15.81 | -0.0138 | -0.16 | -0.851*** | -3.97 | -1.053 | -0.50 | 392 | 75.8 | -4.528*** | -15.68 | -0.0412 | -0.48 | -0.856*** | -4.02 | -0.668 | -0.81 | 2.077 | 0.53 | 392 | 75.9 |
| 5 | 4 | -5.318*** | -15.84 | -0.0195 | -0.20 | -0.780*** | -3.29 | -2.171 | -0.91 | 392 | 76.1 | -5.338*** | -15.61 | -0.0858 | -0.92 | -0.792*** | -3.39 | -1.618* | -1.66 | 5.412 | 1.26 | 392 | 76.3 |
| 1 | 5 | -2.545*** | -20.64 | -0.0158 | -0.40 | -0.348*** | -4.15 | 0.748 | 0.80 | 392 | 84.4 | -2.537*** | -20.69 | 0.00989 | 0.23 | -0.344*** | -4.11 | 0.627 | 1.39 | -2.193 | -0.99 | 392 | 84.5 |
| 2 | 5 | -3.044*** | -21.54 | -0.0540 | -1.08 | -0.369*** | -3.72 | 1.125 | 0.95 | 392 | 82.9 | -3.045*** | -21.20 | -0.0553 | -1.08 | -0.369*** | -3.70 | -0.0309 | -0.05 | 1.270 | 0.51 | 392 | 82.9 |
| 3 | 5 | -3.435*** | -18.09 | -0.0472 | -0.83 | -0.368*** | -2.95 | 0.611 | 0.45 | 392 | 82.0 | -3.440*** | -17.84 | -0.0617 | -1.10 | -0.370*** | -2.96 | -0.354 | -0.62 | 2.269 | 0.86 | 392 | 82.0 |
| 4 | 5 | -3.635*** | -19.32 | -0.0181 | -0.29 | -0.497*** | -3.98 | -0.492 | -0.34 | 392 | 78.8 | -3.648*** | -18.96 | -0.0591 | -0.96 | -0.505*** | -4.14 | -1.000 | -1.54 | 4.197 | 1.38 | 392 | 78.9 |
| 5 | 5 | -4.412*** | -12.45 | 0.00107 | 0.01 | -0.377 | -1.64 | -1.756 | -0.90 | 392 | 77.0 | -4.429*** | -12.36 | -0.0536 | -0.72 | -0.387* | -1.67 | -1.334 | -1.53 | 4.496 | 1.21 | 392 | 77.2 |
| 1 | 6 | -2.258*** | -14.04 | -0.0182 | -0.47 | -0.433** | -2.10 | 0.709 | 0.78 | 367 | 73.0 | -2.243*** | -13.80 | 0.0244 | 0.46 | -0.427** | -2.15 | 1.084 | 1.36 | -4.333 | -1.11 | 367 | 73.4 |
| 2 | 6 | -2.814*** | -17.93 | -0.0710 | -1.41 | -0.310*** | -2.89 | 1.477 | 1.22 | 367 | 82.8 | -2.814*** | -17.66 | -0.0726 | -1.52 | -0.311*** | -2.86 | -0.0407 | -0.08 | 1.666 | 0.76 | 367 | 82.8 |
| 3 | 6 | -3.221*** | -16.40 | -0.00605 | -0.11 | -0.318** | -2.48 | -0.193 | -0.14 | 371 | 83.0 | -3.217*** | -16.46 | 0.00764 | 0.15 | -0.316** | -2.45 | 0.352 | 0.67 | -1.828 | -0.77 | 371 | 83.0 |
| 4 | 6 | -3.137*** | -16.66 | -0.0377 | -0.60 | -0.564*** | -4.20 | 0.226 | 0.15 | 368 | 77.1 | -3.138*** | -16.54 | -0.0442 | -0.74 | -0.566*** | -4.20 | -0.170 | -0.27 | 1.016 | 0.37 | 368 | 77.1 |
| 5 | 6 | -3.385*** | -16.18 | 0.0719 | 1.12 | -0.522*** | -3.55 | -2.990** | -1.96 | 369 | 75.0 | -3.402*** | -16.06 | -0.000253 | 0.00 | -0.537*** | -3.75 | -1.909*** | -2.73 | 5.818* | 1.78 | 369 | 75.6 |

## Table B3 Option Return Sensitivity to All Options Market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for call and put option portfolios. Option excess return is regressed on stock market excess return $(r_m - r_f)$, all options market expected illiquidity $(eliq_{om})$ and all options market unexpected illiquidity $(ueliq_{om})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the options market. The log volatility is the average implied volatility across all call and put options in the market. $ueliq_{om}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at 10%, 5%, and 1% levels respectively.

### Calls

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{om}$ | | $ueliq_{om}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{om}$ | | $ueliq_{om}$ | | $\ln(iv)_{om}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 6.590*** | 11.92 | 0.442 | 1.38 | 0.203 | 0.47 | -5.565 | -0.77 | 236 | 67.0 | 6.600*** | 12.35 | 0.276 | 0.87 | 0.205 | 0.47 | 6.183*** | 3.38 | -25.08*** | -2.73 | 236 | 68.9 |
| 2 | 1 | 7.408*** | 18.84 | 0.492 | 1.61 | 0.0453 | 0.09 | -8.474 | -1.23 | 240 | 77.0 | 7.414*** | 19.44 | 0.419 | 1.40 | 0.0535 | 0.11 | 2.539 | 1.46 | -16.38* | -1.68 | 240 | 77.3 |
| 3 | 1 | 9.884*** | 15.01 | 0.560 | 1.23 | -0.531 | -0.87 | -13.66 | -1.35 | 240 | 75.6 | 9.893*** | 15.18 | 0.445 | 1.00 | -0.518 | -0.83 | 4.040 | 1.65 | -26.24* | -1.86 | 240 | 76.0 |
| 4 | 1 | 11.31*** | 11.12 | 0.531 | 0.89 | 0.122 | 0.13 | -20.89 | -1.56 | 240 | 67.2 | 11.33*** | 11.13 | 0.288 | 0.51 | 0.150 | 0.16 | 8.517** | 2.44 | -47.41** | -2.42 | 240 | 68.4 |
| 5 | 1 | 13.40*** | 12.23 | -0.231 | -0.29 | 0.626 | 0.56 | -7.068 | -0.39 | 238 | 56.7 | 13.41*** | 12.31 | -0.356 | -0.46 | 0.640 | 0.56 | 4.440 | 1.00 | -20.93 | -0.83 | 238 | 56.9 |
| 1 | 2 | 5.016*** | 21.66 | 0.159 | 0.88 | 0.501** | 2.37 | -1.211 | -0.30 | 357 | 74.4 | 5.066*** | 23.62 | 0.0548 | 0.33 | 0.489** | 2.44 | 3.786*** | 3.77 | -13.10** | -2.19 | 357 | 75.9 |
| 2 | 2 | 5.337*** | 14.75 | 0.408* | 1.91 | 0.641 | 1.62 | -7.593 | -1.59 | 359 | 71.0 | 5.374*** | 15.48 | 0.352* | 1.67 | 0.631 | 1.61 | 1.977* | 1.82 | -13.76** | -2.19 | 359 | 71.3 |
| 3 | 2 | 6.419*** | 13.50 | 0.272 | 0.99 | 0.562 | 1.31 | -6.264 | -1.03 | 359 | 67.9 | 6.463*** | 13.96 | 0.204 | 0.75 | 0.549 | 1.29 | 2.387* | 1.69 | -13.71* | -1.70 | 359 | 68.2 |
| 4 | 2 | 7.191*** | 11.41 | 0.447 | 1.21 | 0.711 | 1.28 | -13.89* | -1.69 | 359 | 60.5 | 7.285*** | 11.91 | 0.303 | 0.83 | 0.683 | 1.24 | 5.045*** | 2.70 | -29.64*** | -2.72 | 359 | 61.4 |
| 5 | 2 | 8.650*** | 11.39 | 0.208 | 0.43 | 1.087 | 1.55 | -11.21 | -1.03 | 359 | 56.6 | 8.699*** | 11.64 | 0.133 | 0.28 | 1.072 | 1.53 | 2.644 | 1.08 | -19.46 | -1.29 | 359 | 56.8 |
| 1 | 3 | 4.140*** | 12.57 | 0.118 | 0.66 | 0.465* | 1.81 | -0.878 | -0.23 | 360 | 71.9 | 4.174*** | 13.52 | 0.0417 | 0.25 | 0.453* | 1.83 | 3.229*** | 3.39 | -11.29* | -1.90 | 360 | 73.2 |
| 2 | 3 | 4.581*** | 12.15 | -0.0648 | -0.31 | 0.492 | 1.45 | 2.914 | 0.64 | 360 | 68.8 | 4.601*** | 12.77 | -0.109 | -0.55 | 0.485 | 1.45 | 1.883* | 1.77 | -3.155 | -0.48 | 360 | 69.2 |
| 3 | 3 | 5.299*** | 12.74 | -0.0544 | -0.24 | 0.521 | 1.47 | 1.146 | 0.23 | 360 | 70.1 | 5.306*** | 13.01 | -0.0695 | -0.31 | 0.519 | 1.48 | 0.637 | 0.53 | -0.907 | -0.12 | 360 | 70.1 |
| 4 | 3 | 6.102*** | 12.60 | -0.114 | -0.42 | 0.662 | 1.56 | 0.271 | 0.05 | 360 | 65.8 | 6.127*** | 13.03 | -0.173 | -0.65 | 0.652 | 1.56 | 2.478 | 1.61 | -7.718 | -0.86 | 360 | 66.2 |
| 5 | 3 | 6.923*** | 11.55 | -0.656* | -1.66 | 0.853 | 1.45 | 9.735 | 1.12 | 360 | 60.1 | 6.927*** | 11.65 | -0.664* | -1.73 | 0.852 | 1.45 | 0.371 | 0.18 | 8.539 | 0.69 | 360 | 60.1 |
| 1 | 4 | 2.877*** | 10.60 | 0.253** | 1.99 | 0.334 | 1.49 | -4.494 | -1.62 | 392 | 69.4 | 2.929*** | 11.59 | 0.163 | 1.40 | 0.321 | 1.50 | 3.204*** | 5.07 | -14.51*** | -3.84 | 392 | 72.0 |
| 2 | 4 | 3.575*** | 14.81 | 0.163 | 1.20 | 0.331 | 1.44 | -2.932 | -0.97 | 392 | 72.9 | 3.604*** | 15.67 | 0.112 | 0.85 | 0.323 | 1.43 | 1.808*** | 2.67 | -8.583** | -2.10 | 392 | 73.5 |
| 3 | 4 | 4.006*** | 15.02 | 0.103 | 0.62 | 0.208 | 0.81 | -2.085 | -0.57 | 392 | 71.3 | 4.028*** | 15.43 | 0.0658 | 0.41 | 0.203 | 0.79 | 1.341* | 1.67 | -6.277 | -1.27 | 392 | 71.5 |
| 4 | 4 | 4.437*** | 14.07 | 0.156 | 0.80 | 0.376 | 1.19 | -3.668 | -0.85 | 392 | 68.2 | 4.463*** | 14.53 | 0.111 | 0.58 | 0.369 | 1.17 | 1.622* | 1.73 | -8.738 | -1.50 | 392 | 68.5 |
| 5 | 4 | 5.114*** | 13.94 | -0.153 | -0.63 | 0.507 | 1.42 | 1.208 | 0.23 | 392 | 66.9 | 5.134*** | 14.19 | -0.188 | -0.80 | 0.502 | 1.40 | 1.233 | 1.06 | -2.645 | -0.36 | 392 | 67.0 |
| 1 | 5 | 2.870*** | 23.98 | 0.243** | 2.36 | 0.165 | 1.12 | -4.295* | -1.87 | 391 | 77.5 | 2.913*** | 27.89 | 0.155* | 1.72 | 0.159 | 1.22 | 3.261*** | 6.42 | -14.56*** | -5.01 | 391 | 80.7 |
| 2 | 5 | 2.693*** | 5.25 | 0.421** | 2.21 | 0.524 | 1.36 | -8.666** | -2.11 | 392 | 50.1 | 2.730*** | 5.52 | 0.357** | 2.07 | 0.514 | 1.36 | 2.292** | 2.49 | -15.83** | -2.47 | 392 | 51.2 |
| 3 | 5 | 3.244*** | 12.04 | 0.216 | 1.64 | 0.270 | 1.16 | -4.495 | -1.55 | 392 | 71.2 | 3.265*** | 12.57 | 0.180 | 1.42 | 0.265 | 1.15 | 1.304** | 1.98 | -8.570** | -2.07 | 392 | 71.6 |
| 4 | 5 | 3.526*** | 11.63 | 0.207 | 1.37 | 0.369 | 1.37 | -4.877 | -1.46 | 392 | 68.6 | 3.528*** | 11.88 | 0.204 | 1.40 | 0.368 | 1.38 | 0.114 | 0.15 | -5.234 | -1.11 | 392 | 68.6 |
| 5 | 5 | 4.251*** | 12.64 | -0.107 | -0.49 | 0.493 | 1.54 | 0.873 | 0.18 | 392 | 65.4 | 4.253*** | 12.75 | -0.110 | -0.53 | 0.492 | 1.54 | 0.103 | 0.10 | 0.551 | 0.08 | 392 | 65.4 |
| 1 | 6 | 2.678*** | 20.59 | 0.270*** | 2.61 | 0.205 | 1.39 | -5.058** | -2.21 | 364 | 72.4 | 2.713*** | 24.49 | 0.177* | 1.84 | 0.201 | 1.50 | 2.811*** | 5.32 | -13.53*** | -4.56 | 364 | 75.1 |
| 2 | 6 | 2.963*** | 17.18 | 0.294** | 2.52 | -0.0361 | -0.16 | -6.202** | -2.40 | 368 | 65.6 | 2.974*** | 17.72 | 0.268** | 2.31 | -0.0385 | -0.17 | 0.840 | 1.10 | -8.775** | -2.41 | 368 | 65.7 |
| 3 | 6 | 3.092*** | 10.65 | 0.391*** | 3.10 | 0.263 | 0.86 | -8.352*** | -3.02 | 372 | 64.4 | 3.103*** | 10.99 | 0.368*** | 3.10 | 0.259 | 0.85 | 0.688 | 0.89 | -10.43** | -2.48 | 372 | 64.5 |
| 4 | 6 | 3.521*** | 20.52 | 0.263** | 2.15 | 0.0762 | 0.37 | -6.036** | -2.21 | 365 | 73.6 | 3.530*** | 21.03 | 0.241* | 1.96 | 0.0700 | 0.34 | 0.703 | 1.15 | -8.174** | -2.41 | 365 | 73.7 |
| 5 | 6 | 3.789*** | 12.84 | 0.0439 | 0.17 | 0.712* | 1.65 | -1.970 | -0.35 | 370 | 49.6 | 3.775*** | 12.62 | 0.0755 | 0.32 | 0.718* | 1.66 | -0.923 | -0.68 | 0.791 | 0.09 | 370 | 49.7 |

## Table B3 Option Return Sensitivity to Options market Illiquidity (Continued)

### Puts

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{om}$ | | $ueliq_{om}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{om}$ | | $ueliq_{om}$ | | $\ln(iv)_{om}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | **Model 1** | | | | | | | | | | **Model 2** | | | | | | | | | | | |
| 1 | 1 | -6.027*** | -12.36 | 0.0723 | 0.21 | -0.540 | -1.21 | 1.045 | 0.13 | 234 | 60.3 | -6.026*** | -12.37 | 0.0605 | 0.18 | -0.543 | -1.22 | 0.448 | 0.25 | -0.374 | -0.04 | 234 | 60.3 |
| 2 | 1 | -7.246*** | -11.18 | -0.0441 | -0.13 | 0.465 | 0.93 | 2.881 | 0.39 | 240 | 72.0 | -5.125*** | -20.38 | 0.102 | 0.56 | 0.104 | 0.42 | -0.306 | -0.29 | 0.492 | 0.09 | 359 | 75.9 |
| 3 | 1 | -9.948*** | -11.68 | -0.532 | -1.22 | 0.303 | 0.56 | 8.917 | 0.92 | 240 | 75.8 | -4.204*** | -17.14 | 0.404** | 2.31 | -0.164 | -0.54 | 1.340 | 1.32 | -12.76** | -2.12 | 360 | 73.7 |
| 4 | 1 | -11.79*** | -10.50 | -0.679 | -1.19 | 0.683 | 0.94 | 6.492 | 0.51 | 240 | 72.5 | -3.020*** | -22.67 | 0.0961 | 1.01 | 0.0266 | 0.20 | 0.144 | 0.32 | -2.154 | -0.81 | 392 | 82.8 |
| 5 | 1 | -12.70*** | -10.38 | -0.861 | -1.30 | 0.895 | 1.12 | 6.524 | 0.44 | 240 | 66.7 | -2.643*** | -24.10 | 0.0958 | 1.17 | -0.0312 | -0.28 | 0.489 | 1.18 | -3.528 | -1.39 | 392 | 83.5 |
| 1 | 2 | -5.120*** | -20.67 | 0.0928 | 0.50 | 0.102 | 0.41 | -0.462 | -0.11 | 359 | 75.9 | -2.380*** | -22.68 | 0.112 | 1.12 | -0.181 | -0.75 | 0.912 | 1.35 | -5.592 | -1.32 | 367 | 72.0 |
| 2 | 2 | -5.942*** | -19.74 | -0.0705 | -0.33 | -0.246 | -0.77 | 2.564 | 0.55 | 359 | 76.6 | -7.254*** | -11.01 | 0.0526 | 0.17 | 0.454 | 0.93 | -3.400* | -1.83 | 13.47 | 1.28 | 240 | 72.5 |
| 3 | 2 | -7.398*** | -16.12 | -0.179 | -0.67 | -0.483 | -1.07 | 2.631 | 0.45 | 359 | 75.3 | -5.979*** | -19.26 | -0.0135 | -0.06 | -0.235 | -0.74 | -1.997* | -1.79 | 8.797 | 1.41 | 359 | 76.9 |
| 4 | 2 | -8.623*** | -14.71 | -0.252 | -0.72 | -0.718 | -1.19 | 1.502 | 0.20 | 359 | 71.5 | -4.972*** | -18.08 | 0.232 | 1.31 | -0.202 | -0.73 | -0.587 | -0.66 | -2.292 | -0.44 | 360 | 78.3 |
| 5 | 2 | -9.924*** | -14.51 | 0.205 | 0.53 | -0.595 | -0.83 | -11.76 | -1.37 | 358 | 70.9 | -3.751*** | -20.73 | 0.0325 | 0.26 | -0.0479 | -0.26 | -0.459 | -0.79 | 0.790 | 0.24 | 392 | 80.1 |
| 1 | 3 | -4.218*** | -17.32 | 0.436** | 2.36 | -0.158 | -0.53 | -8.440** | -2.07 | 360 | 73.5 | -3.163*** | -23.24 | 0.0222 | 0.22 | -0.0493 | -0.37 | 0.123 | 0.25 | -0.987 | -0.35 | 392 | 82.0 |
| 2 | 3 | -4.966*** | -18.26 | 0.218 | 1.22 | -0.204 | -0.73 | -4.184 | -1.07 | 360 | 78.2 | -2.893*** | -19.04 | -0.00200 | -0.02 | 0.0283 | 0.23 | 0.167 | 0.34 | -0.620 | -0.24 | 367 | 82.0 |
| 3 | 3 | -5.848*** | -16.72 | 0.120 | 0.60 | -0.207 | -0.68 | -3.492 | -0.80 | 360 | 78.1 | -9.952*** | -11.60 | -0.492 | -1.15 | 0.299 | 0.55 | -1.432 | -0.63 | 13.38 | 0.99 | 240 | 75.9 |
| 4 | 3 | -6.753*** | -14.78 | 0.129 | 0.48 | -0.0627 | -0.14 | -5.292 | -0.91 | 360 | 73.7 | -7.432*** | -15.93 | -0.126 | -0.46 | -0.472 | -1.06 | -1.866 | -1.34 | 8.456 | 1.13 | 359 | 75.5 |
| 5 | 3 | -7.417*** | -15.34 | -0.00757 | -0.03 | -0.0148 | -0.04 | -4.212 | -0.70 | 360 | 75.9 | -5.847*** | -16.54 | 0.119 | 0.59 | -0.208 | -0.68 | 0.0561 | 0.05 | -3.672 | -0.64 | 360 | 78.1 |
| 1 | 4 | -3.022*** | -23.11 | 0.100 | 1.05 | 0.0272 | 0.20 | -1.702 | -0.81 | 392 | 82.8 | -4.271*** | -18.65 | -0.0250 | -0.16 | -0.0373 | -0.17 | -0.538 | -0.73 | 1.998 | 0.51 | 392 | 77.1 |
| 2 | 4 | -3.743*** | -21.02 | 0.0196 | 0.16 | -0.0498 | -0.27 | -0.646 | -0.24 | 392 | 80.0 | -3.545*** | -20.84 | 0.0444 | 0.39 | 0.0474 | 0.30 | -0.226 | -0.40 | -0.502 | -0.16 | 392 | 81.4 |
| 3 | 4 | -4.262*** | -18.96 | -0.0402 | -0.26 | -0.0396 | -0.18 | 0.316 | 0.09 | 392 | 77.0 | -3.284*** | -19.47 | 0.0646 | 0.69 | 0.0521 | 0.31 | 0.267 | 0.52 | -2.681 | -0.99 | 371 | 82.4 |
| 4 | 4 | -4.795*** | -17.06 | -0.0945 | -0.50 | -0.101 | -0.35 | 0.954 | 0.23 | 392 | 74.0 | -11.80*** | -10.46 | -0.670 | -1.19 | 0.682 | 0.94 | -0.316 | -0.11 | 7.475 | 0.44 | 240 | 72.5 |
| 5 | 4 | -5.559*** | -16.56 | 0.0445 | 0.21 | -0.0451 | -0.14 | -3.427 | -0.74 | 392 | 75.0 | -8.644*** | -14.53 | -0.221 | -0.62 | -0.712 | -1.18 | -1.109 | -0.61 | 4.964 | 0.52 | 359 | 71.5 |
| 1 | 5 | -2.651*** | -24.40 | 0.110 | 1.29 | -0.0291 | -0.26 | -1.998 | -1.07 | 392 | 83.4 | -6.756*** | -14.74 | 0.135 | 0.50 | -0.0617 | -0.14 | -0.268 | -0.20 | -4.429 | -0.63 | 360 | 73.7 |
| 2 | 5 | -3.165*** | -23.83 | 0.0257 | 0.26 | -0.0488 | -0.37 | -0.601 | -0.27 | 392 | 82.0 | -4.802*** | -16.87 | -0.0818 | -0.42 | -0.0991 | -0.35 | -0.454 | -0.51 | 2.372 | 0.50 | 392 | 74.1 |
| 3 | 5 | -3.541*** | -21.35 | 0.0380 | 0.34 | 0.0464 | 0.29 | -1.208 | -0.49 | 392 | 81.3 | -3.809*** | -20.52 | -0.0815 | -0.59 | -0.0478 | -0.24 | -0.751 | -1.13 | 3.870 | 1.13 | 392 | 77.9 |
| 4 | 5 | -3.797*** | -21.11 | -0.103 | -0.77 | -0.0510 | -0.26 | 1.523 | 0.52 | 392 | 77.8 | -3.328*** | -19.23 | 0.0131 | 0.12 | -0.119 | -0.56 | 0.0440 | 0.07 | -0.963 | -0.30 | 368 | 75.3 |
| 5 | 5 | -4.508*** | -15.62 | 0.137 | 0.81 | 0.0880 | 0.34 | -4.684 | -1.27 | 392 | 76.7 | -12.71*** | -10.37 | -0.690 | -1.05 | 0.875 | 1.08 | -5.999* | -1.82 | 25.20 | 1.33 | 240 | 67.2 |
| 1 | 6 | -2.394*** | -23.11 | 0.143 | 1.23 | -0.174 | -0.73 | -2.861 | -1.11 | 367 | 71.7 | -9.967*** | -14.36 | 0.282 | 0.72 | -0.586 | -0.83 | -2.796 | -1.32 | -2.977 | -0.27 | 358 | 71.1 |
| 2 | 6 | -2.895*** | -19.46 | 0.00371 | 0.04 | 0.0295 | 0.24 | -0.121 | -0.06 | 367 | 81.9 | -7.425*** | -15.24 | 0.0110 | 0.04 | -0.0118 | -0.03 | -0.786 | -0.55 | -1.677 | -0.22 | 360 | 75.9 |
| 3 | 6 | -3.288*** | -19.57 | 0.0737 | 0.78 | 0.0537 | 0.32 | -1.882 | -0.91 | 371 | 82.4 | -5.582*** | -16.24 | 0.0839 | 0.38 | -0.0391 | -0.13 | -1.404 | -1.34 | 0.963 | 0.18 | 392 | 75.1 |
| 4 | 6 | -3.329*** | -19.45 | 0.0145 | 0.14 | -0.119 | -0.56 | -0.830 | -0.36 | 368 | 75.3 | -4.529*** | -15.46 | 0.174 | 1.02 | 0.0937 | 0.36 | -1.326 | -1.52 | -0.541 | -0.11 | 392 | 76.9 |
| 5 | 6 | -3.563*** | -17.70 | -0.0190 | -0.15 | -0.151 | -0.70 | -0.820 | -0.30 | 369 | 73.6 | -3.586*** | -17.62 | 0.0432 | 0.35 | -0.149 | -0.71 | -1.877*** | -2.70 | 4.830 | 1.39 | 369 | 74.3 |

## Table B4 Call Option Return Sensitivity to Stock Market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for call option portfolios. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the call options market. The log volatility is the average implied volatility across call options in the market. $ueliq_{sm}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{sm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | | |
| 1 | 1 | 6.595*** | 14.88 | 20.89 | 1.65 | 53.51** | 2.11 | 1.400 | 0.95 | 300 | 66.8 | 6.711*** | 16.93 | -40.56 | -1.21 | 25.54 | 1.01 | 9.072** | 2.00 | -25.14* | -1.87 | 300 | 67.6 |
| 2 | 1 | 7.690*** | 19.42 | 8.064 | 0.65 | 24.39 | 1.16 | 1.548 | 1.05 | 303 | 77.1 | 7.761*** | 19.94 | -28.91 | -1.18 | 7.519 | 0.33 | 5.440* | 1.67 | -14.35 | -1.46 | 303 | 77.3 |
| 3 | 1 | 10.22*** | 16.58 | 18.74 | 1.07 | 49.49* | 1.67 | -3.233 | -1.55 | 303 | 75.6 | 10.32*** | 16.85 | -32.48 | -1.03 | 26.12 | 0.82 | 7.536* | 1.85 | -25.26** | -2.05 | 303 | 75.9 |
| 4 | 1 | 11.33*** | 12.80 | 42.12* | 1.86 | 70.29* | 1.73 | -14.51*** | -5.52 | 303 | 68.4 | 11.49*** | 12.96 | -44.63 | -1.03 | 30.70 | 0.74 | 12.77** | 2.21 | -51.81*** | -2.98 | 303 | 68.9 |
| 5 | 1 | 12.87*** | 13.87 | -19.17 | -0.65 | 88.03 | 1.64 | -11.06*** | -2.97 | 300 | 54.6 | 13.08*** | 14.01 | -130.2** | -2.15 | 37.59 | 0.62 | 16.37** | 2.03 | -58.92** | -2.42 | 300 | 55.1 |
| 1 | 2 | 5.137*** | 25.89 | 15.94** | 2.55 | 21.36* | 1.67 | 0.137 | 0.19 | 495 | 76.3 | 5.174*** | 26.74 | -14.56 | -1.17 | 8.159 | 0.64 | 4.415** | 2.48 | -12.71** | -2.36 | 495 | 76.7 |
| 2 | 2 | 5.612*** | 16.59 | 11.11 | 1.36 | 22.52 | 1.29 | 0.0830 | 0.09 | 497 | 72.7 | 5.617*** | 16.41 | 7.128 | 0.42 | 20.80 | 1.09 | 0.578 | 0.30 | -1.601 | -0.28 | 497 | 72.7 |
| 3 | 2 | 6.859*** | 15.23 | 11.37 | 1.09 | 23.23 | 1.22 | -1.614 | -1.28 | 497 | 70.2 | 6.880*** | 15.19 | -8.136 | -0.41 | 14.82 | 0.76 | 2.832 | 1.27 | -9.863 | -1.52 | 497 | 70.2 |
| 4 | 2 | 7.756*** | 13.21 | 28.60** | 2.16 | 29.17 | 1.22 | -7.441*** | -4.68 | 497 | 64.6 | 7.796*** | 13.23 | -8.913 | -0.34 | 12.99 | 0.53 | 5.446* | 1.84 | -23.30*** | -2.69 | 497 | 64.8 |
| 5 | 2 | 8.745*** | 12.90 | -0.123 | 0.00 | 45.23 | 1.46 | -7.454*** | -3.51 | 497 | 57.8 | 8.792*** | 12.89 | -43.96 | -1.37 | 26.32 | 0.81 | 6.364* | 1.71 | -25.99** | -2.37 | 497 | 58.0 |
| 1 | 3 | 4.226*** | 14.32 | 18.15*** | 2.90 | 17.39 | 1.34 | -0.684 | -0.98 | 487 | 73.8 | 4.231*** | 14.36 | 12.71 | 1.06 | 15.09 | 1.13 | 0.813 | 0.50 | -3.066 | -0.63 | 487 | 73.8 |
| 2 | 3 | 4.775*** | 13.77 | 13.70* | 1.82 | 12.78 | 0.88 | -0.345 | -0.40 | 487 | 71.4 | 4.772*** | 13.71 | 16.78 | 1.22 | 14.08 | 0.89 | -0.459 | -0.27 | 1.001 | 0.21 | 487 | 71.4 |
| 3 | 3 | 5.482*** | 14.25 | 6.051 | 0.74 | 27.27* | 1.77 | -0.863 | -0.90 | 487 | 71.8 | 5.476*** | 14.21 | 12.62 | 0.89 | 30.04* | 1.85 | -0.981 | -0.56 | 2.010 | 0.39 | 487 | 71.9 |
| 4 | 3 | 6.325*** | 14.23 | 13.27 | 1.25 | 37.27** | 2.06 | -3.895*** | -3.14 | 487 | 68.2 | 6.329*** | 14.21 | 9.438 | 0.52 | 35.66* | 1.88 | 0.572 | 0.26 | -5.572 | -0.85 | 487 | 68.2 |
| 5 | 3 | 6.876*** | 12.49 | -7.590 | -0.56 | 31.16 | 1.26 | -4.512*** | -2.91 | 487 | 59.4 | 6.889*** | 12.52 | -21.65 | -0.90 | 25.23 | 0.96 | 2.101 | 0.69 | -10.67 | -1.17 | 487 | 59.4 |
| 1 | 4 | 3.018*** | 12.33 | 20.24*** | 4.55 | 13.43* | 1.79 | -1.441*** | -2.87 | 532 | 73.8 | 3.032*** | 12.35 | 10.18 | 1.31 | 9.173 | 1.12 | 1.482 | 1.57 | -5.772** | -2.05 | 532 | 73.9 |
| 2 | 4 | 3.751*** | 16.57 | 11.66** | 2.41 | 15.31* | 1.76 | -0.739 | -1.31 | 532 | 75.3 | 3.762*** | 16.53 | 3.474 | 0.37 | 11.85 | 1.29 | 1.205 | 1.07 | -4.262 | -1.29 | 532 | 75.4 |
| 3 | 4 | 4.228*** | 16.96 | 6.888 | 1.22 | 18.39* | 1.75 | -0.571 | -0.85 | 532 | 73.6 | 4.240*** | 16.91 | -1.763 | -0.16 | 14.74 | 1.34 | 1.274 | 1.04 | -4.294 | -1.19 | 532 | 73.7 |
| 4 | 4 | 4.720*** | 15.71 | 8.687 | 1.26 | 24.36** | 2.01 | -1.250 | -1.52 | 532 | 70.6 | 4.738*** | 15.72 | -3.433 | -0.26 | 19.24 | 1.54 | 1.785 | 1.20 | -6.467 | -1.49 | 532 | 70.7 |
| 5 | 4 | 5.317*** | 15.22 | -1.465 | -0.17 | 26.74* | 1.76 | -2.249** | -2.26 | 532 | 68.3 | 5.346*** | 15.23 | -21.72 | -1.36 | 18.18 | 1.13 | 2.983 | 1.60 | -10.97** | -2.01 | 532 | 68.5 |
| 1 | 5 | 2.929*** | 29.47 | 20.79*** | 6.35 | 11.20* | 1.96 | -1.480*** | -4.02 | 531 | 80.5 | 2.943*** | 29.74 | 11.33* | 1.73 | 7.201 | 1.12 | 1.393 | 1.57 | -5.553** | -2.09 | 531 | 80.6 |
| 2 | 5 | 2.845*** | 6.21 | 18.13*** | 2.60 | 19.98* | 1.93 | -1.514** | -1.98 | 532 | 56.6 | 2.850*** | 6.21 | 14.58 | 1.34 | 18.48* | 1.72 | 0.523 | 0.48 | -3.043 | -0.96 | 532 | 56.6 |
| 3 | 5 | 3.389*** | 13.80 | 8.215* | 1.75 | 17.11** | 2.17 | -0.653 | -1.19 | 532 | 73.4 | 3.395*** | 13.77 | 3.756 | 0.45 | 15.22* | 1.86 | 0.657 | 0.67 | -2.572 | -0.89 | 532 | 73.4 |
| 4 | 5 | 3.679*** | 12.98 | -0.115 | -0.02 | 22.37** | 2.29 | -0.199 | -0.30 | 532 | 70.4 | 3.683*** | 12.93 | -2.981 | -0.30 | 21.16** | 2.08 | 0.422 | 0.37 | -1.433 | -0.42 | 532 | 70.4 |
| 5 | 5 | 4.399*** | 13.92 | -7.628 | -1.04 | 20.00* | 1.74 | -0.755 | -0.91 | 532 | 67.8 | 4.413*** | 13.92 | -17.31 | -1.27 | 15.91 | 1.33 | 1.425 | 0.86 | -4.921 | -1.00 | 532 | 67.9 |
| 1 | 6 | 2.755*** | 25.33 | 17.44*** | 4.95 | 15.85** | 2.16 | -1.247*** | -3.15 | 496 | 75.4 | 2.757*** | 25.35 | 15.04** | 2.11 | 14.79* | 1.85 | 0.354 | 0.36 | -2.285 | -0.77 | 496 | 75.4 |
| 2 | 6 | 3.127*** | 21.52 | 4.435 | 0.90 | 24.02*** | 2.64 | -0.0249 | -0.04 | 501 | 69.7 | 3.126*** | 21.46 | 6.097 | 0.67 | 24.75** | 2.53 | -0.244 | -0.21 | 0.691 | 0.20 | 501 | 69.7 |
| 3 | 6 | 3.188*** | 12.14 | 6.124 | 1.12 | 21.37 | 1.64 | -0.363 | -0.58 | 505 | 68.2 | 3.180*** | 12.10 | 15.28 | 1.62 | 25.14* | 1.81 | -1.349 | -1.22 | 3.589 | 1.09 | 505 | 68.3 |
| 4 | 6 | 3.650*** | 24.80 | 4.144 | 0.95 | 19.79** | 2.11 | -0.539 | -1.03 | 498 | 75.5 | 3.647*** | 24.69 | 7.627 | 0.80 | 21.34** | 2.10 | -0.513 | -0.44 | 0.965 | 0.29 | 498 | 75.5 |
| 5 | 6 | 3.790*** | 13.25 | -13.88 | -1.48 | 23.00 | 1.57 | 0.534 | 0.52 | 501 | 53.6 | 3.785*** | 13.25 | -8.397 | -0.50 | 25.25 | 1.61 | -0.807 | -0.44 | 2.899 | 0.55 | 501 | 53.6 |

## Table B5 Put Option Return Sensitivity to Stock Market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for put option portfolios. Put option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility $(\ln(iv)_{pm})$ in the put options market. The log volatility is the average implied volatility across put options in the market. $ueliq_{sm}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | **Model 1** | | | | | | | | | |
| 1 | 1 | -5.901*** | -14.07 | 18.66 | 1.52 | -28.89 | -1.16 | 0.505 | 0.34 | 299 | 59.9 |
| 2 | 1 | -7.408*** | -13.42 | -10.02 | -0.81 | -23.33 | -0.93 | 3.160** | 2.07 | 303 | 72.8 |
| 3 | 1 | -10.38*** | -14.24 | -1.701 | -0.11 | -43.81 | -1.44 | -2.944 | -1.50 | 303 | 76.4 |
| 4 | 1 | -12.35*** | -13.19 | 21.89 | 1.09 | -54.49 | -1.57 | -11.90*** | -4.81 | 303 | 74.4 |
| 5 | 1 | -12.93*** | -12.68 | 0.842 | 0.03 | -79.85* | -1.75 | -12.81*** | -4.23 | 303 | 67.4 |
| 1 | 2 | -5.107*** | -26.54 | 5.967 | 0.94 | 0.367 | 0.03 | 1.083 | 1.39 | 497 | 76.5 |
| 2 | 2 | -6.119*** | -23.53 | -7.340 | -1.03 | 5.570 | 0.42 | 1.948** | 2.22 | 497 | 78.6 |
| 3 | 2 | -7.678*** | -18.73 | -5.697 | -0.61 | -2.401 | -0.13 | -0.631 | -0.54 | 497 | 77.3 |
| 4 | 2 | -8.956*** | -16.87 | -0.257 | -0.02 | -12.85 | -0.56 | -4.037*** | -2.65 | 497 | 73.9 |
| 5 | 2 | -10.07*** | -17.34 | -6.478 | -0.47 | -16.27 | -0.62 | -5.838*** | -3.46 | 496 | 73.2 |
| 1 | 3 | -4.176*** | -20.60 | 15.68** | 2.36 | 6.860 | 0.69 | -0.397 | -0.52 | 487 | 73.2 |
| 2 | 3 | -5.046*** | -21.54 | -1.465 | -0.24 | -15.77 | -1.38 | 0.836 | 1.15 | 487 | 79.2 |
| 3 | 3 | -5.975*** | -19.72 | 1.594 | 0.24 | -9.077 | -0.69 | -1.063 | -1.26 | 487 | 79.4 |
| 4 | 3 | -6.955*** | -17.33 | -0.815 | -0.09 | 2.943 | 0.17 | -2.411** | -2.18 | 487 | 75.7 |
| 5 | 3 | -7.631*** | -18.60 | -1.957 | -0.21 | -5.676 | -0.31 | -3.965*** | -3.46 | 487 | 76.9 |
| 1 | 4 | -3.082*** | -27.99 | 4.901 | 1.55 | 0.474 | 0.08 | -0.0837 | -0.22 | 532 | 82.9 |
| 2 | 4 | -3.869*** | -24.42 | -1.066 | -0.27 | -4.966 | -0.67 | -0.0892 | -0.18 | 532 | 80.9 |
| 3 | 4 | -4.405*** | -22.49 | -0.693 | -0.14 | -6.158 | -0.67 | -0.554 | -0.89 | 532 | 78.4 |
| 4 | 4 | -4.955*** | -20.16 | -0.954 | -0.16 | -2.130 | -0.20 | -1.079 | -1.40 | 532 | 76.2 |
| 5 | 4 | -5.692*** | -20.06 | -4.117 | -0.59 | 3.265 | 0.27 | -1.779** | -2.04 | 532 | 76.8 |
| 1 | 5 | -2.657*** | -28.45 | 6.512** | 2.40 | 0.882 | 0.19 | -0.319 | -0.99 | 532 | 83.6 |
| 2 | 5 | -3.204*** | -28.68 | 2.692 | 0.81 | -1.443 | -0.24 | -0.382 | -0.94 | 532 | 82.2 |
| 3 | 5 | -3.587*** | -25.63 | 1.272 | 0.35 | 0.847 | 0.13 | -0.541 | -1.19 | 532 | 82.0 |
| 4 | 5 | -3.858*** | -24.64 | -4.661 | -1.10 | 3.551 | 0.51 | -0.202 | -0.37 | 532 | 79.3 |
| 5 | 5 | -4.529*** | -18.45 | -4.640 | -0.82 | 4.974 | 0.52 | -0.965 | -1.42 | 532 | 77.9 |
| 1 | 6 | -2.342*** | -24.85 | 9.834** | 2.14 | 2.520 | 0.47 | -0.859* | -1.72 | 498 | 73.7 |
| 2 | 6 | -2.923*** | -24.59 | 1.992 | 0.66 | -1.522 | -0.26 | -0.361 | -1.00 | 500 | 82.4 |
| 3 | 6 | -3.267*** | -23.86 | 4.172 | 1.29 | -3.845 | -0.47 | -0.815** | -2.08 | 504 | 82.9 |
| 4 | 6 | -3.368*** | -23.54 | 2.659 | 0.60 | -3.448 | -0.39 | -0.889* | -1.69 | 500 | 76.9 |
| 5 | 6 | -3.601*** | -21.45 | -10.35** | -2.35 | -9.647 | -1.10 | 0.137 | 0.26 | 502 | 74.9 |

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | **Model 2** | | | | | | | | | | | |
| 1 | 1 | -5.942*** | -14.14 | 44.24* | 1.67 | -16.60 | -0.60 | -3.863 | -1.15 | 11.89 | 1.21 | 299 | 60.1 |
| 2 | 1 | -7.500*** | -14.22 | 45.29* | 1.69 | 2.460 | 0.10 | -8.311** | -2.42 | 27.60*** | 2.72 | 303 | 73.3 |
| 3 | 1 | -10.45*** | -14.77 | 41.30 | 1.22 | -23.76 | -0.77 | -6.461 | -1.49 | 16.06 | 1.26 | 303 | 76.6 |
| 4 | 1 | -12.43*** | -13.75 | 67.10 | 1.44 | -33.41 | -0.99 | -6.793 | -1.16 | 8.078 | 0.47 | 303 | 74.6 |
| 5 | 1 | -13.11*** | -13.50 | 108.6** | 2.03 | -29.59 | -0.65 | -16.20** | -2.37 | 34.83* | 1.74 | 303 | 68.1 |
| 1 | 2 | -5.114*** | -26.69 | 14.54 | 1.28 | 4.052 | 0.30 | -1.270 | -0.83 | 4.807 | 1.03 | 497 | 76.5 |
| 2 | 2 | -6.139*** | -23.69 | 15.77 | 1.22 | 15.50 | 1.17 | -3.425** | -2.14 | 11.99** | 2.52 | 497 | 78.7 |
| 3 | 2 | -7.688*** | -18.75 | 5.335 | 0.32 | 2.340 | 0.13 | -1.635 | -0.86 | 4.160 | 0.75 | 497 | 77.3 |
| 4 | 2 | -8.941*** | -16.84 | -17.22 | -0.79 | -20.14 | -0.83 | 2.513 | 1.02 | -11.40 | -1.59 | 497 | 73.9 |
| 5 | 2 | -10.07*** | -17.27 | -6.152 | -0.24 | -16.13 | -0.58 | -0.0484 | -0.02 | -5.697 | -0.65 | 496 | 73.2 |
| 1 | 3 | -4.173*** | -20.66 | 12.58 | 1.00 | 5.538 | 0.52 | 0.472 | 0.31 | -1.788 | -0.40 | 487 | 73.2 |
| 2 | 3 | -5.052*** | -21.91 | 6.826 | 0.51 | -12.23 | -1.05 | -1.262 | -0.76 | 4.555 | 0.96 | 487 | 79.2 |
| 3 | 3 | -5.977*** | -19.78 | 3.251 | 0.25 | -8.371 | -0.62 | -0.252 | -0.15 | -0.320 | -0.07 | 487 | 79.4 |
| 4 | 3 | -6.953*** | -17.41 | -3.289 | -0.18 | 1.889 | 0.11 | 0.377 | 0.17 | -3.521 | -0.54 | 487 | 75.7 |
| 5 | 3 | -7.626*** | -18.67 | -7.950 | -0.35 | -8.230 | -0.43 | 0.912 | 0.32 | -6.653 | -0.81 | 487 | 76.9 |
| 1 | 4 | -3.091*** | -28.76 | 12.51* | 1.83 | 3.746 | 0.59 | -1.141 | -1.36 | 3.269 | 1.35 | 532 | 83.0 |
| 2 | 4 | -3.875*** | -24.74 | 3.629 | 0.43 | -2.947 | -0.40 | -0.704 | -0.69 | 1.979 | 0.68 | 532 | 80.9 |
| 3 | 4 | -4.410*** | -22.70 | 3.946 | 0.39 | -4.164 | -0.44 | -0.695 | -0.57 | 1.489 | 0.42 | 532 | 78.4 |
| 4 | 4 | -4.958*** | -20.38 | 1.878 | 0.15 | -0.912 | -0.09 | -0.424 | -0.29 | 0.168 | 0.04 | 532 | 76.2 |
| 5 | 4 | -5.701*** | -20.40 | 3.579 | 0.23 | 6.574 | 0.53 | -1.154 | -0.63 | 1.612 | 0.31 | 532 | 76.8 |
| 1 | 5 | -2.657*** | -28.38 | 6.869 | 1.42 | 1.036 | 0.21 | -0.0536 | -0.09 | -0.162 | -0.09 | 532 | 83.6 |
| 2 | 5 | -3.203*** | -28.73 | 2.262 | 0.36 | -1.628 | -0.27 | 0.0645 | 0.08 | -0.572 | -0.25 | 532 | 82.2 |
| 3 | 5 | -3.589*** | -25.72 | 2.902 | 0.42 | 1.548 | 0.24 | -0.244 | -0.29 | 0.177 | 0.07 | 532 | 82.0 |
| 4 | 5 | -3.860*** | -24.72 | -3.076 | -0.39 | 4.232 | 0.58 | -0.238 | -0.25 | 0.496 | 0.18 | 532 | 79.3 |
| 5 | 5 | -4.534*** | -18.62 | -0.495 | -0.04 | 6.757 | 0.69 | -0.621 | -0.46 | 0.862 | 0.22 | 532 | 77.9 |
| 1 | 6 | -2.344*** | -25.07 | 12.48* | 1.69 | 3.710 | 0.63 | -0.396 | -0.59 | 0.306 | 0.17 | 498 | 73.7 |
| 2 | 6 | -2.921*** | -24.57 | -1.014 | -0.18 | -2.876 | -0.49 | 0.450 | 0.66 | -1.685 | -0.83 | 500 | 82.4 |
| 3 | 6 | -3.267*** | -23.87 | 3.248 | 0.51 | -4.234 | -0.50 | 0.138 | 0.17 | -1.222 | -0.52 | 504 | 82.9 |
| 4 | 6 | -3.368*** | -23.52 | 2.817 | 0.34 | -3.381 | -0.37 | -0.0236 | -0.03 | -0.819 | -0.31 | 500 | 76.9 |
| 5 | 6 | -3.601*** | -21.39 | -10.31 | -1.13 | -9.633 | -1.04 | -0.00469 | 0.00 | 0.150 | 0.05 | 502 | 74.9 |

**Table B6 Call Option Return Sensitivity to Illiquidity in the Option and Stock Markets**

This table reports when considering the expected and unexpected illiquidity of both the options market and stock market in the same regression estimation. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, call options market expected illiquidity $(eliq_{cm})$, call options market unexpected illiquidity $(ueliq_{cm})$, stock market *expected illiquidity* $(eliq_{sm})$ and stock market *unexpected illiquidity* $(ueliq_{sm})$ for each moneyness and maturity portfolio. $ueliq_{cm}$ and $ueliq_{sm}$ are the residuals obtained from the AR (p) specifications of the proportional bid-ask spread in the call options market and the stock market respectively after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | T | | |
| 1 | 1 | 6.193*** | 11.18 | 0.274* | 1.74 | -0.763*** | -2.90 | 26.43* | 1.95 | 46.97* | 1.67 | -5.248 | -1.35 | 232 | 69.7 |
| 2 | 1 | 6.749*** | 16.31 | 0.260** | 2.20 | -1.308*** | -3.50 | 8.855 | 0.72 | 18.42 | 0.83 | -4.739 | -1.60 | 235 | 80.0 |
| 3 | 1 | 8.889*** | 13.50 | 0.325* | 1.81 | -2.118*** | -4.58 | 14.60 | 0.84 | 60.86** | 2.00 | -10.65** | -2.40 | 235 | 80.0 |
| 4 | 1 | 10.35*** | 9.95 | 0.219 | 0.86 | -1.924*** | -3.32 | 42.65* | 1.67 | 88.26** | 2.04 | -19.63*** | -3.07 | 235 | 70.2 |
| 5 | 1 | 12.95*** | 10.44 | 0.210 | 0.54 | -1.039 | -1.14 | -1.481 | -0.04 | 86.98 | 1.43 | -17.34* | -1.85 | 233 | 58.2 |
| 1 | 2 | 4.732*** | 18.70 | 0.211*** | 2.67 | -0.488** | -2.54 | 20.82*** | 2.89 | 18.92 | 1.28 | -5.139** | -2.54 | 352 | 76.6 |
| 2 | 2 | 4.841*** | 13.44 | 0.291*** | 3.28 | -0.863*** | -3.69 | 11.31 | 1.30 | 22.21 | 1.29 | -6.703*** | -2.99 | 354 | 73.3 |
| 3 | 2 | 5.697*** | 11.71 | 0.268** | 2.11 | -1.309*** | -5.17 | 10.59 | 0.98 | 33.39* | 1.77 | -7.970*** | -2.61 | 354 | 71.0 |
| 4 | 2 | 6.433*** | 10.02 | 0.429** | 2.50 | -1.433*** | -4.01 | 25.82* | 1.79 | 32.75 | 1.37 | -17.20*** | -4.08 | 354 | 64.0 |
| 5 | 2 | 7.807*** | 9.83 | 0.329 | 1.42 | -1.370*** | -2.67 | 6.156 | 0.31 | 39.12 | 1.15 | -15.33*** | -2.62 | 354 | 57.8 |
| 1 | 3 | 3.809*** | 10.68 | 0.165* | 1.84 | -0.516*** | -3.19 | 20.06*** | 3.16 | 20.18 | 1.37 | -4.598** | -2.09 | 355 | 74.4 |
| 2 | 3 | 4.103*** | 10.21 | 0.194** | 2.02 | -0.739*** | -3.39 | 11.83 | 1.49 | 13.63 | 0.97 | -4.626* | -1.94 | 355 | 71.2 |
| 3 | 3 | 4.757*** | 10.67 | 0.196* | 1.76 | -0.855*** | -3.64 | 2.366 | 0.28 | 28.67* | 1.78 | -5.073* | -1.85 | 355 | 72.0 |
| 4 | 3 | 5.485*** | 10.70 | 0.155 | 1.18 | -0.952*** | -3.18 | 16.17 | 1.38 | 32.06 | 1.64 | -8.147** | -2.47 | 355 | 67.5 |
| 5 | 3 | 6.373*** | 9.65 | -0.0110 | -0.06 | -0.741* | -1.81 | 1.077 | 0.07 | 19.92 | 0.75 | -5.322 | -1.15 | 355 | 59.7 |
| 1 | 4 | 2.649*** | 9.35 | 0.177*** | 2.79 | -0.420*** | -4.45 | 19.86*** | 4.60 | 12.46 | 1.59 | -5.402*** | -3.55 | 387 | 74.0 |
| 2 | 4 | 3.243*** | 13.08 | 0.160** | 2.56 | -0.601*** | -4.87 | 8.838* | 1.81 | 17.63* | 1.84 | -4.165*** | -2.82 | 387 | 75.9 |
| 3 | 4 | 3.586*** | 13.24 | 0.122* | 1.68 | -0.786*** | -5.24 | 5.841 | 0.99 | 21.87** | 1.98 | -3.471** | -2.00 | 387 | 74.4 |
| 4 | 4 | 3.973*** | 12.21 | 0.151* | 1.74 | -0.829*** | -4.52 | 6.027 | 0.85 | 26.10** | 2.05 | -4.595** | -2.21 | 387 | 70.9 |
| 5 | 4 | 4.622*** | 12.00 | 0.102 | 0.94 | -0.841*** | -3.42 | 1.114 | 0.12 | 25.21 | 1.54 | -5.040* | -1.88 | 387 | 68.4 |
| 1 | 5 | 2.707*** | 23.53 | 0.142*** | 3.84 | -0.310*** | -3.26 | 22.26*** | 6.05 | 10.42 | 1.58 | -4.843*** | -5.44 | 386 | 82.5 |
| 2 | 5 | 2.379*** | 4.27 | 0.259** | 2.38 | -0.532*** | -4.65 | 13.25** | 2.41 | 18.15* | 1.73 | -6.883** | -2.50 | 387 | 53.8 |
| 3 | 5 | 2.909*** | 10.34 | 0.158** | 2.47 | -0.615*** | -5.58 | 6.347 | 1.43 | 19.65** | 2.37 | -4.172*** | -2.66 | 387 | 74.6 |
| 4 | 5 | 3.150*** | 9.62 | 0.164** | 2.22 | -0.644*** | -4.84 | -2.983 | -0.56 | 19.68** | 1.97 | -3.773** | -2.10 | 387 | 71.0 |
| 5 | 5 | 3.829*** | 10.58 | 0.109 | 1.15 | -0.690*** | -3.12 | -4.947 | -0.62 | 17.82 | 1.34 | -3.706 | -1.51 | 387 | 66.7 |
| 1 | 6 | 2.557*** | 21.22 | 0.145*** | 3.32 | -0.253*** | -2.64 | 19.18*** | 5.00 | 11.82 | 1.54 | -4.682*** | -4.78 | 359 | 76.8 |
| 2 | 6 | 2.650*** | 14.36 | 0.151*** | 2.92 | -0.630*** | -3.26 | 3.335 | 0.62 | 27.85*** | 2.71 | -3.518*** | -2.79 | 363 | 69.7 |
| 3 | 6 | 2.774*** | 8.66 | 0.205*** | 3.19 | -0.594*** | -2.63 | 2.913 | 0.56 | 29.70* | 1.75 | -4.709*** | -2.93 | 367 | 68.0 |
| 4 | 6 | 3.215*** | 19.35 | 0.0869 | 1.64 | -0.586*** | -4.21 | 6.232 | 1.33 | 21.00** | 2.10 | -2.992*** | -2.59 | 360 | 76.0 |
| 5 | 6 | 3.381*** | 10.53 | 0.0913 | 0.87 | -0.539 | -1.62 | -10.15 | -0.83 | 25.97 | 1.43 | -2.121 | -0.76 | 365 | 50.0 |

**Table B7 Put Option Return Sensitivity to Illiquidity in the Options market and Stock Market**

This table reports when considering the expected and unexpected illiquidity of both the options market and stock market in the same regression estimation. Put option excess return is regressed on stock market excess return $(r_m - r_f)$, put options market expected illiquidity $(eliq_{pm})$, put options market unexpected illiquidity $(ueliq_{pm})$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio. $ueliq_{pm}$ and $ueliq_{sm}$ are the residuals obtained from the AR (p) specifications of the proportional bid-ask spread in the put options market and the stock market respectively after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.5 & Table 3.4). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **T** | | |
| 1 | 1 | -5.491*** | -11.76 | -0.280 | -0.87 | -1.460*** | -3.82 | 13.18 | 0.82 | -38.41 | -1.37 | 7.242 | 0.84 | 232 | 62.9 |
| 2 | 1 | -6.804*** | -10.65 | 0.0228 | 0.13 | -1.039** | -2.13 | -6.877 | -0.47 | -20.91 | -0.75 | 1.872 | 0.43 | 235 | 72.9 |
| 3 | 1 | -9.287*** | -11.43 | -0.0858 | -0.34 | -1.738*** | -3.05 | 1.360 | 0.08 | -56.84* | -1.70 | -1.836 | -0.29 | 235 | 77.2 |
| 4 | 1 | -11.02*** | -10.66 | -0.273 | -0.85 | -2.051*** | -2.71 | 13.73 | 0.59 | -61.31 | -1.59 | -5.099 | -0.64 | 235 | 73.7 |
| 5 | 1 | -12.35*** | -10.68 | 0.175 | 0.46 | -0.984 | -1.20 | -11.86 | -0.41 | -85.96* | -1.77 | -16.17* | -1.70 | 235 | 67.0 |
| 1 | 2 | -4.973*** | -19.92 | 0.127 | 1.20 | -0.675*** | -3.65 | 3.293 | 0.41 | 15.79 | 0.98 | -1.827 | -0.69 | 354 | 77.0 |
| 2 | 2 | -5.631*** | -18.31 | 0.114 | 0.99 | -1.138*** | -4.72 | -9.821 | -1.10 | 19.16 | 1.12 | -0.585 | -0.20 | 354 | 78.9 |
| 3 | 2 | -6.932*** | -14.81 | 0.0265 | 0.19 | -1.604*** | -4.90 | -11.47 | -1.00 | 8.814 | 0.40 | -0.855 | -0.25 | 354 | 78.0 |
| 4 | 2 | -7.967*** | -13.31 | -0.0942 | -0.55 | -2.138*** | -5.28 | -14.63 | -1.01 | 8.240 | 0.30 | -0.611 | -0.15 | 354 | 74.7 |
| 5 | 2 | -9.299*** | -12.24 | 0.167 | 0.79 | -1.955*** | -3.74 | -20.42 | -1.18 | 7.092 | 0.24 | -8.831* | -1.71 | 353 | 73.3 |
| 1 | 3 | -4.011*** | -13.90 | 0.0400 | 0.49 | -0.521** | -2.01 | 14.50 | 1.61 | 12.77 | 0.99 | -1.417 | -0.59 | 355 | 74.2 |
| 2 | 3 | -4.706*** | -16.73 | -0.000259 | 0.00 | -0.757*** | -3.19 | 0.0913 | 0.01 | -5.750 | -0.40 | 0.548 | 0.22 | 355 | 79.6 |
| 3 | 3 | -5.530*** | -15.52 | 0.00928 | 0.08 | -0.904*** | -3.62 | 3.433 | 0.40 | 1.482 | 0.09 | -1.647 | -0.60 | 355 | 79.6 |
| 4 | 3 | -6.366*** | -13.43 | 0.0500 | 0.38 | -1.161*** | -3.31 | 0.245 | 0.02 | 12.19 | 0.58 | -3.904 | -1.19 | 355 | 75.5 |
| 5 | 3 | -7.090*** | -14.81 | -0.0712 | -0.53 | -1.041*** | -2.92 | -6.335 | -0.53 | 0.892 | 0.04 | -2.309 | -0.68 | 355 | 77.2 |
| 1 | 4 | -2.914*** | -21.19 | -0.00268 | -0.06 | -0.361*** | -3.36 | 4.138 | 1.03 | 6.563 | 0.90 | 0.0136 | 0.01 | 387 | 83.8 |
| 2 | 4 | -3.567*** | -19.05 | -0.0288 | -0.48 | -0.580*** | -3.93 | -1.680 | -0.33 | 0.860 | 0.10 | 0.514 | 0.32 | 387 | 81.6 |
| 3 | 4 | -4.052*** | -17.65 | -0.0357 | -0.50 | -0.696*** | -3.99 | -2.784 | -0.45 | -0.442 | -0.04 | 0.378 | 0.20 | 387 | 78.7 |
| 4 | 4 | -4.511*** | -15.64 | -0.0263 | -0.31 | -0.893*** | -4.08 | -2.110 | -0.28 | 3.624 | 0.30 | -0.536 | -0.24 | 387 | 76.0 |
| 5 | 4 | -5.303*** | -15.42 | -0.0534 | -0.58 | -0.838*** | -3.44 | -8.726 | -0.97 | 9.524 | 0.68 | -0.345 | -0.15 | 387 | 76.4 |
| 1 | 5 | -2.534*** | -20.52 | 0.00770 | 0.19 | -0.361*** | -4.25 | 5.544 | 1.56 | 6.501 | 1.18 | -0.466 | -0.42 | 387 | 84.8 |
| 2 | 5 | -3.042*** | -21.12 | -0.0518 | -1.04 | -0.380*** | -3.68 | 0.901 | 0.21 | 1.529 | 0.24 | 0.957 | 0.72 | 387 | 83.0 |
| 3 | 5 | -3.435*** | -17.77 | -0.0526 | -0.96 | -0.385*** | -3.01 | -1.088 | -0.23 | 1.953 | 0.26 | 0.858 | 0.60 | 387 | 82.2 |
| 4 | 5 | -3.627*** | -18.63 | -0.0432 | -0.72 | -0.529*** | -4.25 | -6.876 | -1.25 | 6.559 | 0.85 | 0.918 | 0.57 | 387 | 79.1 |
| 5 | 5 | -4.405*** | -12.16 | -0.0316 | -0.43 | -0.413* | -1.72 | -8.866 | -1.22 | 7.086 | 0.68 | 0.0706 | 0.04 | 387 | 77.3 |
| 1 | 6 | -2.241*** | -13.62 | 0.0140 | 0.29 | -0.443** | -2.16 | 9.642 | 1.44 | 2.359 | 0.36 | -1.219 | -0.71 | 362 | 73.8 |
| 2 | 6 | -2.815*** | -17.44 | -0.0740 | -1.58 | -0.321*** | -2.88 | -0.290 | -0.07 | -0.646 | -0.10 | 1.574 | 1.35 | 362 | 82.8 |
| 3 | 6 | -3.222*** | -16.38 | -0.000125 | 0.00 | -0.325** | -2.53 | 3.260 | 0.75 | -3.771 | -0.47 | -0.745 | -0.59 | 366 | 83.1 |
| 4 | 6 | -3.138*** | -16.34 | -0.0417 | -0.71 | -0.580*** | -4.24 | 0.918 | 0.16 | -5.732 | -0.67 | 0.184 | 0.13 | 363 | 77.3 |
| 5 | 6 | -3.400*** | -15.78 | 0.0185 | 0.30 | -0.555*** | -3.80 | -14.58** | -2.51 | -5.034 | -0.61 | -0.0159 | -0.01 | 364 | 75.8 |

## Table B8 Fixed Effects Model: Effect of Options market Illiquidity on Option Excess Returns

This table reports from the fixed effects panel data regressions. We estimate (1) to (8) models. Panel A reports the results for the call options. Panel B reports the results for the put options. We estimate both the univariate and the multivariate specifications. Model (1), (2), (3) and (4) are the univariate fixed-effects models regressing option returns on stock market excess returns ($r_m - r_f$), options market expected illiquidity ($eliq$), options market unexpected illiquidity ($ueliq$) and log volatility ($\mathbf{ln}(\boldsymbol{iv})$). Model (5), (6), (7) and (8) are the multivariate specifications including two and three independent variables. $ueliq_{cm}$ and $ueliq_{pm}$ are the residuals obtained from the AR(p) specifications of the proportional bid-ask spread in the call options market and put options market respectively after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the within R-square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Variables/Models | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Call Options** | | | | | | | | | |
| $r_m - r_f$ | $Coeff$ | 4.918*** | | | | 5.031*** | 4.588*** | 4.644*** | 4.660*** |
| | $t$ | 13.66 | | | | 12.54 | 12.08 | 12.17 | 12.16 |
| $eliq_{cm}$ | $Coeff$ | | 0.124*** | | | 0.270*** | | 0.247*** | 0.198*** |
| | $t$ | | 4.65 | | | 11.06 | | 10.88 | 12.23 |
| $ueliq_{cm}$ | $Coeff$ | | | -2.748*** | | | -0.724*** | -0.684*** | -0.688*** |
| | $t$ | | | -13.17 | | | -12.83 | -12.59 | -12.65 |
| $\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{cm}}$ | $Coeff$ | | | | 0.383 | | | | 1.659*** |
| | $t$ | | | | 1.39 | | | | 5.19 |
| Constant | $Coeff$ | -1.086*** | -3.926*** | -1.931*** | -2.652** | -6.771*** | -0.980*** | -6.484*** | -11.62*** |
| | $t$ | -118.10 | -6.60 | -32.90 | -2.56 | -12.89 | -41.78 | -13.07 | -8.25 |
| Observations | | 17,786 | 10,545 | 10,545 | 17,786 | 10,545 | 10,545 | 10,545 | 10,545 |
| R-squared | | 56.70 | 0.20 | 20.30 | 0.00 | 53.50 | 53.80 | 54.40 | 54.60 |
| Portfolios | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| **Panel B: Put Options** | | | | | | | | | |
| $r_m - r_f$ | $Coeff$ | -5.188*** | | | | -5.299*** | -5.034*** | -5.036*** | -5.047*** |
| | $t$ | -12.32 | | | | -12.39 | -12.67 | -12.65 | -12.62 |
| $eliq_{pm}$ | $Coeff$ | | -0.0660** | | | 0.0434* | | 0.0308 | -0.0110 |
| | $t$ | | -2.07 | | | 1.94 | | 1.37 | -0.68 |
| $ueliq_{pm}$ | $Coeff$ | | | -2.641*** | | | -0.856*** | -0.855*** | -0.862*** |
| | $t$ | | | -10.21 | | | -9.18 | -9.20 | -9.16 |
| $\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{pm}}$ | $Coeff$ | | | | 0.902*** | | | | -1.020*** |
| | $t$ | | | | 4.28 | | | | -3.63 |
| Constant | $Coeff$ | -1.220*** | 0.652 | -1.596*** | -4.472*** | -2.289*** | -1.521*** | -2.221*** | 2.560** |
| | $t$ | -105.00 | 0.90 | -21.82 | -5.63 | -4.32 | -25.64 | -4.10 | 2.63 |
| Observations | | 17,794 | 10,550 | 10,550 | 17,794 | 10,550 | 10,550 | 10,550 | 10,550 |
| R-squared | | 62.50 | 0.00 | 13.00 | 0.10 | 60.20 | 61.40 | 61.40 | 61.50 |
| Portfolios | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |

## Table B9 Fixed Effects Model: Effect of Stock Market Illiquidity on Option Returns

This table reports from the fixed effects panel data regressions. We estimate (1) to (11) models. Panel A reports the results for the call options. Panel B repots the results for the put options. We estimate both the univariate and the multivariate specifications as reported in the table. Model (1), (2), (3), (4) and (5) are the univariate fixed-effects models regressing option return on stock market excess return ($r_m - r_f$), stock market expected illiquidity ($eliq_{sm}$), stock market unexpected illiquidity ($ueliq_{sm}$), log volatility ($\mathbf{ln}(\boldsymbol{iv})$) and residual obtained from the regression of options market illiquidity on stock market illiquidity($res_{com}$). Model (5) to (11) are the multivariate specifications including two and three independent variables. $eliq_{sm}$ and $ueliq_{sm}$ are the predicted values and the residuals obtained from the AR (p) specification of the proportional bid-ask spread in the stock market, respectively after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the within R-square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Variables/Models | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Call Options** | | | | | | | | | | | | |
| $r_m - r_f$ | $Coeff$ | 4.918*** | | | | | 5.155*** | 5.165*** | 5.154*** | 5.213*** | 5.218*** | 5.265*** |
| | $t$ | 13.66 | | | | | 13.21 | 13.19 | 13.20 | 13.10 | 13.24 | 13.14 |
| $eliq_{sm}$ | $Coeff$ | | 18.45*** | | | | 6.198*** | | 7.003*** | -9.696*** | 5.923*** | -9.919*** |
| | $t$ | | 5.91 | | | | 3.31 | | 3.58 | -4.17 | 3.10 | -4.26 |
| $ueliq_{sm}$ | $Coeff$ | | | 7.829*** | | | | 0.844 | 0.914 | -2.827** | 1.338* | -2.308** |
| | $t$ | | | 8.94 | | | | 1.27 | 1.38 | -2.65 | 1.99 | -2.18 |
| $\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{cm}}$ | $Coeff$ | | | | 0.383 | | | | | 3.139*** | | 3.007*** |
| | $t$ | | | | 1.39 | | | | | 6.79 | | 6.60 |
| $res_{com}$ | $Coeff$ | | | | | -0.618*** | | | | | 0.0874*** | 0.0746*** |
| | $t$ | | | | | -12.40 | | | | | 6.77 | 6.30 |
| Constant | $Coeff$ | -1.086*** | -3.562*** | -1.149*** | -2.652** | -1.211*** | -1.650*** | -0.837*** | -1.742*** | -11.39*** | -1.599*** | -10.86*** |
| | $t$ | -118.10 | -8.81 | -716.20 | -2.56 | -2243.00 | -6.85 | -34.99 | -6.97 | -7.40 | -6.54 | -7.19 |
| Observations | | 17,786 | 14,396 | 14,247 | 17,786 | 17,637 | 14,396 | 14,247 | 14,247 | 14,247 | 14,247 | 14,247 |
| R-squared | | 56.70 | 0.50 | 0.20 | 0.00 | 4.40 | 55.00 | 55.10 | 55.10 | 55.40 | 55.20 | 55.40 |
| Portfolios | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| **Panel B: Put Options** | | | | | | | | | | | | |
| $r_m - r_f$ | $Coeff$ | -5.188*** | | | | | -5.391*** | -5.398*** | -5.403*** | -5.450*** | -5.336*** | -5.380*** |
| | $t$ | -12.32 | | | | | -12.23 | -12.25 | -12.25 | -12.15 | -12.27 | -12.20 |
| $eliq_{sm}$ | $Coeff$ | | -9.806*** | | | | 2.780*** | | 2.768*** | 17.05*** | 1.542* | 21.79*** |
| | $t$ | | -4.32 | | | | 3.09 | | 3.02 | 6.73 | 1.73 | 7.21 |
| $ueliq_{sm}$ | $Coeff$ | | | -2.206*** | | | | 4.895*** | 4.922*** | 8.106*** | 5.668*** | 10.55*** |
| | $t$ | | | -3.03 | | | | 10.45 | 10.41 | 8.85 | 10.85 | 9.11 |
| $\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{pm}}$ | $Coeff$ | | | | 0.902*** | | | | | -2.725*** | | -3.946*** |
| | $t$ | | | | 4.28 | | | | | -5.43 | | -6.39 |
| $res_{pom}$ | $Coeff$ | | | | | -0.750*** | | | | | -0.192*** | -0.260*** |
| | $t$ | | | | | -10.78 | | | | | -8.82 | -8.57 |
| Constant | $Coeff$ | -1.220*** | 0.391 | -0.887*** | -4.472*** | -1.078*** | -1.588*** | -1.224*** | -1.581*** | 6.821*** | -1.401*** | 10.83*** |
| | $t$ | -105.00 | 1.33 | -671.30 | -5.63 | -2584.00 | -13.00 | -43.76 | -12.73 | 4.37 | -11.87 | 5.61 |
| Observations | | 17,794 | 14,401 | 14,254 | 17,794 | 17,647 | 14,401 | 14,254 | 14,254 | 14,254 | 14,254 | 14,254 |
| R-squared | | 62.50 | 0.10 | 0.00 | 0.10 | 3.70 | 61.20 | 61.30 | 61.30 | 61.50 | 61.60 | 61.90 |
| Portfolios | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

**Table B10(a) Robustness Check 1: Call Option Return Sensitivity to Call Options market Illiquidity**

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for call option portfolios when illiquidity is measured as the natural log of the proportional bid-ask spread. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, call options market expected illiquidity $(eliq_{cm})$ and call options market unexpected illiquidity $(ueliq_{cm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{cm}$ is the residual obtained from the AR (p) specification of the natural log of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | T | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 6.126*** | 10.60 | 8.522*** | 2.61 | -20.39*** | -3.01 | -23.22** | -2.30 | 236 | 69.1 | 6.152*** | 11.06 | 5.527* | 1.72 | -19.97*** | -3.06 | 5.052*** | 2.86 | -32.82*** | -3.04 | 236 | 70.2 |
| 2 | 1 | 6.705*** | 16.13 | 5.709** | 2.26 | -31.92*** | -3.52 | -16.63** | -2.09 | 240 | 79.7 | 6.716*** | 16.49 | 4.792* | 1.96 | -31.73*** | -3.49 | 1.530 | 0.98 | -19.50** | -2.13 | 240 | 79.8 |
| 3 | 1 | 8.731*** | 13.33 | 7.793** | 2.02 | -53.93*** | -5.00 | -27.61** | -2.30 | 240 | 79.7 | 8.750*** | 13.47 | 6.162 | 1.63 | -53.60*** | -5.03 | 2.720 | 1.26 | -32.71** | -2.42 | 240 | 79.9 |
| 4 | 1 | 10.22*** | 9.67 | 7.940 | 1.38 | -49.57*** | -3.42 | -35.93** | -2.00 | 240 | 69.7 | 10.27*** | 9.78 | 3.392 | 0.64 | -48.63*** | -3.49 | 7.585** | 2.34 | -50.15** | -2.43 | 240 | 70.5 |
| 5 | 1 | 12.71*** | 10.34 | 3.047 | 0.37 | -31.30 | -1.46 | -23.39 | -0.89 | 238 | 57.2 | 12.74*** | 10.41 | 0.824 | 0.10 | -30.79 | -1.44 | 3.754 | 0.86 | -30.52 | -1.06 | 238 | 57.4 |
| 1 | 2 | 4.672*** | 17.75 | 5.710*** | 3.32 | -12.76*** | -2.92 | -16.12*** | -3.05 | 357 | 75.9 | 4.709*** | 18.85 | 3.790** | 2.55 | -12.57*** | -3.05 | 3.119*** | 3.32 | -21.85*** | -3.43 | 357 | 76.8 |
| 2 | 2 | 4.784*** | 12.47 | 6.508*** | 3.47 | -21.33*** | -3.94 | -19.80*** | -3.43 | 359 | 73.0 | 4.802*** | 12.79 | 5.793*** | 3.24 | -21.25*** | -3.93 | 1.140 | 1.11 | -21.86*** | -3.30 | 359 | 73.1 |
| 3 | 2 | 5.612*** | 10.98 | 5.896** | 2.30 | -32.96*** | -5.39 | -20.10** | -2.53 | 359 | 71.0 | 5.637*** | 11.16 | 4.918* | 1.93 | -32.85*** | -5.38 | 1.558 | 1.18 | -22.91*** | -2.60 | 359 | 71.1 |
| 4 | 2 | 6.292*** | 9.28 | 10.33*** | 2.98 | -37.51*** | -4.55 | -37.84*** | -3.51 | 359 | 63.9 | 6.350*** | 9.49 | 8.074** | 2.36 | -37.24*** | -4.51 | 3.592** | 2.04 | -44.31*** | -3.66 | 359 | 64.4 |
| 5 | 2 | 7.612*** | 9.17 | 6.609 | 1.37 | -39.39*** | -3.46 | -29.14* | -1.94 | 359 | 58.3 | 7.640*** | 9.27 | 5.549 | 1.21 | -39.27*** | -3.46 | 1.690 | 0.73 | -32.18* | -1.90 | 359 | 58.4 |
| 1 | 3 | 3.740*** | 9.75 | 4.571** | 2.44 | -13.93*** | -3.63 | -13.19** | -2.28 | 360 | 73.6 | 3.766*** | 10.21 | 3.063* | 1.85 | -13.96*** | -3.73 | 2.709*** | 3.12 | -18.66*** | -2.79 | 360 | 74.4 |
| 2 | 3 | 4.034*** | 9.50 | 4.432** | 2.21 | -19.72*** | -4.00 | -13.32** | -2.15 | 360 | 71.1 | 4.045*** | 9.73 | 3.790** | 2.06 | -19.73*** | -4.00 | 1.154 | 1.16 | -15.65** | -2.15 | 360 | 71.2 |
| 3 | 3 | 4.668*** | 10.01 | 3.896* | 1.68 | -22.92*** | -4.34 | -13.33* | -1.86 | 360 | 72.2 | 4.668*** | 10.07 | 3.910* | 1.83 | -22.92*** | -4.33 | -0.0246 | -0.02 | -13.28 | -1.60 | 360 | 72.2 |
| 4 | 3 | 5.381*** | 9.98 | 4.059 | 1.47 | -25.68*** | -3.80 | -16.22* | -1.89 | 360 | 67.6 | 5.400*** | 10.18 | 2.987 | 1.16 | -25.71*** | -3.81 | 1.927 | 1.32 | -20.11** | -1.98 | 360 | 67.7 |
| 5 | 3 | 6.177*** | 9.01 | -0.591 | -0.15 | -24.92*** | -2.75 | -4.467 | -0.36 | 360 | 60.3 | 6.179*** | 9.05 | -0.740 | -0.19 | -24.92*** | -2.74 | 0.267 | 0.13 | -5.006 | -0.35 | 360 | 60.3 |
| 1 | 4 | 2.580*** | 8.28 | 4.823*** | 3.77 | -11.76*** | -4.84 | -14.45*** | -3.66 | 392 | 72.4 | 2.621*** | 8.74 | 3.283*** | 2.82 | -11.61*** | -4.93 | 2.641*** | 4.70 | -19.57*** | -4.41 | 392 | 74.1 |
| 2 | 4 | 3.179*** | 11.99 | 3.862*** | 3.07 | -15.89*** | -5.36 | -12.09*** | -3.12 | 392 | 75.7 | 3.198*** | 12.36 | 3.141*** | 2.62 | -15.82*** | -5.35 | 1.237** | 2.00 | -14.49*** | -3.29 | 392 | 76.0 |
| 3 | 4 | 3.520*** | 12.41 | 2.859* | 1.92 | -20.34*** | -5.98 | -9.623** | -2.10 | 392 | 74.5 | 3.533*** | 12.58 | 2.353 | 1.64 | -20.29*** | -5.96 | 0.868 | 1.19 | -11.30** | -2.17 | 392 | 74.6 |
| 4 | 4 | 3.894*** | 11.36 | 3.465* | 1.95 | -21.80*** | -5.18 | -12.02** | -2.19 | 392 | 71.0 | 3.911*** | 11.56 | 2.837 | 1.64 | -21.74*** | -5.15 | 1.077 | 1.23 | -14.11** | -2.28 | 392 | 71.1 |
| 5 | 4 | 4.518*** | 11.35 | 2.151 | 0.94 | -23.30*** | -4.30 | -10.13 | -1.43 | 392 | 68.8 | 4.529*** | 11.45 | 1.734 | 0.79 | -23.26*** | -4.29 | 0.715 | 0.64 | -11.51 | -1.43 | 392 | 68.9 |
| 1 | 5 | 2.672*** | 20.94 | 4.407*** | 5.26 | -8.113*** | -3.35 | -12.96*** | -5.06 | 391 | 80.0 | 2.708*** | 23.52 | 2.785*** | 3.74 | -7.987*** | -3.68 | 2.822*** | 5.73 | -18.49*** | -6.34 | 391 | 82.2 |
| 2 | 5 | 2.301*** | 3.76 | 5.796*** | 2.62 | -14.74*** | -4.23 | -18.05*** | -2.62 | 392 | 53.0 | 2.325*** | 3.87 | 4.856** | 2.50 | -14.65*** | -4.22 | 1.612** | 2.20 | -21.17*** | -2.69 | 392 | 53.5 |
| 3 | 5 | 2.855*** | 9.37 | 3.541*** | 2.72 | -15.83*** | -5.73 | -11.43*** | -2.84 | 392 | 74.4 | 2.868*** | 9.57 | 3.062** | 2.52 | -15.78*** | -5.71 | 0.820 | 1.42 | -13.02*** | -2.84 | 392 | 74.5 |
| 4 | 5 | 3.101*** | 8.86 | 3.023** | 2.02 | -16.58*** | -5.01 | -10.47** | -2.26 | 392 | 71.0 | 3.096*** | 8.91 | 3.230** | 2.31 | -16.60*** | -5.05 | -0.355 | -0.52 | -9.783* | -1.86 | 392 | 71.1 |
| 5 | 5 | 3.757*** | 9.93 | 1.737 | 0.84 | -18.82*** | -3.79 | -7.919 | -1.23 | 392 | 67.0 | 3.752*** | 9.94 | 1.917 | 1.01 | -18.84*** | -3.81 | -0.309 | -0.31 | -7.321 | -0.98 | 392 | 67.0 |
| 1 | 6 | 2.501*** | 18.23 | 4.209*** | 4.55 | -7.025*** | -3.07 | -12.46*** | -4.43 | 364 | 74.5 | 2.529*** | 20.43 | 2.817*** | 3.13 | -6.797*** | -3.19 | 2.344*** | 4.52 | -16.93*** | -5.52 | 364 | 76.2 |
| 2 | 6 | 2.646*** | 14.13 | 3.477*** | 3.07 | -14.04*** | -3.41 | -11.04*** | -3.24 | 368 | 68.7 | 2.650*** | 14.21 | 3.285*** | 2.99 | -14.03*** | -3.39 | 0.322 | 0.45 | -11.65*** | -2.93 | 368 | 68.7 |
| 3 | 6 | 2.734*** | 7.95 | 4.466*** | 3.30 | -14.22*** | -2.70 | -14.18*** | -3.46 | 372 | 67.2 | 2.735*** | 8.02 | 4.449*** | 3.59 | -14.21*** | -2.70 | 0.0295 | 0.04 | -14.24*** | -2.98 | 372 | 67.2 |
| 4 | 6 | 3.184*** | 18.44 | 2.304** | 2.15 | -14.05*** | -4.54 | -7.931** | -2.43 | 365 | 75.6 | 3.190*** | 18.69 | 1.960* | 1.76 | -14.07*** | -4.53 | 0.582 | 1.01 | -9.050** | -2.57 | 365 | 75.7 |
| 5 | 6 | 3.322*** | 10.07 | 1.293 | 0.54 | -14.71* | -1.96 | -5.878 | -0.79 | 370 | 50.0 | 3.306*** | 9.94 | 2.033 | 0.93 | -14.78** | -2.00 | -1.221 | -0.90 | -3.595 | -0.41 | 370 | 50.1 |

## Table B10(b) Robustness Check 1: Put Option Return Sensitivity to Put Options market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for put option portfolios when illiquidity is measured as the natural log of the proportional bid-ask spread. Put option excess return is regressed on stock market excess return $(r_m - r_f)$, put options market expected illiquidity $(eliq_{pm})$ and put options market unexpected illiquidity $(ueliq_{pm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the put options market. The log volatility is the average implied volatility across all put options in the market. $ueliq_{pm}$ is the residual obtained from the AR (p) specification of the natural log of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | -5.441*** | -11.51 | -7.450 | -1.14 | -29.37*** | -3.33 | 25.20 | 1.22 | 234 | 62.4 | -5.444*** | -11.47 | -7.716 | -1.04 | -29.32*** | -3.35 | -0.318 | -0.15 | 27.23 | 0.94 | 234 | 62.4 |
| 2 | 1 | -6.932*** | -10.68 | 1.618 | 0.42 | -15.95 | -1.49 | -3.876 | -0.31 | 240 | 72.3 | -6.956*** | -10.62 | -1.467 | -0.38 | -15.88 | -1.54 | -3.557* | -1.96 | 19.20 | 1.31 | 240 | 72.8 |
| 3 | 1 | -9.308*** | -11.47 | -0.433 | -0.08 | -31.59** | -2.60 | -2.971 | -0.16 | 240 | 76.6 | -9.322*** | -11.41 | -2.209 | -0.39 | -31.55*** | -2.64 | -2.047 | -0.94 | 10.31 | 0.50 | 240 | 76.6 |
| 4 | 1 | -11.15*** | -10.58 | -4.680 | -0.64 | -33.33** | -2.04 | 4.480 | 0.19 | 240 | 72.9 | -11.17*** | -10.54 | -6.195 | -0.85 | -33.29** | -2.06 | -1.747 | -0.63 | 15.82 | 0.59 | 240 | 73.0 |
| 5 | 1 | -12.41*** | -10.70 | 6.955 | 0.88 | -13.22 | -0.76 | -35.55 | -1.42 | 240 | 66.5 | -12.45*** | -10.86 | 1.255 | 0.16 | -13.09 | -0.78 | -6.572** | -1.98 | 7.092 | 0.23 | 240 | 67.0 |
| 1 | 2 | -5.003*** | -20.19 | 2.151 | 0.97 | -12.85*** | -3.14 | -5.694 | -0.81 | 359 | 76.8 | -5.000*** | -20.03 | 2.340 | 1.06 | -12.85*** | -3.14 | 0.222 | 0.21 | -7.121 | -0.83 | 359 | 76.8 |
| 2 | 2 | -5.649*** | -18.90 | 2.889 | 1.17 | -22.50*** | -4.28 | -8.958 | -1.14 | 359 | 78.7 | -5.674*** | -18.50 | 1.481 | 0.60 | -22.51*** | -4.34 | -1.653 | -1.51 | 1.683 | 0.18 | 359 | 78.8 |
| 3 | 2 | -6.930*** | -15.17 | 1.464 | 0.46 | -32.67*** | -4.53 | -7.208 | -0.71 | 359 | 77.8 | -6.956*** | -15.05 | -0.0401 | -0.01 | -32.67*** | -4.61 | -1.767 | -1.36 | 4.164 | 0.39 | 359 | 78.0 |
| 4 | 2 | -7.971*** | -13.60 | -0.644 | -0.16 | -43.45*** | -4.83 | -3.734 | -0.29 | 359 | 74.5 | -7.991*** | -13.45 | -1.773 | -0.49 | -43.46*** | -4.87 | -1.326 | -0.81 | 4.801 | 0.38 | 359 | 74.6 |
| 5 | 2 | -9.300*** | -12.42 | 5.739 | 1.20 | -39.08*** | -3.41 | -26.64* | -1.74 | 358 | 73.0 | -9.322*** | -12.34 | 4.073 | 0.89 | -39.18*** | -3.44 | -1.980 | -1.00 | -13.96 | -0.86 | 358 | 73.1 |
| 1 | 3 | -4.027*** | -13.91 | -0.380 | -0.23 | -10.66** | -2.00 | 2.153 | 0.42 | 360 | 73.6 | -4.015*** | -13.99 | 1.141 | 0.63 | -10.32** | -1.98 | 1.822 | 1.61 | -9.452 | -1.11 | 360 | 74.0 |
| 2 | 3 | -4.683*** | -16.89 | 0.143 | 0.08 | -16.33*** | -3.44 | -0.349 | -0.06 | 360 | 79.6 | -4.686*** | -16.71 | -0.244 | -0.12 | -16.41*** | -3.47 | -0.463 | -0.50 | 2.599 | 0.32 | 360 | 79.6 |
| 3 | 3 | -5.531*** | -15.73 | 0.174 | 0.07 | -18.58*** | -3.54 | -2.054 | -0.26 | 360 | 79.5 | -5.530*** | -15.62 | 0.310 | 0.13 | -18.55*** | -3.51 | 0.163 | 0.16 | -3.091 | -0.36 | 360 | 79.5 |
| 4 | 3 | -6.387*** | -13.56 | 1.341 | 0.46 | -23.41*** | -3.18 | -7.578 | -0.81 | 360 | 75.3 | -6.387*** | -13.52 | 1.326 | 0.47 | -23.41*** | -3.16 | -0.0181 | -0.01 | -7.463 | -0.73 | 360 | 75.3 |
| 5 | 3 | -7.094*** | -14.99 | -0.508 | -0.17 | -20.92*** | -2.89 | -3.657 | -0.38 | 360 | 77.0 | -7.101*** | -14.94 | -1.394 | -0.49 | -21.12*** | -2.93 | -1.062 | -0.76 | 3.105 | 0.29 | 360 | 77.0 |
| 1 | 4 | -2.925*** | -21.41 | -0.445 | -0.50 | -7.202*** | -3.29 | 1.653 | 0.58 | 392 | 83.5 | -2.921*** | -21.14 | -0.240 | -0.27 | -7.182*** | -3.28 | 0.247 | 0.53 | 0.0826 | 0.02 | 392 | 83.5 |
| 2 | 4 | -3.560*** | -19.48 | -0.345 | -0.27 | -12.24*** | -4.06 | 0.396 | 0.10 | 392 | 81.5 | -3.567*** | -19.25 | -0.757 | -0.59 | -12.27*** | -4.10 | -0.497 | -0.86 | 3.557 | 0.71 | 392 | 81.6 |
| 3 | 4 | -4.049*** | -18.02 | -0.358 | -0.23 | -14.28*** | -3.96 | -0.0336 | -0.01 | 392 | 78.5 | -4.058*** | -17.78 | -0.872 | -0.58 | -14.33*** | -4.01 | -0.620 | -0.90 | 3.910 | 0.69 | 392 | 78.6 |
| 4 | 4 | -4.514*** | -15.94 | -0.121 | -0.07 | -18.31*** | -4.10 | -1.512 | -0.26 | 392 | 75.9 | -4.522*** | -15.78 | -0.570 | -0.32 | -18.36*** | -4.13 | -0.541 | -0.66 | 1.933 | 0.29 | 392 | 75.9 |
| 5 | 4 | -5.313*** | -15.93 | -0.295 | -0.14 | -16.77*** | -3.43 | -2.168 | -0.33 | 392 | 76.1 | -5.334*** | -15.68 | -1.540 | -0.81 | -16.89*** | -3.50 | -1.501 | -1.56 | 7.382 | 1.05 | 392 | 76.3 |
| 1 | 5 | -2.543*** | -20.71 | -0.323 | -0.39 | -7.428*** | -4.12 | 1.192 | 0.45 | 392 | 84.4 | -2.534*** | -20.75 | 0.226 | 0.26 | -7.376*** | -4.09 | 0.662 | 1.47 | -3.019 | -0.82 | 392 | 84.6 |
| 2 | 5 | -3.043*** | -21.57 | -1.124 | -1.07 | -7.868*** | -3.73 | 3.204 | 0.96 | 392 | 83.0 | -3.043*** | -21.23 | -1.113 | -1.05 | -7.867*** | -3.72 | 0.0122 | 0.02 | 3.126 | 0.74 | 392 | 83.0 |
| 3 | 5 | -3.435*** | -18.02 | -0.940 | -0.79 | -7.787*** | -2.88 | 2.273 | 0.60 | 392 | 82.0 | -3.439*** | -17.77 | -1.190 | -1.02 | -7.811*** | -2.88 | -0.301 | -0.54 | 4.189 | 0.94 | 392 | 82.0 |
| 4 | 5 | -3.631*** | -19.43 | -0.318 | -0.25 | -10.73*** | -4.11 | -0.213 | -0.05 | 392 | 78.8 | -3.644*** | -19.05 | -1.088 | -0.87 | -10.81*** | -4.22 | -0.928 | -1.45 | 5.695 | 1.15 | 392 | 79.0 |
| 5 | 5 | -4.417*** | -12.35 | 0.0400 | 0.02 | -7.565 | -1.49 | -2.067 | -0.38 | 392 | 77.0 | -4.435*** | -12.28 | -1.022 | -0.66 | -7.667 | -1.50 | -1.279 | -1.49 | 6.073 | 1.02 | 392 | 77.2 |
| 1 | 6 | -2.260*** | -14.01 | -0.352 | -0.43 | -8.814** | -2.07 | 1.156 | 0.44 | 367 | 72.9 | -2.243*** | -13.70 | 0.542 | 0.49 | -8.778** | -2.11 | 1.127 | 1.39 | -5.890 | -0.97 | 367 | 73.4 |
| 2 | 6 | -2.814*** | -17.92 | -1.490 | -1.41 | -6.419*** | -2.72 | 4.368 | 1.29 | 367 | 82.8 | -2.814*** | -17.65 | -1.495 | -1.51 | -6.419*** | -2.71 | -0.00523 | -0.01 | 4.401 | 1.20 | 367 | 82.8 |
| 3 | 6 | -3.221*** | -16.24 | -0.123 | -0.11 | -6.616** | -2.33 | -0.130 | -0.04 | 371 | 83.0 | -3.216*** | -16.31 | 0.179 | 0.17 | -6.594** | -2.32 | 0.384 | 0.74 | -2.519 | -0.63 | 371 | 83.0 |
| 4 | 6 | -3.131*** | -16.61 | -0.729 | -0.56 | -11.93*** | -4.15 | 1.323 | 0.32 | 368 | 77.1 | -3.132*** | -16.48 | -0.810 | -0.66 | -11.95*** | -4.14 | -0.103 | -0.17 | 1.964 | 0.43 | 368 | 77.1 |
| 5 | 6 | -3.379*** | -16.22 | 1.479 | 1.11 | -11.08*** | -3.46 | -6.320 | -1.49 | 369 | 75.0 | -3.397*** | -16.09 | 0.0659 | 0.05 | -11.27*** | -3.60 | -1.852*** | -2.66 | 5.073 | 0.94 | 369 | 75.6 |

## Table B11(a) Robustness Check 1: Call Option Return Sensitivity to Stock Market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for call option portfolios when illiquidity is measured as the natural log of the proportional bid-ask spread. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{sm}$ is the residual obtained from the AR (p) specification of the natural log of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient, and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 6.551*** | 15.02 | 1.994 | 1.37 | 5.645** | 2.06 | 8.094** | 2.42 | 300 | 66.80 | 6.712*** | 17.66 | -4.590 | -1.40 | 2.561 | 1.00 | 8.725** | 2.24 | -38.90* | -1.83 | 300 | 67.7 |
| 1 | 2 | 7.672*** | 19.01 | 0.721 | 0.53 | 1.736 | 0.87 | 4.028 | 1.30 | 303 | 77.00 | 7.774*** | 20.28 | -3.462 | -1.44 | -0.227 | -0.10 | 5.524* | 1.91 | -25.75* | -1.66 | 303 | 77.3 |
| 1 | 3 | 10.18*** | 16.17 | 1.871 | 0.94 | 1.672 | 0.46 | 3.011 | 0.68 | 303 | 75.40 | 10.34*** | 17.56 | -4.959 | -1.38 | -1.532 | -0.36 | 9.018** | 2.28 | -45.60** | -2.09 | 303 | 75.9 |
| 1 | 4 | 11.26*** | 12.70 | 4.252 | 1.61 | -0.901 | -0.16 | -0.199 | -0.03 | 303 | 68.00 | 11.58*** | 14.35 | -8.939* | -1.73 | -7.089 | -1.18 | 17.42*** | 3.09 | -94.09*** | -3.00 | 303 | 69.2 |
| 1 | 5 | 12.82*** | 13.76 | -2.667 | -0.78 | 2.821 | 0.50 | -19.43** | -2.59 | 300 | 54.30 | 13.13*** | 14.69 | -15.49** | -2.38 | -3.165 | -0.47 | 16.96** | 2.29 | -110.8*** | -2.73 | 300 | 55.1 |
| 1 | 6 | 5.116*** | 25.30 | 1.674** | 2.25 | 1.537 | 1.00 | 5.661*** | 3.32 | 495 | 76.20 | 5.173*** | 26.83 | -1.861 | -1.36 | 0.134 | 0.09 | 4.557*** | 2.74 | -19.10** | -2.15 | 495 | 76.6 |
| 2 | 1 | 5.590*** | 16.02 | 1.036 | 1.06 | 1.299 | 0.62 | 3.626* | 1.65 | 497 | 72.60 | 5.615*** | 16.02 | -0.537 | -0.29 | 0.684 | 0.31 | 2.031 | 1.11 | -7.403 | -0.69 | 497 | 72.7 |
| 2 | 2 | 6.836*** | 14.80 | 0.910 | 0.73 | 0.414 | 0.18 | 1.704 | 0.61 | 497 | 70.00 | 6.896*** | 15.14 | -2.927 | -1.29 | -1.086 | -0.48 | 4.955** | 2.22 | -25.20* | -1.96 | 497 | 70.3 |
| 2 | 3 | 7.722*** | 12.84 | 3.001* | 1.96 | -0.479 | -0.18 | 2.538 | 0.74 | 497 | 64.40 | 7.816*** | 13.24 | -3.033 | -1.09 | -2.838 | -1.11 | 7.791*** | 2.74 | -39.77** | -2.47 | 497 | 64.9 |
| 2 | 4 | 8.708*** | 12.59 | -0.508 | -0.24 | 1.265 | 0.34 | -8.697* | -1.89 | 497 | 57.70 | 8.807*** | 12.83 | -6.842* | -1.91 | -1.212 | -0.33 | 8.179** | 2.29 | -53.11*** | -2.62 | 497 | 58.1 |
| 2 | 5 | 4.209*** | 14.02 | 1.924*** | 2.64 | 1.914 | 1.26 | 5.658*** | 3.37 | 487 | 73.80 | 4.225*** | 14.25 | 0.838 | 0.68 | 1.485 | 0.97 | 1.454 | 1.00 | -2.142 | -0.28 | 487 | 73.8 |
| 2 | 6 | 4.760*** | 13.45 | 1.564* | 1.85 | 0.860 | 0.62 | 4.693** | 2.43 | 487 | 71.40 | 4.761*** | 13.48 | 1.454 | 1.07 | 0.816 | 0.55 | 0.147 | 0.10 | 3.905 | 0.48 | 487 | 71.4 |
| 3 | 1 | 5.459*** | 13.83 | 0.619 | 0.64 | 0.930 | 0.54 | 1.147 | 0.53 | 487 | 71.70 | 5.464*** | 13.93 | 0.306 | 0.19 | 0.807 | 0.45 | 0.419 | 0.25 | -1.102 | -0.12 | 487 | 71.7 |
| 3 | 2 | 6.292*** | 13.80 | 1.394 | 1.10 | 1.375 | 0.67 | 0.655 | 0.23 | 487 | 67.90 | 6.316*** | 13.99 | -0.273 | -0.13 | 0.716 | 0.34 | 2.231 | 1.05 | -11.31 | -0.95 | 487 | 68.0 |
| 3 | 3 | 6.855*** | 12.24 | -0.962 | -0.60 | 0.286 | 0.11 | -7.613** | -2.11 | 487 | 59.30 | 6.888*** | 12.41 | -3.214 | -1.24 | -0.603 | -0.24 | 3.014 | 1.06 | -23.78 | -1.53 | 487 | 59.4 |
| 3 | 4 | 2.999*** | 11.90 | 2.162*** | 4.44 | 1.020 | 1.32 | 5.699*** | 5.13 | 532 | 73.50 | 3.034*** | 12.23 | 0.353 | 0.48 | 0.309 | 0.39 | 2.382*** | 2.68 | -7.157 | -1.54 | 532 | 73.8 |
| 3 | 5 | 3.732*** | 16.04 | 1.225** | 2.25 | 0.726 | 0.74 | 3.309*** | 2.69 | 532 | 75.10 | 3.761*** | 16.28 | -0.269 | -0.29 | 0.139 | 0.14 | 1.967* | 1.91 | -7.309 | -1.29 | 532 | 75.3 |
| 3 | 6 | 4.208*** | 16.46 | 0.606 | 0.94 | 0.542 | 0.43 | 1.542 | 1.06 | 532 | 73.40 | 4.244*** | 16.75 | -1.220 | -1.09 | -0.176 | -0.14 | 2.405** | 2.05 | -11.44* | -1.74 | 532 | 73.6 |
| 4 | 1 | 4.694*** | 15.23 | 0.852 | 1.07 | 0.688 | 0.50 | 1.601 | 0.90 | 532 | 70.40 | 4.736*** | 15.53 | -1.316 | -0.97 | -0.164 | -0.12 | 2.855** | 2.05 | -13.81* | -1.76 | 532 | 70.6 |
| 4 | 2 | 5.296*** | 14.93 | -0.371 | -0.37 | 0.982 | 0.55 | -3.313 | -1.46 | 532 | 68.20 | 5.350*** | 15.16 | -3.143* | -1.82 | -0.107 | -0.06 | 3.651** | 2.05 | -23.01** | -2.30 | 532 | 68.4 |
| 4 | 3 | 2.915*** | 28.35 | 2.222*** | 6.04 | 1.076* | 1.67 | 5.860*** | 6.92 | 531 | 80.20 | 2.946*** | 29.18 | 0.547 | 0.83 | 0.418 | 0.60 | 2.207*** | 2.69 | -6.049 | -1.40 | 531 | 80.5 |
| 4 | 4 | 2.820*** | 6.01 | 1.935** | 2.56 | 1.063 | 1.15 | 4.857*** | 2.81 | 532 | 56.20 | 2.846*** | 6.15 | 0.584 | 0.59 | 0.532 | 0.63 | 1.779* | 1.65 | -4.743 | -0.83 | 532 | 56.3 |
| 4 | 5 | 3.370*** | 13.36 | 0.832 | 1.59 | 0.768 | 0.97 | 2.112* | 1.79 | 532 | 73.20 | 3.392*** | 13.57 | -0.300 | -0.36 | 0.323 | 0.41 | 1.491 | 1.63 | -5.931 | -1.20 | 532 | 73.3 |
| 4 | 6 | 3.660*** | 12.58 | -0.149 | -0.24 | 0.847 | 0.79 | -0.602 | -0.43 | 532 | 70.20 | 3.680*** | 12.73 | -1.172 | -1.19 | 0.445 | 0.41 | 1.347 | 1.25 | -7.873 | -1.34 | 532 | 70.2 |
| 5 | 1 | 4.386*** | 13.66 | -0.964 | -1.20 | 0.583 | 0.46 | -3.843** | -2.09 | 532 | 67.70 | 4.411*** | 13.83 | -2.291* | -1.67 | 0.0618 | 0.05 | 1.748 | 1.12 | -13.28 | -1.57 | 532 | 67.8 |
| 5 | 2 | 2.738*** | 24.45 | 1.850*** | 4.66 | 1.226 | 1.25 | 4.862*** | 5.28 | 496 | 75.00 | 2.753*** | 24.93 | 0.768 | 1.02 | 0.808 | 0.79 | 1.419 | 1.50 | -2.816 | -0.56 | 496 | 75.2 |
| 5 | 3 | 3.108*** | 21.07 | 0.145 | 0.23 | 2.734** | 2.21 | 0.735 | 0.51 | 501 | 70.00 | 3.118*** | 21.34 | -0.630 | -0.57 | 2.432* | 1.91 | 1.015 | 0.92 | -4.759 | -0.76 | 501 | 70.0 |
| 5 | 4 | 3.169*** | 11.79 | 0.495 | 0.75 | 1.990 | 1.45 | 1.383 | 0.91 | 505 | 68.20 | 3.167*** | 11.90 | 0.629 | 0.57 | 2.039 | 1.42 | -0.175 | -0.16 | 2.328 | 0.37 | 505 | 68.2 |
| 5 | 5 | 3.634*** | 24.04 | 0.203 | 0.39 | 1.562 | 1.36 | 0.339 | 0.29 | 498 | 75.40 | 3.642*** | 24.17 | -0.469 | -0.44 | 1.300 | 1.08 | 0.883 | 0.82 | -4.435 | -0.71 | 498 | 75.5 |
| 5 | 6 | 3.774*** | 13.08 | -1.612 | -1.62 | 1.165 | 0.85 | -4.752** | -2.06 | 501 | 53.40 | 3.768*** | 13.06 | -1.162 | -0.75 | 1.328 | 0.91 | -0.590 | -0.34 | -1.558 | -0.17 | 501 | 53.5 |

## Table B11(b) Put Option Return Sensitivity to Stock Market Liquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for put option portfolios when illiquidity is measured as the natural log of the proportional bid-ask spread. Call option excess return is regressed on the stock market excess return ($r_m - r_f$), stock market expected illiquidity ($eliq_{cm}$) and stock market unexpected illiquidity ($ueliq_{cm}$) for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility ($\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{pm}}$) in the put options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{sm}$ is the residual obtained from the AR (p) specification of the natural log of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient, and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | -5.878*** | -14.13 | 1.910 | 1.34 | 0.128 | 0.05 | 7.011** | 2.19 | 299 | 59.7 | -5.935*** | -14.69 | 4.492 | 1.54 | 1.365 | 0.43 | -3.472 | -1.10 | 25.64 | 1.45 | 299 | 59.9 |
| 1 | 2 | -7.397*** | -13.50 | -0.630 | -0.40 | 0.0285 | 0.01 | 0.598 | 0.17 | 303 | 72.6 | -7.573*** | -15.96 | 7.213** | 2.10 | 3.704 | 1.02 | -10.49*** | -3.03 | 56.96*** | 2.83 | 303 | 73.7 |
| 1 | 3 | -10.35*** | -14.25 | 0.0920 | 0.04 | 0.263 | 0.06 | -2.878 | -0.63 | 303 | 76.3 | -10.50*** | -16.27 | 6.822 | 1.48 | 3.417 | 0.67 | -9.005** | -1.98 | 45.48* | 1.70 | 303 | 76.7 |
| 1 | 4 | -12.33*** | -13.34 | 3.053 | 1.16 | -0.00151 | 0.00 | -2.481 | -0.43 | 303 | 74.3 | -12.50*** | -15.24 | 10.68* | 1.79 | 3.573 | 0.60 | -10.20* | -1.75 | 52.32 | 1.52 | 303 | 74.7 |
| 1 | 5 | -12.89*** | -12.73 | 0.934 | 0.32 | -4.174 | -0.69 | -10.45 | -1.58 | 303 | 67.2 | -13.20*** | -14.80 | 14.80** | 2.38 | 2.326 | 0.39 | -18.56*** | -2.87 | 89.21** | 2.41 | 303 | 68.3 |
| 1 | 6 | -5.109*** | -26.74 | 0.772 | 1.05 | 1.180 | 0.94 | 3.473** | 2.14 | 497 | 76.6 | -5.129*** | -27.80 | 2.217* | 1.70 | 1.735 | 1.28 | -1.892 | -1.26 | 13.70* | 1.69 | 497 | 76.6 |
| 2 | 1 | -6.120*** | -23.77 | -0.639 | -0.75 | 2.054 | 1.51 | -0.392 | -0.21 | 497 | 78.7 | -6.171*** | -25.01 | 3.008* | 1.90 | 3.456** | 2.37 | -4.774*** | -2.94 | 25.43*** | 2.76 | 497 | 79.1 |
| 2 | 2 | -7.673*** | -18.56 | -0.403 | -0.36 | 2.128 | 1.12 | -2.240 | -0.91 | 497 | 77.4 | -7.715*** | -19.16 | 2.558 | 1.22 | 3.266 | 1.57 | -3.877* | -1.95 | 18.73 | 1.62 | 497 | 77.5 |
| 2 | 3 | -8.944*** | -16.61 | 0.198 | 0.14 | 2.077 | 0.79 | -3.645 | -1.14 | 497 | 74.0 | -8.952*** | -16.85 | 0.742 | 0.26 | 2.286 | 0.77 | -0.712 | -0.28 | 0.203 | 0.01 | 497 | 74.0 |
| 2 | 4 | -10.06*** | -17.21 | -0.640 | -0.38 | 1.864 | 0.59 | -8.019** | -2.12 | 496 | 73.2 | -10.09*** | -17.38 | 1.194 | 0.37 | 2.567 | 0.73 | -2.404 | -0.79 | 4.979 | 0.28 | 496 | 73.2 |
| 2 | 5 | -4.183*** | -21.03 | 1.763** | 2.36 | 1.784* | 1.65 | 5.315*** | 3.13 | 487 | 73.4 | -4.181*** | -21.35 | 1.631 | 1.20 | 1.732 | 1.54 | 0.179 | 0.12 | 4.358 | 0.54 | 487 | 73.4 |
| 2 | 6 | -5.034*** | -21.33 | -0.00558 | -0.01 | -0.234 | -0.18 | 0.684 | 0.42 | 487 | 79.1 | -5.057*** | -22.49 | 1.721 | 1.12 | 0.445 | 0.35 | -2.341 | -1.48 | 13.20 | 1.46 | 487 | 79.2 |
| 3 | 1 | -5.966*** | -19.56 | 0.335 | 0.41 | 1.104 | 0.73 | -0.138 | -0.08 | 487 | 79.4 | -5.984*** | -20.30 | 1.743 | 1.03 | 1.657 | 0.99 | -1.909 | -1.13 | 10.07 | 1.03 | 487 | 79.5 |
| 3 | 2 | -6.953*** | -17.17 | 0.119 | 0.11 | 1.608 | 0.89 | -2.289 | -0.98 | 487 | 75.7 | -6.968*** | -17.70 | 1.202 | 0.54 | 2.034 | 1.06 | -1.469 | -0.66 | 5.561 | 0.43 | 487 | 75.7 |
| 3 | 3 | -7.624*** | -18.55 | 0.0514 | 0.04 | 0.717 | 0.33 | -4.096 | -1.59 | 487 | 76.9 | -7.636*** | -19.21 | 0.936 | 0.35 | 1.064 | 0.46 | -1.199 | -0.44 | 2.314 | 0.15 | 487 | 76.9 |
| 3 | 4 | -3.083*** | -28.43 | 0.639* | 1.75 | 0.554 | 0.89 | 1.896** | 2.32 | 532 | 83.0 | -3.101*** | -30.05 | 1.688** | 2.26 | 0.966 | 1.55 | -1.397* | -1.79 | 9.411** | 2.13 | 532 | 83.1 |
| 3 | 5 | -3.861*** | -24.20 | -0.00605 | -0.01 | 0.396 | 0.50 | -0.229 | -0.22 | 532 | 80.9 | -3.881*** | -25.33 | 1.134 | 1.19 | 0.844 | 1.03 | -1.519 | -1.58 | 7.941 | 1.44 | 532 | 81.0 |
| 3 | 6 | -4.395*** | -22.26 | 0.0436 | 0.07 | 0.601 | 0.60 | -0.541 | -0.42 | 532 | 78.4 | -4.417*** | -23.21 | 1.318 | 1.10 | 1.102 | 1.04 | -1.698 | -1.44 | 8.593 | 1.26 | 532 | 78.5 |
| 4 | 1 | -4.947*** | -19.97 | 0.0254 | 0.04 | 1.022 | 0.90 | -1.154 | -0.74 | 532 | 76.2 | -4.968*** | -20.76 | 1.226 | 0.84 | 1.494 | 1.26 | -1.599 | -1.14 | 7.449 | 0.91 | 532 | 76.3 |
| 4 | 2 | -5.686*** | -20.07 | -0.236 | -0.28 | 1.480 | 1.01 | -2.833 | -1.51 | 532 | 76.9 | -5.722*** | -21.26 | 1.803 | 0.98 | 2.281 | 1.50 | -2.717 | -1.52 | 11.78 | 1.13 | 532 | 77.0 |
| 4 | 3 | -2.658*** | -28.84 | 0.760** | 2.54 | 0.604 | 1.26 | 2.120*** | 3.15 | 532 | 83.6 | -2.661*** | -29.09 | 0.928* | 1.78 | 0.670 | 1.28 | -0.225 | -0.39 | 3.329 | 1.05 | 532 | 83.6 |
| 4 | 4 | -3.199*** | -28.98 | 0.333 | 0.86 | 0.809 | 1.22 | 0.662 | 0.78 | 532 | 82.3 | -3.206*** | -29.74 | 0.706 | 0.94 | 0.956 | 1.33 | -0.497 | -0.65 | 3.334 | 0.77 | 532 | 82.3 |
| 4 | 5 | -3.583*** | -25.78 | 0.176 | 0.41 | 0.895 | 1.27 | -0.0194 | -0.02 | 532 | 82.1 | -3.593*** | -26.53 | 0.742 | 0.88 | 1.118 | 1.43 | -0.755 | -0.89 | 4.041 | 0.84 | 532 | 82.1 |
| 4 | 6 | -3.852*** | -24.88 | -0.524 | -1.07 | 1.418* | 1.83 | -1.946* | -1.83 | 532 | 79.5 | -3.865*** | -25.65 | 0.231 | 0.25 | 1.715* | 1.94 | -1.006 | -1.10 | 3.464 | 0.66 | 532 | 79.5 |
| 5 | 1 | -4.525*** | -18.36 | -0.475 | -0.72 | 1.299 | 1.27 | -2.601* | -1.76 | 532 | 78.0 | -4.543*** | -18.99 | 0.562 | 0.43 | 1.707 | 1.59 | -1.381 | -1.03 | 4.826 | 0.64 | 532 | 78.1 |
| 5 | 2 | -2.347*** | -26.06 | 1.089** | 2.34 | 0.818 | 1.56 | 2.699** | 2.50 | 498 | 73.8 | -2.350*** | -26.09 | 1.290** | 2.15 | 0.897 | 1.61 | -0.267 | -0.44 | 4.141 | 1.25 | 498 | 73.8 |
| 5 | 3 | -2.922*** | -25.40 | 0.309 | 0.84 | 0.825 | 1.14 | 0.547 | 0.67 | 500 | 82.5 | -2.927*** | -26.17 | 0.681 | 0.87 | 0.970 | 1.17 | -0.493 | -0.64 | 3.207 | 0.71 | 500 | 82.5 |
| 5 | 4 | -3.264*** | -24.06 | 0.522 | 1.38 | 0.429 | 0.53 | 0.834 | 0.99 | 504 | 82.9 | -3.268*** | -24.49 | 0.817 | 1.05 | 0.538 | 0.59 | -0.391 | -0.48 | 2.942 | 0.64 | 504 | 82.9 |
| 5 | 5 | -3.366*** | -23.80 | 0.393 | 0.70 | 0.217 | 0.22 | 0.297 | 0.23 | 500 | 76.9 | -3.371*** | -24.13 | 0.854 | 0.83 | 0.386 | 0.37 | -0.612 | -0.67 | 3.594 | 0.65 | 500 | 76.9 |
| 5 | 6 | -3.591*** | -21.11 | -1.032** | -2.09 | -0.179 | -0.19 | -3.354*** | -3.03 | 502 | 74.7 | -3.602*** | -21.51 | -0.0774 | -0.08 | 0.166 | 0.16 | -1.263 | -1.15 | 3.458 | 0.57 | 502 | 74.8 |

**Table B12(a) Robustness Check 2: Call Option Return Sensitivity to Call Options market Illiquidity**

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for call option portfolios for the sample period from January 2009 to December 2010. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, call options market expected illiquidity $(eliq_{cm})$ and call options market unexpected illiquidity $(ueliq_{cm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{cm}$ is the residual obtained from the AR (p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 8.585*** | 16.22 | 0.461*** | 2.86 | -0.0148 | -0.03 | -6.051* | -1.82 | 159 | 73.4 | 8.477*** | 16.08 | 0.391** | 2.55 | -0.0850 | -0.18 | 3.690* | 1.85 | -18.32** | -2.23 | 159 | 74.1 |
| 2 | 1 | 9.058*** | 19.83 | 0.150 | 1.21 | -0.303 | -0.58 | -1.092 | -0.42 | 163 | 84.6 | 9.045*** | 19.63 | 0.138 | 1.10 | -0.309 | -0.59 | 0.595 | 0.38 | -3.061 | -0.52 | 163 | 84.6 |
| 3 | 1 | 12.03*** | 19.87 | 0.151 | 0.63 | -0.915 | -1.62 | -5.017 | -1.03 | 163 | 86.6 | 12.00*** | 19.91 | 0.122 | 0.52 | -0.931* | -1.67 | 1.491 | 0.74 | -9.952 | -1.09 | 163 | 86.6 |
| 4 | 1 | 15.81*** | 18.62 | 0.236 | 0.73 | 0.569 | 0.77 | -14.36** | -2.15 | 163 | 81.0 | 15.71*** | 18.22 | 0.145 | 0.46 | 0.517 | 0.70 | 4.715* | 1.70 | -29.96** | -2.37 | 163 | 81.3 |
| 5 | 1 | 20.32*** | 13.71 | 0.270 | 0.61 | 2.230 | 1.62 | -17.04* | -1.79 | 161 | 64.4 | 20.30*** | 13.64 | 0.250 | 0.55 | 2.220 | 1.62 | 1.058 | 0.24 | -20.55 | -1.18 | 161 | 64.4 |
| 1 | 2 | 5.602*** | 22.18 | 0.230** | 2.33 | -0.502** | -2.36 | -3.013 | -1.55 | 246 | 81.5 | 5.616*** | 22.55 | 0.189** | 2.13 | -0.489** | -2.32 | 1.964* | 1.96 | -9.469** | -2.05 | 246 | 81.9 |
| 2 | 2 | 6.648*** | 26.16 | 0.256*** | 3.19 | -0.381* | -1.80 | -4.316*** | -2.63 | 246 | 86.9 | 6.643*** | 26.02 | 0.270*** | 3.47 | -0.386* | -1.83 | -0.697 | -0.80 | -2.025 | -0.57 | 246 | 87.0 |
| 3 | 2 | 7.983*** | 18.77 | 0.230* | 1.84 | -0.717** | -2.22 | -5.459** | -2.15 | 246 | 81.6 | 7.982*** | 18.77 | 0.233* | 1.87 | -0.718** | -2.22 | -0.131 | -0.10 | -5.027 | -0.98 | 246 | 81.6 |
| 4 | 2 | 9.532*** | 20.11 | 0.349*** | 2.60 | -0.470 | -1.13 | -12.10*** | -4.34 | 246 | 77.9 | 9.544*** | 20.43 | 0.315** | 2.26 | -0.459 | -1.10 | 1.650 | 1.04 | -17.52*** | -2.97 | 246 | 78.0 |
| 5 | 2 | 11.81*** | 19.50 | 0.447** | 2.02 | -0.311 | -0.46 | -16.19*** | -3.59 | 246 | 70.5 | 11.80*** | 19.47 | 0.472** | 2.11 | -0.319 | -0.48 | -1.214 | -0.54 | -12.20 | -1.36 | 246 | 70.5 |
| 1 | 3 | 4.726*** | 16.42 | 0.131 | 1.44 | -0.598*** | -2.97 | -1.636 | -0.91 | 245 | 80.1 | 4.722*** | 17.47 | 0.0951 | 1.14 | -0.577*** | -2.98 | 2.154** | 2.42 | -8.878** | -2.14 | 245 | 80.9 |
| 2 | 3 | 5.571*** | 18.48 | 0.0357 | 0.49 | -0.566*** | -2.90 | -0.0151 | -0.01 | 245 | 84.2 | 5.570*** | 18.61 | 0.0289 | 0.41 | -0.562*** | -2.87 | 0.407 | 0.48 | -1.382 | -0.39 | 245 | 84.2 |
| 3 | 3 | 6.385*** | 18.10 | 0.0515 | 0.58 | -0.830*** | -3.57 | -1.863 | -1.05 | 245 | 84.2 | 6.387*** | 17.66 | 0.0708 | 0.84 | -0.841*** | -3.65 | -1.157 | -1.18 | 2.028 | 0.48 | 245 | 84.3 |
| 4 | 3 | 7.355*** | 15.20 | 0.00269 | 0.02 | -1.117*** | -3.56 | -3.417 | -1.45 | 245 | 79.1 | 7.355*** | 15.16 | 0.00171 | 0.02 | -1.117*** | -3.54 | 0.0588 | 0.04 | -3.615 | -0.66 | 245 | 79.1 |
| 5 | 3 | 9.091*** | 16.47 | -0.0852 | -0.43 | -0.713 | -1.22 | -3.755 | -0.94 | 245 | 73.3 | 9.093*** | 16.25 | -0.0695 | -0.34 | -0.722 | -1.23 | -0.941 | -0.50 | -0.590 | -0.09 | 245 | 73.3 |
| 1 | 4 | 3.606*** | 19.69 | 0.134*** | 2.87 | -0.380*** | -2.67 | -2.133** | -2.32 | 268 | 85.5 | 3.611*** | 21.45 | 0.101** | 2.33 | -0.368*** | -2.72 | 1.741*** | 3.22 | -7.908*** | -3.69 | 268 | 86.4 |
| 2 | 4 | 4.319*** | 23.32 | 0.126** | 2.51 | -0.411*** | -2.66 | -2.350** | -2.31 | 268 | 86.2 | 4.320*** | 23.58 | 0.120** | 2.39 | -0.409*** | -2.66 | 0.339 | 0.60 | -3.475 | -1.56 | 268 | 86.3 |
| 3 | 4 | 4.820*** | 18.14 | 0.0949 | 1.29 | -0.549*** | -2.83 | -2.080 | -1.41 | 268 | 83.6 | 4.820*** | 18.15 | 0.0940 | 1.29 | -0.549*** | -2.83 | 0.0489 | 0.07 | -2.242 | -0.77 | 268 | 83.6 |
| 4 | 4 | 5.415*** | 18.22 | 0.135* | 1.78 | -0.505** | -2.28 | -3.377** | -2.16 | 268 | 80.9 | 5.415*** | 18.21 | 0.136* | 1.76 | -0.505** | -2.27 | -0.0105 | -0.01 | -3.342 | -1.04 | 268 | 80.9 |
| 5 | 4 | 6.449*** | 20.03 | 0.163* | 1.94 | -0.502* | -1.70 | -5.915*** | -3.41 | 268 | 80.9 | 6.449*** | 20.02 | 0.164* | 1.89 | -0.502* | -1.69 | -0.0319 | -0.03 | -5.810 | -1.58 | 268 | 80.9 |
| 1 | 5 | 3.196*** | 21.42 | 0.112*** | 2.82 | -0.325*** | -2.83 | -1.625** | -2.07 | 268 | 85.4 | 3.200*** | 23.65 | 0.0781** | 2.18 | -0.314*** | -2.87 | 1.758*** | 3.62 | -7.455*** | -3.86 | 268 | 86.6 |
| 2 | 5 | 3.455*** | 20.83 | 0.0965** | 2.16 | -0.395*** | -2.99 | -1.792** | -2.00 | 268 | 84.5 | 3.456*** | 20.88 | 0.0946** | 2.14 | -0.394*** | -2.98 | 0.0970 | 0.20 | -2.113 | -1.09 | 268 | 84.5 |
| 3 | 5 | 3.762*** | 20.14 | 0.0817 | 1.49 | -0.417*** | -3.01 | -1.715 | -1.55 | 268 | 83.6 | 3.762*** | 20.07 | 0.0857 | 1.61 | -0.418*** | -3.01 | -0.210 | -0.39 | -1.019 | -0.44 | 268 | 83.6 |
| 4 | 5 | 4.148*** | 19.74 | 0.111* | 1.89 | -0.358** | -2.22 | -2.779** | -2.34 | 268 | 80.9 | 4.145*** | 19.46 | 0.134** | 2.33 | -0.366** | -2.25 | -1.201* | -1.88 | 1.205 | 0.47 | 268 | 81.2 |
| 5 | 5 | 4.912*** | 21.84 | 0.0944 | 1.28 | -0.526** | -2.19 | -3.783** | -2.55 | 268 | 79.3 | 4.910*** | 21.59 | 0.110 | 1.50 | -0.531** | -2.21 | -0.791 | -0.96 | -1.162 | -0.36 | 268 | 79.4 |
| 1 | 6 | 2.982*** | 22.80 | 0.112** | 2.47 | -0.163 | -1.51 | -1.777* | -1.96 | 264 | 79.7 | 2.987*** | 24.67 | 0.0819** | 2.02 | -0.152 | -1.40 | 1.646*** | 3.03 | -7.245*** | -3.19 | 264 | 80.8 |
| 2 | 6 | 3.389*** | 17.27 | 0.103* | 1.67 | -0.129 | -0.93 | -1.994 | -1.60 | 266 | 75.8 | 3.391*** | 17.30 | 0.0954 | 1.62 | -0.125 | -0.90 | 0.427 | 0.62 | -3.413 | -1.19 | 266 | 75.9 |
| 3 | 6 | 3.525*** | 23.27 | 0.113** | 2.35 | -0.186 | -1.57 | -2.388** | -2.46 | 265 | 82.6 | 3.524*** | 22.97 | 0.120** | 2.57 | -0.189 | -1.60 | -0.386 | -0.73 | -1.106 | -0.51 | 265 | 82.6 |
| 4 | 6 | 3.770*** | 18.42 | 0.0719 | 1.29 | -0.233 | -1.54 | -1.807 | -1.60 | 264 | 79.3 | 3.769*** | 18.34 | 0.0778 | 1.43 | -0.235 | -1.55 | -0.322 | -0.57 | -0.736 | -0.31 | 264 | 79.4 |
| 5 | 6 | 4.418*** | 18.34 | 0.130 | 1.39 | -0.286 | -1.06 | -3.887** | -2.01 | 264 | 68.0 | 4.415*** | 18.22 | 0.146 | 1.50 | -0.291 | -1.09 | -0.848 | -0.92 | -1.068 | -0.33 | 264 | 68.1 |

## Table B12(b) Robustness Check 2: Put Option Return Sensitivity to Put Options market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for put option portfolios for the sample period from January 2009 to December 2010. Put option excess return is regressed on stock market excess return ($r_m - r_f$), put options market expected illiquidity ($eliq_{pm}$) and put options market unexpected illiquidity ($ueliq_{pm}$) for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the put options market. The log volatility is the average implied volatility across all put options in the market. $ueliq_{pm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient, and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | -5.984*** | -10.02 | -0.0731 | -0.23 | -1.471** | -2.43 | 3.219 | 0.42 | 157 | 59.2 | -5.953*** | -9.92 | -0.243 | -0.60 | -1.474** | -2.43 | -2.291 | -0.97 | 15.78 | 0.92 | 157 | 59.4 |
| 2 | 1 | -9.396*** | -14.79 | -0.0722 | -0.30 | -0.0909 | -0.18 | 3.610 | 0.62 | 163 | 78.8 | -9.323*** | -14.85 | -0.386 | -1.48 | -0.145 | -0.30 | -4.228** | -2.02 | 26.72** | 2.22 | 163 | 79.3 |
| 3 | 1 | -12.43*** | -17.30 | -0.513* | -1.87 | -1.060** | -2.14 | 8.965 | 1.34 | 163 | 85.0 | -12.38*** | -17.21 | -0.727** | -2.50 | -1.097** | -2.27 | -2.882 | -1.13 | 24.72* | 1.79 | 163 | 85.1 |
| 4 | 1 | -15.72*** | -17.18 | -0.886** | -2.40 | -1.130 | -1.60 | 11.91 | 1.33 | 163 | 83.9 | -15.65*** | -17.20 | -1.174*** | -2.97 | -1.180* | -1.72 | -3.874 | -1.21 | 33.08* | 1.84 | 163 | 84.1 |
| 5 | 1 | -18.02*** | -16.85 | 0.242 | 0.47 | -1.100 | -1.26 | -18.25 | -1.50 | 163 | 78.1 | -17.94*** | -16.78 | -0.118 | -0.19 | -1.162 | -1.33 | -4.847 | -1.25 | 8.247 | 0.33 | 163 | 78.3 |
| 1 | 2 | -5.914*** | -18.44 | 0.161 | 1.15 | -0.536** | -2.28 | -2.587 | -0.79 | 246 | 76.4 | -5.915*** | -18.34 | 0.163 | 1.17 | -0.535** | -2.22 | 0.0363 | 0.03 | -2.775 | -0.49 | 246 | 76.4 |
| 2 | 2 | -6.950*** | -16.96 | 0.127 | 1.01 | -0.691** | -2.33 | -2.325 | -0.77 | 246 | 80.9 | -6.938*** | -16.95 | 0.0335 | 0.25 | -0.734** | -2.46 | -1.498 | -1.40 | 5.429 | 0.93 | 246 | 81.0 |
| 3 | 2 | -8.775*** | -14.98 | 0.0594 | 0.44 | -0.915** | -2.51 | -3.265 | -0.98 | 246 | 80.7 | -8.769*** | -14.98 | 0.0105 | 0.08 | -0.938** | -2.55 | -0.782 | -0.58 | 0.783 | 0.11 | 246 | 80.7 |
| 4 | 2 | -10.93*** | -14.76 | -0.185 | -1.00 | -0.989** | -2.17 | -0.199 | -0.04 | 246 | 78.8 | -10.93*** | -14.75 | -0.184 | -0.98 | -0.989** | -2.15 | 0.0110 | 0.01 | -0.256 | -0.03 | 246 | 78.8 |
| 5 | 2 | -12.73*** | -16.31 | 0.0875 | 0.35 | -0.436 | -0.80 | -8.999 | -1.48 | 246 | 78.9 | -12.71*** | -16.37 | -0.0772 | -0.32 | -0.513 | -0.94 | -2.634 | -1.28 | 4.638 | 0.45 | 246 | 79.0 |
| 1 | 3 | -5.230*** | -15.76 | -0.0336 | -0.35 | -0.147 | -0.70 | 1.873 | 0.80 | 245 | 78.2 | -5.244*** | -15.63 | 0.0122 | 0.11 | -0.125 | -0.58 | 0.716 | 0.67 | -1.848 | -0.32 | 245 | 78.3 |
| 2 | 3 | -5.919*** | -16.89 | 0.0404 | 0.41 | -0.290 | -1.36 | -0.455 | -0.19 | 245 | 83.0 | -5.910*** | -16.80 | 0.0105 | 0.10 | -0.304 | -1.39 | -0.467 | -0.50 | 1.973 | 0.39 | 245 | 83.0 |
| 3 | 3 | -6.961*** | -14.96 | -0.00643 | -0.05 | -0.381 | -1.48 | -0.926 | -0.32 | 245 | 81.6 | -6.961*** | -14.90 | -0.00467 | -0.04 | -0.380 | -1.46 | 0.0275 | 0.03 | -1.069 | -0.21 | 245 | 81.6 |
| 4 | 3 | -8.565*** | -12.96 | -0.100 | -0.65 | -0.397 | -1.06 | -0.213 | -0.06 | 245 | 77.7 | -8.569*** | -12.93 | -0.0879 | -0.57 | -0.391 | -1.03 | 0.192 | 0.14 | -1.211 | -0.17 | 245 | 77.7 |
| 5 | 3 | -9.169*** | -15.21 | -0.127 | -0.73 | -0.595 | -1.60 | -1.533 | -0.37 | 245 | 79.6 | -9.125*** | -15.23 | -0.281 | -1.61 | -0.670* | -1.82 | -2.422 | -1.61 | 11.06 | 1.40 | 245 | 79.8 |
| 1 | 4 | -3.493*** | -17.47 | 0.0720 | 1.29 | -0.283** | -2.38 | -1.502 | -1.10 | 268 | 83.4 | -3.493*** | -17.41 | 0.0671 | 1.14 | -0.285** | -2.38 | -0.0775 | -0.15 | -1.099 | -0.41 | 268 | 83.4 |
| 2 | 4 | -4.239*** | -16.17 | 0.0656 | 0.95 | -0.310* | -1.88 | -2.017 | -1.18 | 268 | 80.7 | -4.237*** | -16.18 | 0.0529 | 0.74 | -0.316* | -1.91 | -0.198 | -0.33 | -0.986 | -0.31 | 268 | 80.7 |
| 3 | 4 | -5.035*** | -14.18 | 0.00951 | 0.11 | -0.359* | -1.73 | -1.075 | -0.49 | 268 | 78.0 | -5.034*** | -14.17 | 0.00491 | 0.06 | -0.361* | -1.74 | -0.0721 | -0.09 | -0.699 | -0.18 | 268 | 78.0 |
| 4 | 4 | -5.846*** | -13.19 | -0.0413 | -0.39 | -0.451* | -1.71 | -0.423 | -0.16 | 268 | 75.4 | -5.848*** | -13.18 | -0.0300 | -0.28 | -0.446* | -1.69 | 0.177 | 0.19 | -1.346 | -0.28 | 268 | 75.4 |
| 5 | 4 | -6.932*** | -13.07 | 0.0510 | 0.38 | -0.492 | -1.55 | -3.958 | -1.20 | 268 | 76.0 | -6.916*** | -13.09 | -0.0490 | -0.38 | -0.536* | -1.68 | -1.565 | -1.40 | 4.194 | 0.74 | 268 | 76.2 |
| 1 | 5 | -2.803*** | -17.29 | 0.0296 | 0.65 | -0.246** | -2.58 | -0.518 | -0.46 | 268 | 83.3 | -2.805*** | -17.26 | 0.0411 | 0.87 | -0.241** | -2.51 | 0.179 | 0.46 | -1.453 | -0.70 | 268 | 83.3 |
| 2 | 5 | -3.376*** | -15.86 | 0.0352 | 0.63 | -0.327*** | -2.60 | -1.150 | -0.83 | 268 | 80.6 | -3.376*** | -15.86 | 0.0393 | 0.69 | -0.325** | -2.58 | 0.0637 | 0.13 | -1.482 | -0.57 | 268 | 80.6 |
| 3 | 5 | -3.800*** | -13.96 | 0.00276 | 0.04 | -0.291* | -1.81 | -0.669 | -0.42 | 268 | 78.5 | -3.798*** | -13.96 | -0.0111 | -0.17 | -0.297* | -1.85 | -0.216 | -0.39 | 0.459 | 0.15 | 268 | 78.5 |
| 4 | 5 | -4.357*** | -12.36 | 0.0181 | 0.23 | -0.266 | -1.28 | -1.339 | -0.67 | 268 | 74.9 | -4.353*** | -12.36 | -0.00894 | -0.11 | -0.278 | -1.34 | -0.423 | -0.61 | 0.864 | 0.24 | 268 | 74.9 |
| 5 | 5 | -5.090*** | -12.86 | 0.0825 | 0.87 | -0.444* | -1.85 | -3.800 | -1.61 | 268 | 76.1 | -5.075*** | -12.90 | -0.0154 | -0.17 | -0.486** | -2.03 | -1.532* | -1.85 | 4.182 | 0.98 | 268 | 76.3 |
| 1 | 6 | -2.468*** | -20.02 | -0.0140 | -0.35 | -0.266*** | -3.10 | 0.403 | 0.41 | 264 | 83.8 | -2.465*** | -19.95 | -0.0312 | -0.68 | -0.274*** | -3.11 | -0.285 | -0.71 | 1.863 | 0.84 | 264 | 83.8 |
| 2 | 6 | -2.890*** | -16.72 | -0.0372 | -0.76 | -0.374*** | -3.36 | 0.526 | 0.43 | 264 | 82.0 | -2.884*** | -16.80 | -0.0771 | -1.51 | -0.392*** | -3.52 | -0.660 | -1.54 | 3.909* | 1.68 | 264 | 82.2 |
| 3 | 6 | -3.249*** | -15.20 | 0.00283 | 0.05 | -0.289** | -2.26 | -0.503 | -0.38 | 264 | 81.6 | -3.245*** | -15.21 | -0.0265 | -0.48 | -0.303** | -2.37 | -0.486 | -1.02 | 1.988 | 0.78 | 264 | 81.6 |
| 4 | 6 | -3.410*** | -14.01 | -0.0103 | -0.15 | -0.435*** | -3.04 | -0.522 | -0.31 | 264 | 78.5 | -3.399*** | -14.07 | -0.0812 | -1.15 | -0.467*** | -3.26 | -1.174** | -2.12 | 5.494* | 1.77 | 264 | 78.9 |
| 5 | 6 | -3.879*** | -14.46 | 0.0782 | 0.96 | -0.438** | -2.37 | -3.150 | -1.56 | 264 | 76.7 | -3.859*** | -14.58 | -0.0497 | -0.63 | -0.495*** | -2.70 | -2.117*** | -3.05 | 7.697** | 2.14 | 264 | 77.5 |

**Table B13(a) Robustness Check 2: Call Option Return Sensitivity to Stock Market Illiquidity**

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for call option portfolios for the sample period from January 2009 to December 2010. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility $(\mathbf{ln}(iv)_{cm})$ in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{sm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient, and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | T | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 8.036*** | 18.6 | 18.39 | 1.45 | 33.50*** | 4.01 | 1.395 | 1.02 | 202 | 71.00 | 8.043*** | 18.79 | 1.466 | 0.06 | 26.32* | 1.96 | 2.566 | 0.72 | -6.210 | -0.57 | 202 | 71.1 |
| 2 | 1 | 9.192*** | 29 | 6.138 | 0.69 | 9.789 | 1.4 | 1.573 | 1.47 | 205 | 84.80 | 9.195*** | 29.03 | 0.0105 | 0.00 | 7.179 | 0.79 | 0.924 | 0.37 | -1.160 | -0.15 | 205 | 84.8 |
| 3 | 1 | 12.57*** | 27.2 | 17.09 | 1.28 | -2.186 | -0.2 | -3.393** | -2.17 | 205 | 86.40 | 12.58*** | 27.27 | -9.818 | -0.50 | -13.65 | -1.00 | 4.058 | 1.40 | -15.39* | -1.67 | 205 | 86.5 |
| 4 | 1 | 15.08*** | 26 | 31.69* | 1.84 | -13.27 | -0.6 | -13.08*** | -6.78 | 205 | 81.00 | 15.12*** | 26.31 | -40.45 | -1.16 | -44.00** | -2.31 | 10.88** | 2.34 | -45.25*** | -3.20 | 205 | 81.6 |
| 5 | 1 | 17.39*** | 17.3 | -24.59 | -0.85 | 3.336 | 0.16 | -9.142** | -2.46 | 202 | 62.10 | 17.42*** | 17.43 | -88.84 | -1.43 | -23.94 | -0.87 | 9.728 | 1.26 | -37.95 | -1.62 | 202 | 62.4 |
| 1 | 2 | 5.923*** | 35.8 | 2.101 | 0.31 | 26.40*** | 3.37 | 1.627** | 2.19 | 340 | 83.20 | 5.943*** | 35.98 | -12.91 | -1.10 | 19.93* | 1.65 | 2.154 | 1.33 | -4.663 | -0.95 | 340 | 83.3 |
| 2 | 2 | 6.944*** | 37 | -9.897* | -1.78 | 12.77** | 1.99 | 2.383*** | 3.65 | 340 | 87.30 | 6.952*** | 36.90 | -15.89 | -1.61 | 10.19 | 1.17 | 0.860 | 0.65 | -0.130 | -0.03 | 340 | 87.4 |
| 3 | 2 | 8.565*** | 27.4 | -6.797 | -0.84 | 11.91 | 1.2 | 0.504 | 0.51 | 340 | 82.70 | 8.585*** | 27.47 | -22.32 | -1.56 | 5.229 | 0.37 | 2.227 | 1.25 | -6.000 | -1.12 | 340 | 82.8 |
| 4 | 2 | 10.10*** | 28.1 | 11.21 | 1.13 | -5.102 | -0.5 | -5.699*** | -4.69 | 340 | 79.30 | 10.15*** | 28.39 | -26.33 | -1.36 | -21.27 | -1.46 | 5.387** | 2.31 | -21.43*** | -3.07 | 340 | 79.6 |
| 5 | 2 | 11.77*** | 23.5 | -15.48 | -1.03 | 16.72 | 1.46 | -5.335*** | -2.81 | 340 | 69.40 | 11.81*** | 23.80 | -46.69** | -1.99 | 3.275 | 0.23 | 4.480 | 1.38 | -18.42* | -1.82 | 340 | 69.5 |
| 1 | 3 | 5.031*** | 27.9 | 6.149 | 1.16 | 29.51*** | 3.68 | 0.572 | 1.03 | 332 | 82.00 | 5.032*** | 27.90 | 5.113 | 0.44 | 29.07*** | 2.70 | 0.150 | 0.09 | 0.132 | 0.03 | 332 | 82.0 |
| 2 | 3 | 5.954*** | 29.6 | 2.117 | 0.42 | 9.781** | 2.45 | 0.786 | 1.37 | 332 | 85.20 | 5.954*** | 29.59 | 2.834 | 0.30 | 10.08* | 1.96 | -0.104 | -0.07 | 1.089 | 0.26 | 332 | 85.2 |
| 3 | 3 | 6.871*** | 28.3 | -6.482 | -1.11 | 14.35*** | 3.02 | 0.468 | 0.69 | 332 | 84.40 | 6.869*** | 28.34 | -1.446 | -0.14 | 16.48*** | 2.79 | -0.731 | -0.46 | 2.604 | 0.54 | 332 | 84.4 |
| 4 | 3 | 8.025*** | 24.5 | -0.531 | -0.06 | 17.31*** | 2.72 | -2.459** | -2.55 | 332 | 79.10 | 8.024*** | 24.49 | 0.346 | 0.03 | 17.68** | 2.31 | -0.127 | -0.06 | -2.086 | -0.33 | 332 | 79.1 |
| 5 | 3 | 9.140*** | 23 | -12.17 | -1 | 0.0155 | 0 | -3.816*** | -2.78 | 332 | 73.50 | 9.143*** | 23.10 | -20.06 | -0.82 | -3.329 | -0.15 | 1.145 | 0.36 | -7.163 | -0.75 | 332 | 73.5 |
| 1 | 4 | 3.809*** | 31.8 | 10.30*** | 2.86 | 8.671*** | 2.71 | -0.422 | -1.1 | 364 | 85.80 | 3.818*** | 32.19 | 2.626 | 0.45 | 5.391 | 1.02 | 1.093 | 1.34 | -3.607 | -1.45 | 364 | 85.9 |
| 2 | 4 | 4.589*** | 38.2 | 3.095 | 0.87 | 6.423* | 1.9 | 0.138 | 0.34 | 364 | 86.60 | 4.594*** | 38.44 | -1.136 | -0.17 | 4.615 | 0.94 | 0.602 | 0.67 | -1.617 | -0.60 | 364 | 86.6 |
| 3 | 4 | 5.209*** | 28.7 | -0.713 | -0.15 | 9.106** | 2.15 | 0.280 | 0.5 | 364 | 84.20 | 5.211*** | 28.75 | -2.327 | -0.30 | 8.416 | 1.54 | 0.230 | 0.23 | -0.390 | -0.13 | 364 | 84.2 |
| 4 | 4 | 5.836*** | 29 | 1.153 | 0.21 | 7.784* | 1.78 | -0.414 | -0.63 | 364 | 82.00 | 5.841*** | 29.03 | -2.777 | -0.30 | 6.104 | 1.13 | 0.560 | 0.48 | -2.045 | -0.58 | 364 | 82.0 |
| 5 | 4 | 6.782*** | 33.1 | -2.733 | -0.42 | 10.11** | 2.15 | -1.970*** | -2.65 | 364 | 81.70 | 6.790*** | 33.23 | -9.539 | -0.86 | 7.197 | 1.12 | 0.969 | 0.67 | -4.793 | -1.08 | 364 | 81.7 |
| 1 | 5 | 3.341*** | 33.9 | 9.994*** | 3.14 | 9.488*** | 3.26 | -0.389 | -1.18 | 364 | 85.90 | 3.347*** | 34.13 | 4.363 | 0.85 | 7.082 | 1.60 | 0.802 | 1.10 | -2.725 | -1.22 | 364 | 86.0 |
| 2 | 5 | 3.708*** | 30.8 | 3.207 | 1.05 | 3.266 | 1.31 | 0.0628 | 0.17 | 364 | 84.60 | 3.712*** | 30.84 | 0.214 | 0.04 | 1.987 | 0.66 | 0.426 | 0.62 | -1.179 | -0.56 | 364 | 84.7 |
| 3 | 5 | 4.068*** | 30.9 | -0.155 | -0.04 | 2.567 | 0.8 | 0.221 | 0.51 | 364 | 84.10 | 4.068*** | 30.90 | -0.0147 | 0.00 | 2.627 | 0.72 | -0.0200 | -0.02 | 0.279 | 0.11 | 364 | 84.1 |
| 4 | 5 | 4.428*** | 29.3 | -6.166 | -1.44 | 1.225 | 0.3 | 0.492 | 0.97 | 364 | 81.70 | 4.430*** | 29.35 | -7.769 | -1.08 | 0.540 | 0.11 | 0.228 | 0.24 | -0.173 | -0.06 | 364 | 81.7 |
| 5 | 5 | 5.258*** | 34.2 | -11.53** | -2.27 | 7.731* | 1.69 | -0.219 | -0.37 | 364 | 80.60 | 5.259*** | 34.35 | -12.73 | -1.27 | 7.215 | 1.36 | 0.172 | 0.13 | -0.719 | -0.17 | 364 | 80.6 |
| 1 | 6 | 3.076*** | 36.2 | 6.182* | 1.8 | 13.00*** | 3.82 | -0.163 | -0.46 | 359 | 81.80 | 3.082*** | 36.53 | 1.709 | 0.29 | 11.00** | 2.05 | 0.638 | 0.74 | -2.025 | -0.77 | 359 | 81.9 |
| 2 | 6 | 3.483*** | 28 | 2.282 | 0.53 | 14.58*** | 3.38 | 0.0540 | 0.12 | 361 | 79.20 | 3.480*** | 27.77 | 5.029 | 0.77 | 15.81*** | 3.55 | -0.390 | -0.43 | 1.189 | 0.42 | 361 | 79.2 |
| 3 | 6 | 3.689*** | 32 | -3.820 | -1.12 | 2.844 | 0.52 | 0.500 | 1.36 | 360 | 84.20 | 3.690*** | 31.95 | -4.812 | -0.68 | 2.419 | 0.35 | 0.143 | 0.16 | 0.0835 | 0.03 | 360 | 84.2 |
| 4 | 6 | 3.997*** | 26.9 | -4.746 | -1.34 | 5.896* | 1.91 | 0.421 | 1.02 | 359 | 81.40 | 3.998*** | 27.06 | -5.656 | -0.88 | 5.490 | 1.42 | 0.130 | 0.15 | 0.0422 | 0.02 | 359 | 81.4 |
| 5 | 6 | 4.547*** | 26.3 | -12.11** | -2.05 | 10.25** | 2.35 | 0.295 | 0.46 | 359 | 70.40 | 4.532*** | 26.20 | -0.265 | -0.02 | 15.54** | 2.59 | -1.690 | -1.21 | 5.225 | 1.26 | 359 | 70.5 |

**Table B13(b) Robustness Check 2: Put Option Return Sensitivity to Stock Market Illiquidity**

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for put option portfolios for the sample period from January 2009 to December 2010. Put option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility $(\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{pm}})$ in the put options market. The log volatility is the average implied volatility across all put options in the market. $ueliq_{sm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff' is the estimated coefficient, and 't' is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$ is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | T | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | -6.289*** | -14.59 | 1.512 | 0.13 | -18.02** | -2.17 | 1.741 | 1.24 | 201 | 58.8 | -6.288*** | -14.67 | 28.71 | 1.28 | -6.273 | -0.57 | -4.155 | -1.53 | 14.02* | 1.73 | 201 | 59.2 |
| 2 | 1 | -9.190*** | -19.23 | -22.75** | -2.13 | -1.314 | -0.15 | 4.283*** | 3.25 | 205 | 78.8 | -9.192*** | -19.07 | -0.174 | -0.01 | 8.331 | 0.81 | -3.427 | -1.31 | 14.39* | 1.75 | 205 | 79.0 |
| 3 | 1 | -12.77*** | -20.91 | -16.48 | -1.12 | 12.29 | 1.01 | -1.160 | -0.66 | 205 | 84.3 | -12.77*** | -20.85 | -15.07 | -0.73 | 12.89 | 0.90 | -0.213 | -0.07 | -0.531 | -0.05 | 205 | 84.3 |
| 4 | 1 | -15.86*** | -21.53 | -4.499 | -0.25 | 16.03 | 1.20 | -8.645*** | -3.97 | 205 | 84.1 | -15.86*** | -21.59 | -29.10 | -1.17 | 5.518 | 0.32 | 3.735 | 0.93 | -19.66 | -1.56 | 205 | 84.1 |
| 5 | 1 | -17.44*** | -18.36 | -19.14 | -0.82 | 3.729 | 0.20 | -9.713*** | -3.48 | 205 | 76.0 | -17.44*** | -18.30 | -3.806 | -0.09 | 10.28 | 0.54 | -2.327 | -0.44 | -2.852 | -0.18 | 205 | 76.0 |
| 1 | 2 | -5.810*** | -25.87 | -0.205 | -0.03 | -6.326 | -0.97 | 1.548** | 1.98 | 340 | 75.8 | -5.809*** | -25.94 | -1.016 | -0.10 | -6.674 | -0.83 | 0.117 | 0.08 | 1.207 | 0.27 | 340 | 75.8 |
| 2 | 2 | -7.067*** | -24.66 | -7.242 | -1.05 | 1.503 | 0.26 | 1.676** | 2.00 | 340 | 80.6 | -7.081*** | -24.52 | 8.362 | 0.80 | 8.195 | 1.30 | -2.250 | -1.58 | 8.226* | 1.88 | 340 | 80.8 |
| 3 | 2 | -9.041*** | -21.93 | -2.773 | -0.31 | 2.200 | 0.30 | -1.284 | -1.15 | 340 | 80.7 | -9.040*** | -21.89 | -3.446 | -0.26 | 1.912 | 0.23 | 0.0970 | 0.06 | -1.567 | -0.30 | 340 | 80.7 |
| 4 | 2 | -11.15*** | -20.85 | 4.938 | 0.40 | 12.99 | 1.18 | -4.822*** | -3.23 | 340 | 78.8 | -11.13*** | -20.95 | -22.08 | -1.26 | 1.404 | 0.13 | 3.896 | 1.63 | -16.16** | -2.20 | 340 | 78.9 |
| 5 | 2 | -12.34*** | -21.23 | -13.74 | -1.05 | -4.133 | -0.38 | -4.806*** | -3.08 | 340 | 78.5 | -12.32*** | -21.21 | -26.64 | -1.32 | -9.666 | -0.79 | 1.860 | 0.65 | -10.22 | -1.15 | 340 | 78.5 |
| 1 | 3 | -5.003*** | -20.91 | 3.497 | 0.64 | 5.775 | 1.11 | 0.761 | 1.23 | 332 | 77.0 | -5.005*** | -20.97 | -6.956 | -0.65 | 1.355 | 0.18 | 1.532 | 1.03 | -3.709 | -0.83 | 332 | 77.1 |
| 2 | 3 | -5.804*** | -23.03 | -6.032 | -1.11 | -8.934* | -1.90 | 1.175* | 1.83 | 332 | 82.4 | -5.805*** | -23.02 | -9.087 | -1.00 | -10.23* | -1.82 | 0.448 | 0.34 | -0.132 | -0.03 | 332 | 82.4 |
| 3 | 3 | -6.951*** | -20.05 | -4.051 | -0.63 | 3.183 | 0.65 | -0.580 | -0.73 | 332 | 81.6 | -6.952*** | -20.08 | -12.24 | -1.23 | -0.279 | -0.05 | 1.200 | 0.81 | -4.081 | -0.90 | 332 | 81.6 |
| 4 | 3 | -8.491*** | -18.06 | -6.335 | -0.74 | 12.53* | 1.89 | -1.820* | -1.71 | 332 | 78.2 | -8.494*** | -18.15 | -25.47* | -1.81 | 4.443 | 0.58 | 2.805 | 1.45 | -10.00* | -1.71 | 332 | 78.3 |
| 5 | 3 | -9.084*** | -19.46 | -13.49 | -1.53 | -0.785 | -0.10 | -2.551** | -2.42 | 332 | 79.0 | -9.088*** | -19.59 | -38.34** | -2.30 | -11.29 | -1.29 | 3.642 | 1.52 | -13.18* | -1.83 | 332 | 79.2 |
| 1 | 4 | -3.543*** | -24.35 | -2.500 | -0.77 | -0.211 | -0.07 | 0.590 | 1.56 | 364 | 82.6 | -3.542*** | -24.38 | -4.185 | -0.78 | -0.931 | -0.27 | 0.242 | 0.33 | -0.112 | -0.05 | 364 | 82.6 |
| 2 | 4 | -4.319*** | -22.98 | -3.882 | -0.98 | -2.291 | -0.73 | 0.0927 | 0.19 | 364 | 81.0 | -4.317*** | -23.03 | -6.252 | -0.96 | -3.303 | -0.90 | 0.340 | 0.41 | -0.895 | -0.36 | 364 | 81.0 |
| 3 | 4 | -5.107*** | -19.79 | -4.115 | -0.78 | 2.550 | 0.58 | -0.283 | -0.43 | 364 | 78.5 | -5.102*** | -19.86 | -11.42 | -1.38 | -0.571 | -0.12 | 1.047 | 0.97 | -3.326 | -1.03 | 364 | 78.5 |
| 4 | 4 | -5.895*** | -18.70 | -3.107 | -0.50 | 8.328 | 1.57 | -0.907 | -1.14 | 364 | 76.2 | -5.888*** | -18.80 | -13.92 | -1.40 | 3.706 | 0.66 | 1.551 | 1.20 | -5.415 | -1.41 | 364 | 76.3 |
| 5 | 4 | -6.866*** | -17.81 | -14.74** | -2.00 | 10.22 | 1.64 | -0.672 | -0.75 | 364 | 76.3 | -6.859*** | -17.86 | -24.45** | -2.03 | 6.069 | 0.88 | 1.393 | 0.87 | -4.720 | -0.98 | 364 | 76.3 |
| 1 | 5 | -2.847*** | -24.62 | 0.371 | 0.15 | 0.119 | 0.05 | 0.218 | 0.73 | 364 | 82.8 | -2.844*** | -24.69 | -2.659 | -0.63 | -1.176 | -0.49 | 0.434 | 0.74 | -1.045 | -0.59 | 364 | 82.8 |
| 2 | 5 | -3.444*** | -21.90 | -2.568 | -0.78 | 2.091 | 0.72 | 0.0663 | 0.16 | 364 | 80.4 | -3.442*** | -21.96 | -6.424 | -1.22 | 0.443 | 0.15 | 0.553 | 0.79 | -1.541 | -0.74 | 364 | 80.4 |
| 3 | 5 | -3.870*** | -20.14 | -3.933 | -1.04 | 3.042 | 1.04 | -0.0552 | -0.12 | 364 | 79.3 | -3.866*** | -20.22 | -9.369 | -1.55 | 0.719 | 0.22 | 0.779 | 1.00 | -2.321 | -1.00 | 364 | 79.4 |
| 4 | 5 | -4.345*** | -18.23 | -7.613* | -1.66 | 4.993 | 1.45 | 0.0385 | 0.07 | 364 | 76.2 | -4.343*** | -18.30 | -11.76 | -1.57 | 3.222 | 0.85 | 0.594 | 0.63 | -1.689 | -0.60 | 364 | 76.2 |
| 5 | 5 | -5.078*** | -17.89 | -13.62** | -2.53 | 6.068 | 1.26 | 0.0583 | 0.09 | 364 | 76.5 | -5.073*** | -17.94 | -21.09** | -2.27 | 2.876 | 0.52 | 1.071 | 0.89 | -3.055 | -0.86 | 364 | 76.5 |
| 1 | 6 | -2.471*** | -27.29 | -0.128 | -0.05 | 0.180 | 0.10 | 0.175 | 0.66 | 359 | 82.2 | -2.469*** | -27.32 | -3.221 | -0.81 | -1.202 | -0.54 | 0.446 | 0.82 | -1.122 | -0.69 | 359 | 82.3 |
| 2 | 6 | -2.986*** | -23.95 | -3.067 | -1.07 | -0.139 | -0.06 | 0.135 | 0.39 | 359 | 81.2 | -2.982*** | -24.06 | -8.022* | -1.78 | -2.352 | -0.86 | 0.714 | 1.19 | -1.943 | -1.08 | 359 | 81.2 |
| 3 | 6 | -3.263*** | -22.14 | -2.897 | -0.91 | 2.081 | 0.87 | -0.00894 | -0.02 | 359 | 81.6 | -3.263*** | -22.15 | -3.552 | -0.69 | 1.788 | 0.65 | 0.0944 | 0.15 | -0.284 | -0.15 | 359 | 81.6 |
| 4 | 6 | -3.524*** | -21.12 | -6.149* | -1.71 | -1.339 | -0.40 | 0.0599 | 0.14 | 359 | 78.3 | -3.521*** | -21.17 | -10.48* | -1.73 | -3.274 | -0.86 | 0.624 | 0.80 | -1.756 | -0.75 | 359 | 78.4 |
| 5 | 6 | -3.949*** | -21.03 | -12.30*** | -2.60 | -1.493 | -0.39 | 0.412 | 0.75 | 359 | 76.1 | -3.947*** | -21.01 | -14.51* | -1.77 | -2.479 | -0.58 | 0.318 | 0.30 | -0.513 | -0.16 | 359 | 76.1 |

## Table B14(a) Robustness Check 3: Call Option Return Sensitivity to Call Options market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for call option portfolios for a sample of the stocks which issue options with the maturity in each quarter of the year and maturity in the next three months. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, call options market expected illiquidity $(eliq_{cm})$ and call options market unexpected illiquidity $(ueliq_{cm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility$(\mathbf{ln}(\boldsymbol{iv})_{\boldsymbol{cm}})$ in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{cm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{cm}$ | | $ueliq_{cm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 6.284*** | 10.80 | 0.395** | 2.39 | -0.720*** | -2.74 | -5.044 | -1.38 | 236 | 67.6 | 6.297*** | 11.22 | 0.256 | 1.53 | -0.728*** | -2.86 | 4.740** | 2.48 | -19.72*** | -2.78 | 236 | 68.6 |
| 2 | 1 | 7.034*** | 16.73 | 0.288** | 2.31 | -1.223*** | -3.39 | -4.576* | -1.66 | 240 | 80.4 | 7.041*** | 17.00 | 0.244** | 1.98 | -1.223*** | -3.37 | 1.470 | 0.92 | -9.112 | -1.48 | 240 | 80.5 |
| 3 | 1 | 8.982*** | 13.53 | 0.413** | 2.19 | -2.080*** | -4.66 | -10.88*** | -2.64 | 240 | 79.2 | 8.995*** | 13.68 | 0.331* | 1.74 | -2.081*** | -4.71 | 2.785 | 1.24 | -19.47** | -2.26 | 240 | 79.4 |
| 4 | 1 | 10.66*** | 9.83 | 0.533* | 1.88 | -1.697*** | -2.89 | -21.48*** | -3.44 | 240 | 68.4 | 10.70*** | 9.98 | 0.298 | 1.11 | -1.699*** | -2.99 | 7.889** | 2.35 | -45.82*** | -3.41 | 240 | 69.3 |
| 5 | 1 | 12.87*** | 10.51 | 0.282 | 0.73 | -1.023 | -1.20 | -18.75** | -2.10 | 238 | 55.9 | 12.88*** | 10.54 | 0.216 | 0.56 | -1.022 | -1.20 | 2.253 | 0.50 | -25.72 | -1.44 | 238 | 55.9 |
| 1 | 2 | 4.787*** | 17.59 | 0.303*** | 3.42 | -0.469** | -2.28 | -4.790** | -2.56 | 357 | 75.2 | 4.817*** | 18.60 | 0.204*** | 2.63 | -0.472** | -2.44 | 3.135*** | 3.23 | -14.38*** | -3.44 | 357 | 76.1 |
| 2 | 2 | 4.993*** | 13.20 | 0.343*** | 3.68 | -0.725*** | -2.97 | -6.625*** | -3.31 | 359 | 72.8 | 5.011*** | 13.51 | 0.298*** | 3.34 | -0.727*** | -3.01 | 1.410 | 1.35 | -10.93** | -2.58 | 359 | 72.9 |
| 3 | 2 | 5.861*** | 11.79 | 0.330** | 2.52 | -1.143*** | -4.52 | -8.087*** | -2.86 | 359 | 71.1 | 5.883*** | 11.96 | 0.274** | 2.10 | -1.145*** | -4.57 | 1.763 | 1.34 | -13.46** | -2.49 | 359 | 71.3 |
| 4 | 2 | 6.663*** | 9.96 | 0.553*** | 3.01 | -1.246*** | -3.52 | -16.60*** | -4.16 | 359 | 62.8 | 6.716*** | 10.18 | 0.419** | 2.31 | -1.250*** | -3.56 | 4.214** | 2.31 | -29.45*** | -3.85 | 359 | 63.4 |
| 5 | 2 | 7.891*** | 9.76 | 0.370 | 1.46 | -1.316*** | -2.60 | -15.38*** | -2.80 | 359 | 55.7 | 7.919*** | 9.86 | 0.301 | 1.21 | -1.318*** | -2.59 | 2.182 | 0.89 | -22.03** | -2.15 | 359 | 55.8 |
| 1 | 3 | 4.159*** | 18.96 | 0.135* | 1.89 | -0.461*** | -2.63 | -1.683 | -1.12 | 360 | 80.2 | 4.174*** | 19.83 | 0.0734 | 1.11 | -0.473*** | -2.71 | 2.179*** | 2.75 | -8.495*** | -2.60 | 360 | 80.7 |
| 2 | 3 | 4.466*** | 12.36 | 0.200** | 2.11 | -0.578*** | -2.68 | -3.428* | -1.70 | 360 | 74.9 | 4.471*** | 12.52 | 0.178** | 2.00 | -0.582*** | -2.70 | 0.777 | 0.81 | -5.858 | -1.41 | 360 | 74.9 |
| 3 | 3 | 4.989*** | 11.89 | 0.222** | 1.99 | -0.731*** | -3.34 | -5.364** | -2.26 | 360 | 74.1 | 4.989*** | 11.93 | 0.222** | 2.11 | -0.731*** | -3.33 | -0.0107 | -0.01 | -5.331 | -1.13 | 360 | 74.1 |
| 4 | 3 | 5.757*** | 11.06 | 0.250* | 1.79 | -0.786*** | -2.81 | -8.173*** | -2.73 | 360 | 68.4 | 5.769*** | 11.20 | 0.199 | 1.50 | -0.796*** | -2.84 | 1.813 | 1.24 | -13.84** | -2.22 | 360 | 68.5 |
| 5 | 3 | 6.757*** | 10.61 | 0.0427 | 0.23 | -0.686** | -2.01 | -6.193 | -1.52 | 360 | 62.9 | 6.762*** | 10.67 | 0.0216 | 0.12 | -0.690** | -2.00 | 0.749 | 0.37 | -8.536 | -1.04 | 360 | 62.9 |
| 1 | 4 | 2.986*** | 18.07 | 0.188*** | 3.83 | -0.365*** | -3.34 | -3.403*** | -3.28 | 391 | 78.7 | 3.013*** | 19.83 | 0.112** | 2.37 | -0.372*** | -3.48 | 2.633*** | 4.51 | -11.58*** | -5.13 | 391 | 80.2 |
| 2 | 4 | 3.581*** | 15.42 | 0.195*** | 3.01 | -0.468*** | -3.34 | -3.954*** | -2.85 | 392 | 75.9 | 3.596*** | 15.78 | 0.157** | 2.54 | -0.471*** | -3.37 | 1.262* | 1.78 | -7.865*** | -2.71 | 392 | 76.1 |
| 3 | 4 | 3.896*** | 14.67 | 0.173** | 2.28 | -0.621*** | -4.11 | -3.976** | -2.45 | 392 | 75.2 | 3.913*** | 14.87 | 0.132* | 1.80 | -0.625*** | -4.16 | 1.399* | 1.81 | -8.311** | -2.55 | 392 | 75.4 |
| 4 | 4 | 4.499*** | 15.74 | 0.209** | 2.47 | -0.724*** | -3.67 | -5.064*** | -2.78 | 392 | 73.0 | 4.513*** | 16.02 | 0.176** | 2.04 | -0.727*** | -3.70 | 1.143 | 1.21 | -8.608** | -2.36 | 392 | 73.1 |
| 5 | 4 | 5.101*** | 12.07 | 0.160 | 1.24 | -0.713*** | -2.64 | -6.006** | -2.17 | 392 | 65.3 | 5.119*** | 12.22 | 0.117 | 0.90 | -0.717*** | -2.64 | 1.463 | 1.07 | -10.54* | -1.94 | 392 | 65.4 |
| 1 | 5 | 2.805*** | 19.12 | 0.224*** | 4.80 | -0.265** | -2.33 | -4.081*** | -4.11 | 391 | 78.1 | 2.835*** | 20.98 | 0.138*** | 3.31 | -0.272** | -2.56 | 2.959*** | 5.17 | -13.28*** | -5.82 | 391 | 80.3 |
| 2 | 5 | 3.215*** | 18.57 | 0.211*** | 3.92 | -0.406*** | -3.24 | -4.425*** | -3.83 | 391 | 79.5 | 3.226*** | 18.97 | 0.181*** | 3.58 | -0.409*** | -3.27 | 1.021* | 1.78 | -7.598*** | -3.12 | 391 | 79.7 |
| 3 | 5 | 3.137*** | 9.23 | 0.247*** | 3.09 | -0.488*** | -4.39 | -5.352*** | -3.12 | 392 | 72.4 | 3.153*** | 9.40 | 0.208*** | 2.76 | -0.492*** | -4.38 | 1.346** | 2.14 | -9.524*** | -3.15 | 392 | 72.7 |
| 4 | 5 | 3.562*** | 15.64 | 0.163** | 2.46 | -0.558*** | -3.84 | -4.106*** | -2.91 | 392 | 74.7 | 3.561*** | 15.67 | 0.164** | 2.54 | -0.558*** | -3.83 | -0.0674 | -0.09 | -3.898 | -1.35 | 392 | 74.7 |
| 5 | 5 | 4.195*** | 12.57 | 0.161 | 1.46 | -0.662*** | -2.76 | -5.231** | -2.24 | 392 | 64.9 | 4.196*** | 12.54 | 0.158 | 1.51 | -0.662*** | -2.75 | 0.117 | 0.10 | -5.593 | -1.13 | 392 | 64.9 |
| 1 | 6 | 2.538*** | 19.17 | 0.211*** | 4.71 | -0.239** | -2.36 | -3.808*** | -4.08 | 364 | 74.6 | 2.558*** | 21.13 | 0.142*** | 3.17 | -0.240** | -2.55 | 2.271*** | 4.29 | -10.83*** | -5.56 | 364 | 76.2 |
| 2 | 6 | 2.659*** | 14.18 | 0.173*** | 3.16 | -0.579*** | -3.04 | -3.641*** | -3.23 | 368 | 68.9 | 2.661*** | 14.23 | 0.165*** | 3.04 | -0.580*** | -3.05 | 0.279 | 0.39 | -4.504* | -1.69 | 368 | 68.9 |
| 3 | 6 | 2.798*** | 8.58 | 0.228*** | 3.18 | -0.516** | -2.15 | -4.908*** | -3.27 | 372 | 67.3 | 2.797*** | 8.61 | 0.231*** | 3.45 | -0.516** | -2.15 | -0.0929 | -0.15 | -4.621 | -1.60 | 372 | 67.3 |
| 4 | 6 | 3.251*** | 18.92 | 0.106** | 2.02 | -0.532*** | -3.78 | -2.704** | -2.44 | 365 | 75.2 | 3.255*** | 19.11 | 0.0898 | 1.63 | -0.535*** | -3.81 | 0.540 | 0.91 | -4.377** | -2.01 | 365 | 75.3 |
| 5 | 6 | 3.462*** | 10.83 | 0.0662 | 0.55 | -0.495 | -1.57 | -2.866 | -1.14 | 370 | 50.6 | 3.449*** | 10.71 | 0.107 | 0.97 | -0.491 | -1.56 | -1.341 | -0.98 | 1.264 | 0.23 | 370 | 50.8 |

## Table B14(b) Robustness Check 3: Put Option Return Sensitivity to Put Options market Illiquidity

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.11) for put option portfolios for a sample of the stocks which issue options with the maturity in each quarter of the year and maturity in the next three months. Put option excess return is regressed on stock market excess return $(r_m - r_f)$, put options market expected illiquidity $(eliq_{pm})$ and put options market unexpected illiquidity $(ueliq_{pm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility in the put options market. The log volatility is the average implied volatility across all put options in the market. $ueliq_{pm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{pm}$ | | $ueliq_{pm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | -5.675*** | -11.26 | -0.352 | -1.14 | -1.307*** | -3.31 | 10.41 | 1.45 | 232 | 60.4 | -5.676*** | -11.23 | -0.355 | -1.02 | -1.307*** | -3.31 | -0.0804 | -0.04 | 10.78 | 0.74 | 232 | 60.4 |
| 2 | 1 | -7.213*** | -10.16 | 0.0331 | 0.16 | -0.809 | -1.52 | 0.788 | 0.16 | 240 | 70.6 | -7.232*** | -10.10 | -0.147 | -0.71 | -0.826 | -1.60 | -4.237** | -2.20 | 20.81** | 2.28 | 240 | 71.2 |
| 3 | 1 | -9.476*** | -11.30 | 0.00738 | 0.03 | -1.450*** | -2.61 | -3.509 | -0.55 | 240 | 76.5 | -9.487*** | -11.23 | -0.0973 | -0.36 | -1.460*** | -2.68 | -2.464 | -1.10 | 8.137 | 0.73 | 240 | 76.6 |
| 4 | 1 | -11.40*** | -10.59 | -0.156 | -0.45 | -1.508** | -1.99 | -5.276 | -0.65 | 240 | 73.4 | -11.41*** | -10.55 | -0.246 | -0.71 | -1.516** | -2.02 | -2.102 | -0.74 | 4.657 | 0.33 | 240 | 73.4 |
| 5 | 1 | -12.46*** | -10.64 | 0.385 | 0.98 | -0.729 | -0.90 | -21.89** | -2.42 | 240 | 66.4 | -12.49*** | -10.78 | 0.0901 | 0.22 | -0.757 | -0.96 | -6.957** | -1.99 | 10.99 | 0.61 | 240 | 66.9 |
| 1 | 2 | -5.039*** | -18.97 | 0.1000 | 0.88 | -0.620*** | -3.17 | -0.938 | -0.36 | 359 | 75.5 | -5.042*** | -18.75 | 0.0929 | 0.81 | -0.620*** | -3.16 | -0.169 | -0.15 | -0.143 | -0.03 | 359 | 75.5 |
| 2 | 2 | -5.745*** | -17.89 | 0.139 | 1.14 | -1.101*** | -4.29 | -2.501 | -0.88 | 359 | 77.9 | -5.776*** | -17.46 | 0.0475 | 0.39 | -1.109*** | -4.39 | -2.188* | -1.92 | 7.806 | 1.45 | 359 | 78.2 |
| 3 | 2 | -7.010*** | -14.23 | 0.0708 | 0.45 | -1.537*** | -4.48 | -3.275 | -0.88 | 359 | 77.0 | -7.044*** | -14.12 | -0.0319 | -0.22 | -1.546*** | -4.61 | -2.454* | -1.77 | 8.285 | 1.33 | 359 | 77.2 |
| 4 | 2 | -8.015*** | -12.91 | 0.0167 | 0.08 | -2.045*** | -4.81 | -4.653 | -1.00 | 359 | 73.9 | -8.043*** | -12.78 | -0.0659 | -0.36 | -2.052*** | -4.89 | -1.972 | -1.15 | 4.639 | 0.63 | 359 | 74.0 |
| 5 | 2 | -9.406*** | -11.99 | 0.294 | 1.25 | -1.803*** | -3.30 | -13.91** | -2.53 | 358 | 71.6 | -9.429*** | -11.92 | 0.202 | 0.91 | -1.817*** | -3.35 | -2.231 | -1.09 | -3.421 | -0.37 | 358 | 71.7 |
| 1 | 3 | -4.180*** | -14.64 | 0.0349 | 0.44 | -0.447* | -1.76 | 0.391 | 0.21 | 360 | 75.2 | -4.171*** | -14.71 | 0.102 | 1.16 | -0.427* | -1.73 | 1.612 | 1.45 | -7.172 | -1.35 | 360 | 75.4 |
| 2 | 3 | -4.880*** | -17.74 | 0.0381 | 0.41 | -0.733*** | -3.31 | -0.317 | -0.15 | 360 | 80.4 | -4.882*** | -17.54 | 0.0220 | 0.22 | -0.738*** | -3.35 | -0.389 | -0.40 | 1.507 | 0.31 | 360 | 80.5 |
| 3 | 3 | -5.762*** | -17.61 | -0.0294 | -0.26 | -0.824*** | -3.73 | -0.284 | -0.11 | 360 | 81.0 | -5.762*** | -17.47 | -0.0270 | -0.25 | -0.824*** | -3.70 | 0.0589 | 0.06 | -0.561 | -0.12 | 360 | 81.0 |
| 4 | 3 | -6.629*** | -14.94 | -0.0151 | -0.11 | -1.074*** | -3.30 | -2.232 | -0.70 | 360 | 77.5 | -6.630*** | -14.89 | -0.0259 | -0.20 | -1.078*** | -3.29 | -0.263 | -0.21 | -1.000 | -0.18 | 360 | 77.5 |
| 5 | 3 | -7.354*** | -17.34 | -0.101 | -0.74 | -0.970*** | -3.10 | -2.291 | -0.72 | 360 | 79.3 | -7.360*** | -17.21 | -0.144 | -1.09 | -0.983*** | -3.15 | -1.023 | -0.74 | 2.508 | 0.40 | 360 | 79.3 |
| 1 | 4 | -3.076*** | -20.05 | 0.0110 | 0.22 | -0.355*** | -3.14 | 0.0828 | 0.07 | 392 | 82.4 | -3.077*** | -19.68 | 0.00644 | 0.13 | -0.356*** | -3.15 | -0.111 | -0.20 | 0.602 | 0.24 | 392 | 82.4 |
| 2 | 4 | -3.829*** | -19.82 | -0.00786 | -0.12 | -0.634*** | -4.28 | -0.223 | -0.14 | 392 | 81.3 | -3.841*** | -19.41 | -0.0474 | -0.69 | -0.641*** | -4.38 | -0.964 | -1.44 | 4.297 | 1.34 | 392 | 81.4 |
| 3 | 4 | -4.305*** | -19.05 | -0.0269 | -0.35 | -0.726*** | -4.64 | -0.0903 | -0.05 | 392 | 80.3 | -4.322*** | -18.67 | -0.0823 | -1.08 | -0.736*** | -4.81 | -1.350* | -1.79 | 6.238* | 1.75 | 392 | 80.5 |
| 4 | 4 | -4.717*** | -16.26 | 0.00795 | 0.09 | -0.989*** | -4.84 | -1.486 | -0.70 | 392 | 76.9 | -4.733*** | -16.09 | -0.0453 | -0.51 | -0.998*** | -4.97 | -1.299 | -1.42 | 4.602 | 1.09 | 392 | 77.0 |
| 5 | 4 | -5.403*** | -16.29 | 0.000919 | 0.01 | -0.863*** | -3.59 | -2.572 | -1.04 | 392 | 76.8 | -5.431*** | -16.03 | -0.0910 | -0.88 | -0.880*** | -3.72 | -2.242** | -2.14 | 7.940 | 1.63 | 392 | 77.1 |
| 1 | 5 | -2.639*** | -18.51 | 0.00126 | 0.03 | -0.350*** | -3.61 | 0.226 | 0.23 | 392 | 83.2 | -2.634*** | -18.44 | 0.0193 | 0.45 | -0.347*** | -3.59 | 0.441 | 0.86 | -1.841 | -0.77 | 392 | 83.2 |
| 2 | 5 | -3.259*** | -17.84 | -0.0496 | -0.86 | -0.325*** | -2.78 | 0.999 | 0.73 | 392 | 81.8 | -3.264*** | -17.48 | -0.0650 | -1.18 | -0.328*** | -2.79 | -0.377 | -0.63 | 2.767 | 1.03 | 392 | 81.8 |
| 3 | 5 | -3.557*** | -19.41 | -0.0278 | -0.49 | -0.382*** | -3.20 | 0.214 | 0.16 | 392 | 82.3 | -3.565*** | -18.99 | -0.0553 | -0.95 | -0.387*** | -3.24 | -0.670 | -1.10 | 3.357 | 1.16 | 392 | 82.4 |
| 4 | 5 | -3.754*** | -18.50 | 0.000873 | 0.01 | -0.534*** | -3.98 | -0.767 | -0.52 | 392 | 78.9 | -3.769*** | -18.23 | -0.0461 | -0.71 | -0.542*** | -4.14 | -1.145 | -1.63 | 4.601 | 1.38 | 392 | 79.1 |
| 5 | 5 | -4.160*** | -17.00 | 0.0788 | 1.08 | -0.570*** | -3.32 | -3.548** | -2.07 | 391 | 75.6 | -4.175*** | -16.83 | 0.00510 | 0.07 | -0.588*** | -3.48 | -1.821** | -2.18 | 4.965 | 1.27 | 391 | 76.0 |
| 1 | 6 | -2.296*** | -14.10 | -0.0246 | -0.63 | -0.417** | -2.01 | 0.875 | 0.96 | 367 | 73.4 | -2.280*** | -13.89 | 0.0209 | 0.39 | -0.411** | -2.05 | 1.160 | 1.45 | -4.521 | -1.16 | 367 | 73.9 |
| 2 | 6 | -2.820*** | -18.09 | -0.0814 | -1.60 | -0.307*** | -2.86 | 1.727 | 1.41 | 367 | 82.7 | -2.821*** | -17.80 | -0.0845* | -1.75 | -0.308*** | -2.84 | -0.0788 | -0.16 | 2.093 | 0.95 | 367 | 82.7 |
| 3 | 6 | -3.225*** | -16.45 | -0.00969 | -0.18 | -0.321** | -2.51 | -0.102 | -0.08 | 371 | 83.1 | -3.221*** | -16.51 | 0.00441 | 0.09 | -0.319** | -2.48 | 0.363 | 0.69 | -1.786 | -0.76 | 371 | 83.1 |
| 4 | 6 | -3.137*** | -16.67 | -0.0383 | -0.61 | -0.564*** | -4.20 | 0.243 | 0.16 | 368 | 77.1 | -3.138*** | -16.54 | -0.0449 | -0.75 | -0.565*** | -4.19 | -0.172 | -0.28 | 1.039 | 0.38 | 368 | 77.1 |
| 5 | 6 | -3.385*** | -16.18 | 0.0719 | 1.12 | -0.522*** | -3.55 | -2.990** | -1.97 | 369 | 75.0 | -3.402*** | -16.06 | -0.000254 | 0.00 | -0.537*** | -3.75 | -1.909*** | -2.73 | 5.818* | 1.78 | 369 | 75.6 |

**Table B15(a) Robustness Check 3: Call Option Return Sensitivity to Stock Market Illiquidity**

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for call option portfolios for a sample of the stocks which issue options with the maturity in each quarter of the year and maturity in the next three months. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity $(eliq_{sm})$ and stock market unexpected illiquidity $(ueliq_{sm})$ for each moneyness and maturity portfolio (Model 1). Model 2 includes an additional control variable for the log volatility $(\mathbf{ln}(iv)_{cm})$ in the call options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{sm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient, and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| Mon | Mat | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | Obs | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{cm}$ | | $intercept$ | | Obs | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | | Coeff | t | Coeff | t | Coeff | t | Coeff | t | Coeff | t | | |
| | | Model 1 | | | | | | | | | | Model 2 | | | | | | | | | | | |
| 1 | 1 | 6.651*** | 14.70 | 3.331 | 0.25 | 26.76* | 1.89 | 3.270** | 2.01 | 300 | 66.3 | 6.855*** | 17.50 | -38.36 | -1.58 | 8.576 | 0.62 | 8.198** | 2.49 | -22.20** | -2.24 | 300 | 67.4 |
| 2 | 1 | 7.977*** | 18.86 | -3.092 | -0.27 | 5.651 | 0.47 | 2.584* | 1.86 | 303 | 78.2 | 8.141*** | 20.36 | -36.16** | -2.12 | -8.781 | -0.65 | 6.473*** | 2.66 | -17.50** | -2.30 | 303 | 78.8 |
| 3 | 1 | 10.43*** | 16.34 | 0.350 | 0.02 | 0.987 | 0.04 | -0.974 | -0.48 | 303 | 75.4 | 10.74*** | 18.61 | -62.06** | -2.31 | -26.25 | -1.06 | 12.22*** | 3.21 | -38.88*** | -3.33 | 303 | 76.6 |
| 4 | 1 | 11.57*** | 13.30 | 20.57 | 0.87 | -21.57 | -0.65 | -12.09*** | -4.23 | 303 | 67.0 | 12.10*** | 16.20 | -85.07** | -2.14 | -67.67** | -2.04 | 20.68*** | 3.78 | -76.26*** | -4.63 | 303 | 69.5 |
| 5 | 1 | 12.91*** | 13.95 | -27.66 | -0.98 | -11.93 | -0.40 | -9.622** | -2.56 | 300 | 52.3 | 13.20*** | 14.67 | -88.07* | -1.81 | -38.27 | -1.11 | 11.87* | 1.78 | -46.50** | -2.24 | 300 | 52.9 |
| 1 | 2 | 5.180*** | 24.39 | 12.15* | 1.72 | 2.139 | 0.35 | 0.363 | 0.42 | 495 | 75.2 | 5.250*** | 25.83 | -10.50 | -0.92 | -2.541 | -0.56 | 4.134*** | 2.65 | -12.27*** | -2.62 | 495 | 75.8 |
| 2 | 2 | 5.657*** | 15.58 | 9.550 | 1.08 | 2.533 | 0.37 | 0.00400 | 0.00 | 497 | 72.4 | 5.691*** | 15.68 | -1.428 | -0.10 | 0.281 | 0.04 | 2.006 | 1.20 | -6.124 | -1.27 | 497 | 72.5 |
| 3 | 2 | 6.908*** | 14.66 | 9.102 | 0.83 | -1.255 | -0.19 | -1.517 | -1.11 | 497 | 70.0 | 6.965*** | 15.04 | -8.857 | -0.50 | -4.939 | -0.84 | 3.281 | 1.62 | -11.54* | -1.94 | 497 | 70.2 |
| 4 | 2 | 7.826*** | 12.65 | 26.50** | 2.02 | -2.416 | -0.34 | -7.239*** | -4.40 | 497 | 63.6 | 7.924*** | 13.11 | -4.860 | -0.23 | -8.847 | -1.23 | 5.728** | 2.24 | -24.74*** | -3.22 | 497 | 64.0 |
| 5 | 2 | 8.702*** | 12.19 | -3.062 | -0.16 | -4.761 | -0.45 | -7.132*** | -2.96 | 497 | 55.5 | 8.804*** | 12.42 | -35.60 | -1.10 | -11.43 | -1.34 | 5.943 | 1.60 | -25.29** | -2.34 | 497 | 55.8 |
| 1 | 3 | 4.461*** | 25.69 | 4.035 | 0.65 | 5.673 | 0.87 | 0.847 | 1.14 | 487 | 79.3 | 4.502*** | 26.22 | -8.877 | -0.87 | 2.883 | 0.49 | 2.489** | 1.97 | -6.829* | -1.84 | 487 | 79.6 |
| 2 | 3 | 4.967*** | 15.60 | 8.103 | 1.14 | 1.114 | 0.29 | 0.186 | 0.22 | 487 | 74.3 | 4.981*** | 15.70 | 3.826 | 0.38 | 0.190 | 0.05 | 0.824 | 0.66 | -2.357 | -0.62 | 487 | 74.3 |
| 3 | 3 | 5.603*** | 14.90 | 4.288 | 0.50 | -1.268 | -0.24 | -0.698 | -0.67 | 487 | 73.4 | 5.621*** | 15.09 | -1.413 | -0.11 | -2.499 | -0.49 | 1.099 | 0.73 | -4.086 | -0.92 | 487 | 73.4 |
| 4 | 3 | 6.431*** | 14.22 | 10.59 | 0.93 | -1.274 | -0.21 | -3.553** | -2.54 | 487 | 68.7 | 6.467*** | 14.53 | -0.716 | -0.04 | -3.716 | -0.64 | 2.178 | 1.07 | -10.27* | -1.72 | 487 | 68.8 |
| 5 | 3 | 7.122*** | 13.38 | -6.658 | -0.44 | -3.993 | -0.60 | -4.441** | -2.36 | 487 | 61.4 | 7.155*** | 13.59 | -16.80 | -0.68 | -6.185 | -0.99 | 1.956 | 0.70 | -10.47 | -1.30 | 487 | 61.5 |
| 1 | 4 | 3.291*** | 23.04 | 12.06*** | 2.76 | 4.063 | 0.91 | -0.675 | -1.29 | 531 | 79.0 | 3.343*** | 24.17 | -1.523 | -0.24 | 1.148 | 0.31 | 2.540*** | 2.95 | -8.469*** | -3.25 | 531 | 79.6 |
| 2 | 4 | 4.017*** | 17.72 | 7.246 | 1.44 | 1.780 | 0.46 | -0.407 | -0.67 | 532 | 75.9 | 4.050*** | 17.87 | -1.198 | -0.16 | -0.0345 | -0.01 | 1.577 | 1.53 | -5.246* | -1.68 | 532 | 76.0 |
| 3 | 4 | 4.444*** | 17.68 | 3.937 | 0.63 | 1.024 | 0.21 | -0.345 | -0.45 | 532 | 74.4 | 4.495*** | 18.06 | -9.179 | -0.94 | -1.795 | -0.42 | 2.450** | 2.14 | -7.862** | -2.33 | 532 | 74.6 |
| 4 | 4 | 5.111*** | 18.67 | 5.440 | 0.76 | 0.625 | 0.15 | -0.891 | -0.99 | 532 | 72.2 | 5.151*** | 18.80 | -4.647 | -0.41 | -1.543 | -0.41 | 1.884 | 1.41 | -6.671* | -1.69 | 532 | 72.3 |
| 5 | 4 | 5.650*** | 15.17 | -5.917 | -0.52 | 0.0904 | 0.01 | -1.559 | -1.13 | 532 | 65.0 | 5.714*** | 15.52 | -22.21 | -1.16 | -3.411 | -0.65 | 3.043 | 1.43 | -10.90* | -1.79 | 532 | 65.3 |
| 1 | 5 | 3.013*** | 25.05 | 16.96*** | 4.13 | 2.068 | 0.43 | -1.237** | -2.56 | 531 | 78.3 | 3.064*** | 26.24 | 3.519 | 0.61 | -0.815 | -0.20 | 2.513*** | 2.97 | -8.949*** | -3.42 | 531 | 78.9 |
| 2 | 5 | 3.536*** | 23.39 | 9.672** | 2.17 | 0.485 | 0.12 | -0.820 | -1.51 | 531 | 78.7 | 3.565*** | 23.44 | 2.200 | 0.31 | -1.118 | -0.30 | 1.397 | 1.54 | -5.109* | -1.87 | 531 | 78.9 |
| 3 | 5 | 3.560*** | 11.56 | 9.361* | 1.80 | 1.821 | 0.46 | -0.834 | -1.33 | 532 | 71.5 | 3.603*** | 11.88 | -1.718 | -0.24 | -0.560 | -0.17 | 2.069** | 2.29 | -7.184** | -2.55 | 532 | 71.8 |
| 4 | 5 | 4.046*** | 18.59 | 0.0206 | 0.00 | 0.121 | 0.03 | -0.212 | -0.31 | 532 | 74.1 | 4.080*** | 18.77 | -8.579 | -0.98 | -1.727 | -0.40 | 1.606 | 1.55 | -5.140* | -1.67 | 532 | 74.3 |
| 5 | 5 | 4.711*** | 15.74 | -6.003 | -0.71 | -4.427 | -0.82 | -0.738 | -0.72 | 532 | 65.3 | 4.751*** | 16.00 | -16.31 | -1.19 | -6.642 | -1.34 | 1.925 | 1.16 | -6.647 | -1.36 | 532 | 65.5 |
| 1 | 6 | 2.726*** | 23.75 | 13.93*** | 3.52 | 2.511 | 0.59 | -0.919* | -1.93 | 496 | 74.7 | 2.753*** | 24.39 | 4.054 | 0.72 | 0.576 | 0.15 | 1.802** | 2.24 | -6.431*** | -2.60 | 496 | 75.1 |
| 2 | 6 | 3.095*** | 20.31 | -3.876 | -0.61 | 6.060 | 1.17 | 0.970 | 1.24 | 501 | 69.6 | 3.130*** | 20.82 | -17.03* | -1.82 | 3.438 | 0.79 | 2.411** | 2.35 | -6.412** | -2.17 | 501 | 70.2 |
| 3 | 6 | 3.167*** | 11.45 | 1.507 | 0.24 | 4.368 | 0.84 | 0.147 | 0.19 | 505 | 68.0 | 3.180*** | 11.67 | -3.241 | -0.34 | 3.434 | 0.67 | 0.871 | 0.84 | -2.519 | -0.83 | 505 | 68.1 |
| 4 | 6 | 3.650*** | 23.30 | -1.577 | -0.32 | 2.670 | 0.64 | 0.106 | 0.17 | 498 | 75.1 | 3.672*** | 23.71 | -9.860 | -1.28 | 1.014 | 0.27 | 1.528* | 1.70 | -4.577* | -1.73 | 498 | 75.3 |
| 5 | 6 | 3.833*** | 13.38 | -14.48* | -1.66 | -0.0731 | -0.02 | 0.612 | 0.60 | 501 | 54.2 | 3.831*** | 13.38 | -14.00 | -1.19 | 0.0216 | 0.01 | -0.0890 | -0.06 | 0.885 | 0.20 | 501 | 54.2 |

**Table B15(b) Put Option Return Sensitivity to Stock Market Illiquidity**

This table reports the results of the two versions (Model 1 & Model 2) of the empirical model presented in Equation (5.13) for put option portfolios for the sample period from January 2009 to December 2010. Call option excess return is regressed on stock market excess return $(r_m - r_f)$, stock market expected illiquidity ($eliq_{sm}$) and stock market unexpected illiquidity ($ueliq_{sm}$) for each moneyness and maturity portfolio (Model 1). Model 2 results include a control variable for the log volatility ($\mathbf{ln}(\boldsymbol{iv})_{pm}$) in the put options market. The log volatility is the average implied volatility across all call options in the market. $ueliq_{sm}$ is the residual obtained from the AR(p) specification of the proportional bid-ask spread after adjusting for Kendal's bias correction (see Section 5.5.1 and Table 5.4 & Table 5.5). Column 'Mon' represents the moneyness bin and column 'Mat' represents the maturity bin (see Table 3.4). 'Coeff'is the estimated coefficient and 't'is the t-statistic calculated using the robust standard errors. 'Obs' is the number of observations and $R^2$is the adjusted-R square. *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

| **Mon** | **Mat** | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $intercept$ | | **Obs** | $R^2$ | $(r_m - r_f)$ | | $eliq_{sm}$ | | $ueliq_{sm}$ | | $\ln(iv)_{pm}$ | | $intercept$ | | **Obs** | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | | | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | **Coeff** | **t** | | |
| | | **Model 1** | | | | | | | | | | **Model 2** | | | | | | | | | | | |
| 1 | 1 | -6.112*** | -15.0 | 16.99 | 1.38 | 12.87 | 0.90 | 0.583 | 0.37 | 295 | 58.3 | -6.168*** | -15.39 | 29.64 | 1.38 | 18.42 | 1.06 | -2.551 | -0.85 | 8.559 | 0.92 | 295 | 58.4 |
| 2 | 1 | -7.772*** | -13.9 | 3.580 | 0.25 | 10.18 | 0.47 | 1.457 | 0.81 | 303 | 71.3 | -8.057*** | -17.50 | 65.12** | 2.44 | 36.91* | 1.70 | -12.25*** | -3.49 | 39.62*** | 3.80 | 303 | 73.3 |
| 3 | 1 | -10.66*** | -15.6 | 14.76 | 0.82 | 13.41 | 0.47 | -4.865** | -2.19 | 303 | 76.8 | -10.95*** | -19.44 | 77.91** | 2.17 | 40.84 | 1.32 | -12.57*** | -2.70 | 34.30** | 2.52 | 303 | 78.1 |
| 4 | 1 | -12.79*** | -14.7 | 40.93* | 1.79 | 22.91 | 0.69 | -13.90*** | -4.93 | 303 | 75.7 | -13.13*** | -18.31 | 115.3*** | 2.64 | 55.23 | 1.61 | -14.81*** | -2.71 | 32.23** | 2.03 | 303 | 76.9 |
| 5 | 1 | -13.09*** | -13.2 | 24.04 | 0.97 | -0.584 | -0.02 | -15.42*** | -4.95 | 303 | 67.3 | -13.56*** | -16.14 | 124.7*** | 2.89 | 43.13 | 1.32 | -20.03*** | -3.49 | 46.98*** | 2.73 | 303 | 69.1 |
| 1 | 2 | -5.112*** | -26.2 | 4.571 | 0.72 | 6.557 | 1.56 | 1.183 | 1.47 | 497 | 74.9 | -5.134*** | -27.56 | 12.12 | 1.15 | 8.086* | 1.65 | -1.401 | -0.99 | 5.482 | 1.27 | 497 | 74.9 |
| 2 | 2 | -6.200*** | -23.4 | -5.900 | -0.81 | 6.174 | 1.11 | 1.649* | 1.79 | 497 | 77.7 | -6.256*** | -24.93 | 13.34 | 1.11 | 10.07 | 1.38 | -3.573** | -2.33 | 12.61*** | 2.73 | 497 | 78.0 |
| 3 | 2 | -7.733*** | -18.2 | -5.511 | -0.57 | 8.994 | 1.19 | -0.611 | -0.50 | 497 | 76.8 | -7.783*** | -19.06 | 11.72 | 0.71 | 12.49 | 1.35 | -3.200* | -1.66 | 9.206 | 1.63 | 497 | 77.0 |
| 4 | 2 | -8.988*** | -16.4 | 0.280 | 0.02 | 10.37 | 1.10 | -3.813** | -2.45 | 497 | 73.7 | -9.018*** | -16.88 | 10.48 | 0.51 | 12.43 | 1.12 | -1.895 | -0.80 | 2.001 | 0.29 | 497 | 73.7 |
| 5 | 2 | -10.16*** | -17.1 | 1.367 | 0.09 | 12.91 | 1.30 | -6.516*** | -3.56 | 496 | 72.1 | -10.23*** | -17.58 | 28.93 | 1.30 | 18.48* | 1.66 | -5.129* | -1.95 | 9.226 | 1.18 | 496 | 72.3 |
| 1 | 3 | -4.300*** | -23.6 | 12.02* | 1.76 | 7.612 | 1.62 | -0.105 | -0.13 | 487 | 74.6 | -4.295*** | -23.96 | 10.43 | 0.93 | 7.270 | 1.45 | 0.311 | 0.23 | -1.069 | -0.26 | 487 | 74.6 |
| 2 | 3 | -5.173*** | -23.8 | 3.399 | 0.55 | 3.516 | 0.91 | 0.204 | 0.27 | 487 | 79.8 | -5.214*** | -25.68 | 17.03 | 1.58 | 6.450 | 1.45 | -2.666** | -1.97 | 8.456** | 2.12 | 487 | 80.0 |
| 3 | 3 | -6.143*** | -23.4 | 4.617 | 0.67 | 7.836 | 1.41 | -1.427 | -1.63 | 487 | 80.8 | -6.174*** | -24.77 | 15.12 | 1.24 | 10.10 | 1.50 | -2.054 | -1.39 | 4.932 | 1.14 | 487 | 80.9 |
| 4 | 3 | -7.125*** | -19.4 | 6.163 | 0.72 | 7.119 | 1.18 | -3.229*** | -2.94 | 487 | 77.3 | -7.156*** | -20.28 | 16.46 | 1.16 | 9.334 | 1.32 | -2.013 | -1.14 | 3.002 | 0.58 | 487 | 77.3 |
| 5 | 3 | -7.836*** | -22.3 | 9.549 | 1.09 | 6.365 | 0.97 | -5.338*** | -4.82 | 487 | 78.8 | -7.882*** | -23.53 | 24.83* | 1.65 | 9.655 | 1.33 | -2.989 | -1.52 | 3.913 | 0.67 | 487 | 79.0 |
| 1 | 4 | -3.216*** | -29.1 | 5.181 | 1.52 | 3.023 | 1.29 | -0.243 | -0.57 | 532 | 81.8 | -3.241*** | -31.08 | 12.24** | 2.09 | 4.537* | 1.69 | -1.338* | -1.80 | 3.877* | 1.75 | 532 | 82.0 |
| 2 | 4 | -4.118*** | -25.6 | -0.599 | -0.13 | 3.018 | 0.90 | -0.169 | -0.30 | 532 | 80.7 | -4.145*** | -26.98 | 6.687 | 0.86 | 4.581 | 1.24 | -1.381 | -1.53 | 4.083 | 1.56 | 532 | 80.8 |
| 3 | 4 | -4.638*** | -24.2 | -0.509 | -0.10 | 3.663 | 0.97 | -0.513 | -0.82 | 532 | 79.7 | -4.672*** | -25.52 | 8.777 | 1.03 | 5.654 | 1.29 | -1.760* | -1.70 | 4.905 | 1.62 | 532 | 79.8 |
| 4 | 4 | -5.177*** | -20.9 | -1.507 | -0.25 | 5.164 | 1.26 | -0.857 | -1.12 | 532 | 76.8 | -5.211*** | -21.67 | 7.735 | 0.81 | 7.146 | 1.53 | -1.751 | -1.51 | 4.536 | 1.30 | 532 | 76.9 |
| 5 | 4 | -5.831*** | -21.3 | -0.644 | -0.09 | 5.516 | 1.06 | -2.043** | -2.36 | 532 | 77.2 | -5.896*** | -22.68 | 17.24 | 1.55 | 9.351 | 1.64 | -3.389** | -2.42 | 8.393** | 2.02 | 532 | 77.5 |
| 1 | 5 | -2.746*** | -28.2 | 5.673** | 2.00 | 3.123 | 1.41 | -0.376 | -1.09 | 532 | 82.5 | -2.756*** | -28.84 | 8.357* | 1.80 | 3.698 | 1.41 | -0.509 | -0.84 | 1.190 | 0.65 | 532 | 82.6 |
| 2 | 5 | -3.397*** | -26.4 | 2.221 | 0.53 | 4.875* | 1.67 | -0.377 | -0.73 | 532 | 81.9 | -3.416*** | -28.01 | 7.266 | 0.98 | 5.957* | 1.77 | -0.956 | -1.16 | 2.567 | 1.10 | 532 | 81.9 |
| 3 | 5 | -3.722*** | -27.3 | 1.567 | 0.42 | 3.967 | 1.38 | -0.549 | -1.17 | 532 | 82.3 | -3.749*** | -28.97 | 8.862 | 1.35 | 5.531 | 1.57 | -1.382* | -1.71 | 3.708 | 1.57 | 532 | 82.4 |
| 4 | 5 | -3.992*** | -24.6 | -2.414 | -0.59 | 4.765 | 1.61 | -0.311 | -0.59 | 532 | 79.5 | -4.023*** | -25.84 | 6.231 | 0.99 | 6.618* | 1.82 | -1.638** | -2.01 | 4.734* | 1.92 | 532 | 79.7 |
| 5 | 5 | -4.454*** | -22.6 | -2.531 | -0.47 | 4.331 | 1.25 | -1.137* | -1.67 | 531 | 76.3 | -4.504*** | -24.30 | 11.63 | 1.40 | 7.361** | 2.25 | -2.687** | -2.45 | 7.142** | 2.17 | 531 | 76.6 |
| 1 | 6 | -2.388*** | -28.2 | 10.36*** | 2.78 | 3.538** | 1.97 | -0.964** | -2.32 | 498 | 74.5 | -2.393*** | -27.93 | 12.37*** | 2.97 | 3.940* | 1.92 | -0.374 | -0.70 | 0.183 | 0.10 | 498 | 74.6 |
| 2 | 6 | -2.939*** | -27.4 | 4.040 | 1.30 | 4.080* | 1.69 | -0.613 | -1.59 | 500 | 82.5 | -2.952*** | -28.82 | 9.070* | 1.66 | 5.086* | 1.75 | -0.935 | -1.41 | 2.256 | 1.17 | 500 | 82.6 |
| 3 | 6 | -3.280*** | -25.2 | 6.128** | 2.01 | 3.036 | 1.33 | -1.067*** | -2.77 | 504 | 83.2 | -3.293*** | -25.91 | 11.12** | 2.16 | 4.014 | 1.50 | -0.928 | -1.42 | 1.779 | 0.91 | 504 | 83.3 |
| 4 | 6 | -3.376*** | -24.9 | 5.555 | 1.07 | 2.227 | 0.85 | -1.262** | -1.98 | 500 | 77.0 | -3.392*** | -25.58 | 12.38 | 1.48 | 3.559 | 1.26 | -1.270 | -1.55 | 2.636 | 1.17 | 500 | 77.2 |
| 5 | 6 | -3.593*** | -21.2 | -5.260 | -1.22 | 0.699 | 0.23 | -0.441 | -0.82 | 502 | 74.6 | -3.622*** | -22.21 | 6.655 | 1.06 | 2.969 | 0.96 | -2.196** | -2.50 | 6.284** | 2.35 | 502 | 74.9 |

# C. APPENDIX OF CHAPTER 6

**Table C1 Descriptive Statistics of Weekly Delta-hedged Gains (DHGs)**

This table reports the descriptive statistics of the weekly delta-hedged gains (DHGs), calculated as in Equation 6.7 with the methodology described in Section 6.5.2. The statistics are reported for each moneyness portfolio of calls and puts. In Panel A, statistics are calculated across the whole sample of options for each moneyness portfolio of calls and puts. These include mean (Mean), standard error (SE), skewness (Skew), kurtosis (Kurt), percentage of observations of the negative weekly DHGs (Neg dhg (%)) and total observations (Obs). In Panel B, weekly DHGs are averaged over time for each stock in a moneyness category and then cross-sectional statistics across stocks are reported. The statistics include mean (Mean), standard deviation (SD), skewness (Skew), kurtosis (Kurt), percentage of stocks with average negative weekly DHG (Neg dhg (%)) and percentage of stocks with significant negative weekly DHG (Neg Sig (%)).

| **Weekly delta-hedged gains for NYSE LIFFE London Equity Options** | | | | | | |
|---|---|---|---|---|---|---|
| **Panel A** | **Pooled Descriptive Statistics** | | | | | |
| **Moneyness** | **Mean** | **S E** | **Skew** | **Kurt** | **Neg dhg (%)** | **Obs** |
| **Call Options** | | | | | | |
| DITM | 0.274 | 0.050 | 2.71 | 26.04 | 53.58 | 7,742 |
| ITM | 0.143 | 0.057 | 2.63 | 24.30 | 57.24 | 7,081 |
| ATM | 0.154 | 0.051 | 2.06 | 21.39 | 56.65 | 8,886 |
| OTM | 0.020 | 0.047 | 2.13 | 24.64 | 57.90 | 8,103 |
| DOTM | -0.087 | 0.033 | 1.14 | 29.96 | 58.04 | 8,475 |
| All | 0.097 | 0.021 | 2.36 | 25.99 | 56.71 | 40,287 |
| **Put Options** | | | | | | |
| DITM | -0.533 | 0.058 | 0.01 | 17.73 | 58.80 | 8,419 |
| ITM | -0.475 | 0.060 | 0.54 | 19.01 | 59.54 | 7,899 |
| ATM | -0.308 | 0.057 | 1.61 | 26.02 | 60.62 | 9,150 |
| OTM | -0.324 | 0.052 | 2.06 | 31.68 | 63.13 | 8,513 |
| DOTM | -0.214 | 0.037 | 3.43 | 50.95 | 64.64 | 8,790 |
| All | -0.367 | 0.024 | 1.22 | 26.30 | 61.39 | 42,771 |
| **Panel B** | **Cross-sectional Descriptive Statistics** | | | | | |
| **Moneyness** | **Mean** | **S D** | **Skew** | **Kurt** | **Neg dhg (%)** | **Neg Sig (%)** |
| **Call Options** | | | | | | |
| DITM | 0.265 | 3.579 | 1.85 | 11.74 | 25.00 | 1.56 |
| ITM | 0.131 | 3.853 | 1.76 | 10.59 | 29.69 | 4.69 |
| ATM | 0.153 | 3.910 | 1.61 | 9.75 | 27.27 | 3.03 |
| OTM | 0.018 | 3.429 | 1.62 | 10.95 | 45.45 | 7.58 |
| DOTM | -0.087 | 2.462 | 0.99 | 10.98 | 75.76 | 4.55 |
| **Put Options** | | | | | | |
| DITM | -0.526 | 4.182 | 0.54 | 7.68 | 88.24 | 26.47 |
| ITM | -0.463 | 4.162 | 0.66 | 8.69 | 80.88 | 29.41 |
| ATM | -0.305 | 4.345 | 1.37 | 11.55 | 77.94 | 16.18 |
| OTM | -0.320 | 3.776 | 1.64 | 13.39 | 80.88 | 22.06 |
| DOTM | -0.218 | 2.795 | 2.32 | 20.81 | 79.41 | 19.12 |

**Figure C1 Implied Volatility and Stock's Proportional Bid-Ask Spread Over Time**

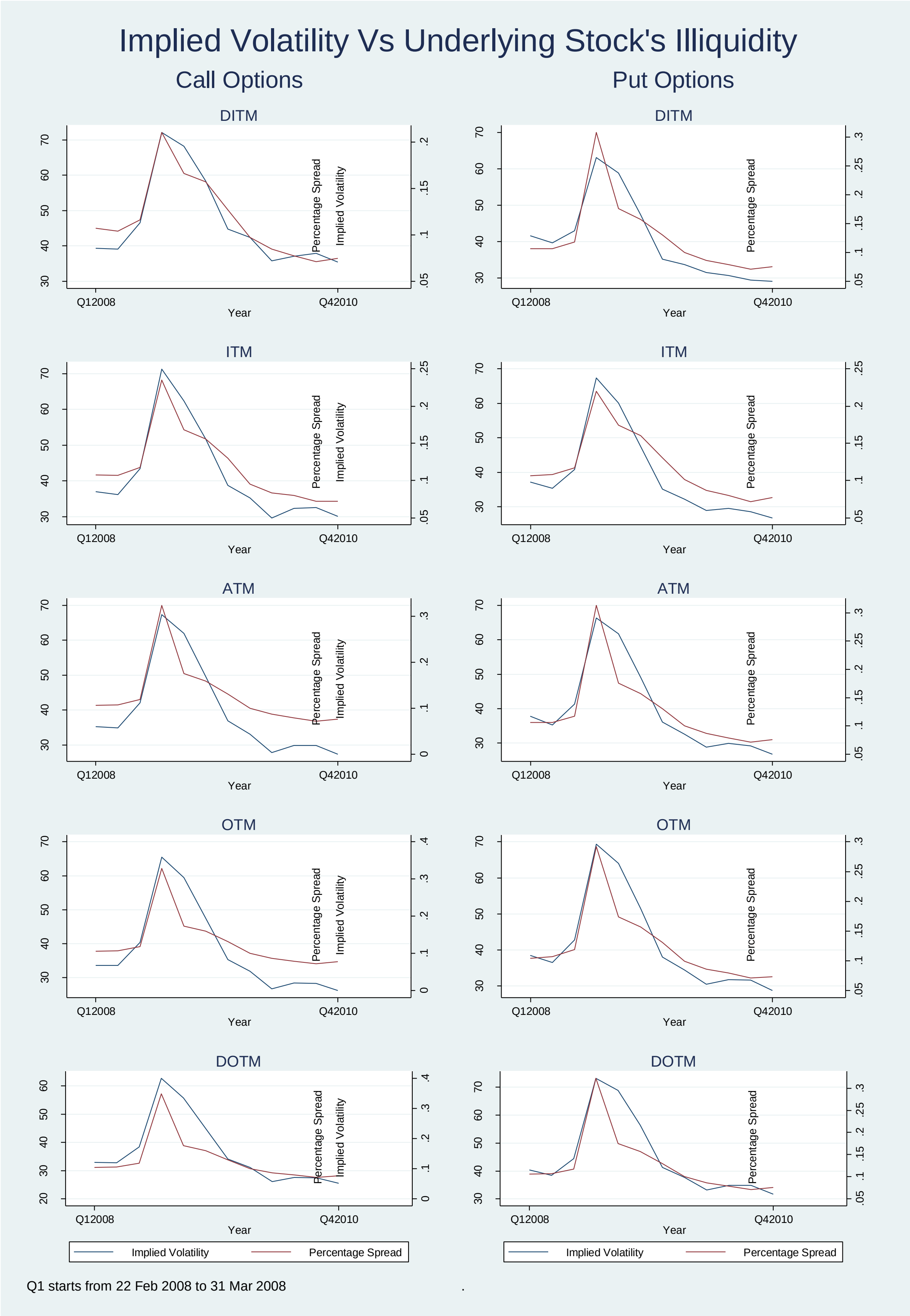


**Table C2 Descriptive Statistics of Liquidity of Options and their Stocks**

This table reports the mean and standard deviation of liquidity as measured by the proportional bid-ask spread. 'Observations' indicate the number of weekly observations. The statistics are reported for call and put moneyness portfolios, as well as the underlying stocks.

| Moneyness | Mean | Standard Deviation | Observations |
|---|---|---|---|
| **Calls** | | | |
| **DITM** | 9.14 | 4.61 | 7,742 |
| **ITM** | 10.41 | 5.77 | 7,081 |
| **ATM** | 15.26 | 8.64 | 8,886 |
| **OTM** | 25.31 | 14.92 | 8,103 |
| **DOTM** | 44.51 | 18.45 | 8,475 |
| **Puts** | | | |
| **DITM** | 8.22 | 4.50 | 8,419 |
| **ITM** | 10.14 | 5.88 | 7,899 |
| **ATM** | 14.78 | 8.74 | 9,150 |
| **OTM** | 23.77 | 14.90 | 8,513 |
| **DOTM** | 42.01 | 17.26 | 8,790 |
| **Stocks** | 0.1182 | 0.1333 | 4,0287 |

**Table C3 Percentage of Stocks with Significant Estimated Beta**

This table reports the percentage of stocks with significant beta, as estimated by Equations 6.1, 6.2 and 6.3. The number of stocks in each portfolio is also reported. The percentage of significant betas is calculated as the number of significant betas in each portfolio divided by the total number of stock regressions in each portfolio, multiplied by 100.

| Moneyness | DITM | ITM | ATM | OTM | DOTM |
|---|---|---|---|---|---|
| **Calls** | | | | | |
| $\beta_{(dhg,rm)}$ | 35.9% | 57.8% | 83.3% | 84.8% | 89.4% |
| $\beta_{(dhg,smliq)}$ | 29.7% | 53.1% | 59.1% | 62.1% | 63.6% |
| $\beta_{(dhg,omliq)}$ | 23.4% | 18.8% | 33.3% | 33.3% | 30.3% |
| $\beta_{(oliq,rm)}$ | 51.6% | 89.1% | 100.0% | 97.0% | 97.0% |
| $\beta_{(oliq,smliq)}$ | 57.8% | 42.2% | 13.6% | 15.2% | 19.7% |
| $\beta_{(oliq,omliq)}$ | 12.5% | 12.5% | 10.6% | 15.2% | 22.7% |
| $\beta_{(sliq,rm)}$ | 14.1% | 12.5% | 16.7% | 12.1% | 10.6% |
| $\beta_{(sliq,smliq)}$ | 12.5% | 10.9% | 12.1% | 15.2% | 13.6% |
| $\beta_{(sliq,omliq)}$ | 14.1% | 14.1% | 16.7% | 19.7% | 16.7% |
| Stocks | 64 | 64 | 66 | 66 | 66 |
| **Puts** | | | | | |
| $\beta_{(dhg,rm)}$ | 92.9% | 92.9% | 97.1% | 94.3% | 75.7% |
| $\beta_{(dhg,smliq)}$ | 58.8% | 63.2% | 73.5% | 76.5% | 64.7% |
| $\beta_{(dhg,omliq)}$ | 27.9% | 32.4% | 47.1% | 52.9% | 38.2% |
| $\beta_{(oliq,rm)}$ | 10.3% | 26.5% | 85.3% | 94.1% | 86.8% |
| $\beta_{(oliq,smliq)}$ | 26.5% | 44.1% | 26.5% | 17.6% | 8.8% |
| $\beta_{(oliq,omliq)}$ | 11.8% | 19.1% | 23.5% | 22.1% | 11.8% |
| $\beta_{(sliq,rm)}$ | 8.8% | 8.8% | 10.3% | 8.8% | 7.4% |
| $\beta_{(sliq,smliq)}$ | 13.2% | 16.2% | 11.8% | 11.8% | 11.8% |
| $\beta_{(sliq,omliq)}$ | 10.3% | 13.2% | 10.3% | 8.8% | 8.8% |
| Stocks | 68 | 68 | 68 | 68 | 68 |

**Table C4 Mean and Standard Deviation of Beta Coefficients**

This table reports the mean and standard deviation of betas across stocks in each moneyness portfolio and across all options in all portfolios. Betas are the coefficients obtained by estimating the time-series regressions of Equations 6.1, 6.2, and 6.3 for every stock in each moneyness portfolio. The total number of stocks in each portfolio is also reported. For each beta, the first row shows the mean and the second row shows the standard deviation (in italics).

| BETA | DITM | ITM | ATM | OTM | DOTM | ALL |
|---|---|---|---|---|---|---|
| **Calls** | | | | | | |
| $\beta_{(dhg,rm)}$ | -0.1216 | -0.245 | -0.3347 | -0.3474 | -0.3139 | -0.2736 |
| | *0.211* | *0.251* | *0.297* | *0.305* | *0.276* | *0.281* |
| $\beta_{(dhg,smliq)}$ | 1.9989 | 3.0911 | 3.3356 | 3.1856 | 2.4896 | 2.8235 |
| | *2.877* | *4.526* | *3.791* | *3.754* | *2.718* | *3.605* |
| $\beta_{(dhg,omliq)}$ | 1.7765 | 2.044 | 3.0091 | 2.3327 | 1.7931 | 2.1945 |
| | *3.659* | *4.069* | *3.994* | *3.808* | *2.907* | *3.714* |
| $\beta_{(oliq,rm)}$ | -0.0161 | -0.0314 | -0.0494 | -0.0579 | -0.0472 | -0.0406 |
| | *0.012* | *0.014* | *0.014* | *0.022* | *0.02* | *0.022* |
| $\beta_{(oliq,smliq)}$ | 0.1721 | 0.1778 | 0.0535 | -0.1104 | -0.0966 | 0.0376 |
| | *0.165* | *0.184* | *0.193* | *0.252* | *0.211* | *0.238* |
| $\beta_{(oliq,omliq)}$ | 0.0401 | 0.0854 | -0.031 | -0.1359 | -0.255 | -0.0608 |
| | *0.212* | *0.292* | *0.279* | *0.401* | *0.32* | *0.33* |
| $\beta_{(sliq,rm)}$ | -0.0025 | -0.0007 | -0.0013 | -0.0011 | -0.0008 | -0.0013 |
| | *0.021* | *0.021* | *0.02* | *0.019* | *0.02* | *0.02* |
| $\beta_{(sliq,smliq)}$ | 0.0477 | 0.0361 | 0.0637 | 0.0408 | 0.0238 | 0.0424 |
| | *0.278* | *0.299* | *0.298* | *0.314* | *0.3* | *0.297* |
| $\beta_{(sliq,omliq)}$ | 0.1117 | 0.1893 | 0.1924 | 0.2228 | 0.1878 | 0.1811 |
| | *0.503* | *0.507* | *0.489* | *0.502* | *0.484* | *0.495* |
| Total stocks | 64 | 64 | 66 | 66 | 66 | 326 |
| **Puts** | | | | | | |
| $\beta_{(dhg,rm)}$ | -0.5951 | -0.5842 | -0.5645 | -0.4748 | -0.3559 | -0.5149 |
| | *0.552* | *0.525* | *0.52* | *0.465* | *0.321* | *0.489* |
| $\beta_{(dhg,smliq)}$ | 3.7378 | 4.2578 | 4.4509 | 4.1178 | 3.3683 | 3.9865 |
| | *3.779* | *4.424* | *4.151* | *4.112* | *3.445* | *3.992* |
| $\beta_{(dhg,omliq)}$ | -2.6496 | -4.1043 | -5.0375 | -4.8212 | -3.39 | -4.0005 |
| | *4.074* | *4.298* | *4.514* | *4.477* | *3.138* | *4.202* |
| $\beta_{(oliq,rm)}$ | 0.0022 | 0.0118 | 0.0299 | 0.0438 | 0.0445 | 0.0265 |
| | *0.012* | *0.014* | *0.012* | *0.014* | *0.016* | *0.022* |
| $\beta_{(oliq,smliq)}$ | 0.1154 | 0.1764 | 0.1346 | 0.0678 | -0.0128 | 0.0963 |
| | *0.167* | *0.238* | *0.21* | *0.3* | *0.199* | *0.235* |
| $\beta_{(oliq,omliq)}$ | -0.0516 | -0.1299 | 0.0173 | 0.2331 | 0.016 | 0.017 |
| | *0.279* | *0.38* | *0.419* | *0.467* | *0.364* | *0.403* |
| $\beta_{(sliq,rm)}$ | -0.0003 | -0.0006 | -0.0004 | 0.0001 | -0.0006 | -0.0003 |
| | *0.019* | *0.019* | *0.018* | *0.019* | *0.018* | *0.019* |
| $\beta_{(sliq,smliq)}$ | 0.0099 | 0.005 | 0.0393 | 0.02 | 0.0638 | 0.0276 |
| | *0.298* | *0.328* | *0.285* | *0.297* | *0.287* | *0.298* |
| $\beta_{(sliq,omliq)}$ | -0.0642 | -0.0379 | -0.0396 | -0.057 | -0.0686 | -0.0535 |
| | *0.533* | *0.576* | *0.549* | *0.566* | *0.558* | *0.554* |
| Total Stocks | 68 | 68 | 68 | 68 | 68 | 340 |

**Table C5(a) Cross-sectional Correlations of Independent Variables for In-the-Money (ITM) Options**

This table reports the cross-sectional correlations of independent variables for in-the-money options. The upper-half triangle reports correlations for puts and the lower half-triangle reports correlations for calls. *lnosprop* is the natural logarithm of proportional bid-ask spread of options, *lnssprop* is the natural logarithm of the proportional bid-ask spread of the underlying stock, $\beta_{(dhg,rm)}$ is the market beta of delta-hedged gain option portfolio of a stock and $\beta_{(dhg,smliq)}$ to $\beta_{(sliq,omliq)}$ are the liquidity risk betas. All betas are estimated by Equations 6.1, 6.2 and 6.3.

| | lnosprop | lnssprop | $\beta_{(dhg,rm)}$ | $\beta_{(dhg,smliq)}$ | $\beta_{(dhg,omliq)}$ | $\beta_{(oliq,rm)}$ | $\beta_{(oliq,smliq)}$ | $\beta_{(oliq,omliq)}$ | $\beta_{(sliq,rm)}$ | $\beta_{(sliq,smliq)}$ | $\beta_{(sliq,omliq)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| lnosprop | 1 | *0.717* | *0.653* | *-0.531* | *0.293* | *0.519* | *-0.238* | *-0.242* | *0.125* | *0.061* | *0.191* |
| lnssprop | 0.663 | 1 | *0.492* | *-0.407* | *0.207* | *0.336* | *-0.300* | *-0.141* | *0.236* | *-0.001* | *0.181* |
| $\beta_{(dhg,rm)}$ | 0.549 | 0.476 | 1 | *-0.831* | *0.629* | *0.282* | *-0.098* | *-0.281* | *0.023* | *-0.134* | *0.281* |
| $\beta_{(dhg,smliq)}$ | -0.438 | -0.350 | -0.436 | 1 | *-0.476* | *-0.249* | *0.103* | *0.335* | *-0.100* | *0.170* | *-0.205* |
| $\beta_{(dhg,omliq)}$ | -0.209 | -0.074 | -0.348 | -0.229 | 1 | *0.097* | *-0.039* | *-0.053* | *0.001* | *-0.103* | *0.173* |
| $\beta_{(oliq,rm)}$ | -0.448 | -0.121 | -0.201 | 0.235 | 0.063 | 1 | *-0.200* | *0.015* | *0.140* | *0.052* | *0.021* |
| $\beta_{(oliq,smliq)}$ | -0.213 | -0.212 | -0.125 | 0.116 | 0.158 | 0.074 | 1 | *-0.066* | *-0.251* | *0.019* | *-0.139* |
| $\beta_{(oliq,omliq)}$ | -0.088 | -0.035 | -0.026 | -0.123 | 0.166 | 0.118 | 0.198 | 1 | *-0.063* | *-0.008* | *0.021* |
| $\beta_{(sliq,rm)}$ | 0.005 | 0.115 | -0.167 | 0.022 | 0.240 | 0.119 | -0.201 | -0.085 | 1 | *0.188* | *0.113* |
| $\beta_{(sliq,smliq)}$ | 0.123 | 0.016 | -0.155 | 0.201 | 0.052 | -0.188 | -0.126 | -0.099 | 0.190 | 1 | *-0.108* |
| $\beta_{(sliq,omliq)}$ | 0.257 | 0.238 | 0.167 | -0.131 | -0.043 | -0.177 | 0.036 | 0.138 | -0.036 | 0.162 | 1 |

**Table C5(b) Cross-sectional Correlations of Independent Variables for At-the-Money (ATM) Options**

This table reports the cross-sectional correlations of independent variables for at-the-money options. The upper-half triangle reports correlations for puts and the lower-half triangle reports correlations for calls. *lnosprop* is the natural logarithm of proportional bid-ask spread of options, *lnssprop* is the natural logarithm of proportional bid-ask spread of the underlying stock, $\beta_{(dhg,rm)}$ is the market beta of delta-hedged gain option portfolio of a stock and $\beta_{(dhg,smliq)}$ to $\beta_{(sliq,omliq)}$ are the liquidity risk betas. All betas are estimated by Equations 6.1, 6.2 and 6.3.

| | *lnosprop* | *lnssprop* | $\beta_{(dhg,rm)}$ | $\beta_{(dhg,smliq)}$ | $\beta_{(dhg,omliq)}$ | $\beta_{(oliq,rm)}$ | $\beta_{(oliq,smliq)}$ | $\beta_{(oliq,omliq)}$ | $\beta_{(sliq,rm)}$ | $\beta_{(sliq,smliq)}$ | $\beta_{(sliq,omliq)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *lnosprop* | 1 | *0.685* | *0.728* | *-0.681* | *0.396* | *0.280* | *-0.372* | *-0.291* | *0.173* | *0.009* | *0.282* |
| *lnssprop* | 0.684 | 1 | *0.499* | *-0.447* | *0.263* | *0.273* | *-0.196* | *-0.153* | *0.259* | *0.032* | *0.239* |
| $\beta_{(dhg,rm)}$ | 0.678 | 0.442 | 1 | *-0.844* | *0.665* | *0.041* | *-0.192* | *-0.263* | *0.096* | *-0.173* | *0.320* |
| $\beta_{(dhg,smliq)}$ | -0.668 | -0.454 | -0.705 | 1 | *-0.659* | *-0.023* | *0.225* | *0.218* | *-0.111* | *0.183* | *-0.202* |
| $\beta_{(dhg,omliq)}$ | -0.398 | -0.252 | -0.353 | 0.385 | 1 | *-0.059* | *-0.122* | *-0.072* | *0.108* | *-0.219* | *0.220* |
| $\beta_{(oliq,rm)}$ | -0.205 | -0.098 | -0.100 | 0.161 | 0.008 | 1 | *-0.095* | *0.064* | *-0.048* | *0.206* | *-0.117* |
| $\beta_{(oliq,smliq)}$ | -0.276 | -0.230 | -0.075 | 0.212 | 0.110 | 0.130 | 1 | *0.015* | *-0.023* | *0.119* | *-0.187* |
| $\beta_{(oliq,omliq)}$ | -0.230 | -0.332 | -0.134 | 0.129 | -0.026 | 0.112 | 0.141 | 1 | *0.019* | *0.004* | *-0.075* |
| $\beta_{(sliq,rm)}$ | 0.066 | 0.148 | -0.117 | -0.089 | -0.035 | -0.006 | -0.116 | -0.174 | 1 | *0.146* | *0.019* |
| $\beta_{(sliq,smliq)}$ | 0.151 | 0.153 | -0.061 | 0.135 | 0.010 | -0.223 | -0.096 | -0.098 | 0.248 | 1 | *-0.132* |
| $\beta_{(sliq,omliq)}$ | 0.228 | 0.193 | 0.173 | -0.104 | -0.006 | -0.162 | 0.089 | 0.044 | -0.115 | 0.157 | 1 |

**Table C5(c) Cross-sectional Correlations of Independent Variables for Out-the-Money (OTM) Options**

This table reports the cross-sectional correlations of independent variables for out-the-money options. The upper half-triangle reports correlations for puts and the lower half-triangle reports correlations for calls. *lnosprop* is the natural logarithm of proportional bid-ask spread of options, *lnssprop* is the natural logarithm of proportional bid-ask spread of the underlying stock, $\beta_{(dhg,rm)}$ is the market beta of delta-hedged gain option portfolio of a stock and $\beta_{(dhg,smliq)}$ to $\beta_{(sliq,omliq)}$ are the liquidity risk betas. All betas are estimated by Equations 6.1, 6.2 and 6.3.

| | *lnosprop* | *lnssprop* | $\beta_{(dhg,rm)}$ | $\beta_{(dhg,smliq)}$ | $\beta_{(dhg,omliq)}$ | $\beta_{(oliq,rm)}$ | $\beta_{(oliq,smliq)}$ | $\beta_{(oliq,omliq)}$ | $\beta_{(sliq,rm)}$ | $\beta_{(sliq,smliq)}$ | $\beta_{(sliq,omliq)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *lnosprop* | 1 | *0.589* | *0.735* | *-0.690* | *0.414* | *-0.164* | *-0.355* | *-0.171* | *0.139* | *-0.130* | *0.212* |
| *lnssprop* | 0.555 | 1 | *0.488* | *-0.450* | *0.247* | *-0.054* | *-0.161* | *-0.093* | *0.305* | *0.010* | *0.142* |
| $\beta_{(dhg,rm)}$ | 0.754 | 0.403 | 1 | *-0.794* | *0.559* | *-0.195* | *-0.161* | *-0.136* | *0.096* | *-0.235* | *0.250* |
| $\beta_{(dhg,smliq)}$ | -0.684 | -0.492 | -0.722 | 1 | *-0.493* | *0.246* | *0.175* | *0.056* | *-0.027* | *0.226* | *-0.114* |
| $\beta_{(dhg,omliq)}$ | -0.355 | -0.146 | -0.386 | 0.396 | 1 | *-0.033* | *-0.036* | *0.098* | *-0.003* | *-0.177* | *0.072* |
| $\beta_{(oliq,rm)}$ | 0.328 | -0.037 | 0.081 | -0.057 | -0.114 | 1 | *0.097* | *0.062* | *-0.079* | *0.321* | *-0.231* |
| $\beta_{(oliq,smliq)}$ | 0.057 | 0.013 | 0.094 | -0.022 | 0.003 | 0.270 | 1 | *0.162* | *-0.014* | *-0.021* | *-0.166* |
| $\beta_{(oliq,omliq)}$ | -0.234 | -0.162 | -0.094 | 0.014 | 0.073 | -0.059 | 0.167 | 1 | *-0.102* | *0.003* | *-0.077* |
| $\beta_{(sliq,rm)}$ | -0.048 | 0.103 | -0.164 | -0.034 | 0.067 | 0.001 | 0.123 | -0.028 | 1 | *0.205* | *-0.037* |
| $\beta_{(sliq,smliq)}$ | -0.122 | 0.023 | -0.146 | 0.119 | 0.139 | -0.176 | -0.029 | -0.046 | 0.224 | 1 | |
| $\beta_{(sliq,omliq)}$ | 0.174 | 0.219 | 0.215 | -0.054 | 0.043 | -0.005 | -0.052 | -0.096 | -0.086 | 0.046 | 1 |

**Table C6 Fama-MacBeth (1973) Results for Deep-In-the-Money (DITM) Call Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for DITM calls. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| *lnosprop* | -0.277 | -0.335 | -0.332 | -0.325 | -0.276 | -0.325 | -0.294 | -0.457* | -0.421* |
| | *0.183* | *0.216* | *0.211* | *0.213* | *0.210* | *0.211* | *0.203* | *0.264* | *0.250* |
| *lnssprop* | 0.030 | 0.044 | 0.019 | 0.033 | 0.021 | 0.017 | | 0.021 | |
| | *0.087* | *0.087* | *0.081* | *0.082* | *0.080* | *0.080* | | *0.083* | |
| $\beta_{(dhg,rm)}$ | -0.223 | | | | | | | | |
| | *0.443* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | 0.053 | 0.050 | 0.049 | 0.048 | 0.051 | 0.047 | 0.048 | | |
| | *0.036* | *0.035* | *0.035* | *0.035* | *0.035* | *0.034* | *0.034* | | |
| $\beta_{(dhg,omliq)}$ | 0.021 | 0.021 | 0.015 | | | | | | |
| | *0.021* | *0.021* | *0.020* | | | | | | |
| $\beta_{(oliq,rm)}$ | 0.314 | -0.670 | -1.524 | -1.584 | | -1.74 | -1.852 | -1.812 | -1.820 |
| | *5.006* | *5.195* | *5.070* | *5.049* | | *5.047* | *4.957* | *5.060* | *5.011* |
| $\beta_{(oliq,smliq)}$ | 0.270 | 0.357 | 0.423 | 0.500 | 0.447 | 0.486 | 0.532 | 0.443 | 0.492 |
| | *0.313* | *0.328* | *0.297* | *0.323* | *0.307* | *0.322* | *0.325* | *0.319* | *0.323* |
| $\beta_{(oliq,omliq)}$ | 0.126 | 0.056 | 0.052 | -0.010 | -0.061 | | 0.030 | 0.041 | 0.084 |
| | *0.182* | *0.194* | *0.177* | *0.171* | *0.173* | | *0.166* | *0.170* | *0.163* |
| $\beta_{(sliq,rm)}$ | -3.174 | -2.028 | | | | | | | |
| | *3.001* | *3.331* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.275 | 0.281 | 0.255 | 0.244 | 0.255 | 0.240 | 0.272 | 0.337 | 0.375 |
| | *0.209* | *0.210* | *0.190* | *0.189* | *0.195* | *0.189* | *0.194* | *0.226* | *0.231* |
| $\beta_{(sliq,omliq)}$ | -0.157 | -0.168* | -0.157* | -0.177* | -0.153 | -0.180* | -0.192** | -0.198** | -0.208** |
| | *0.102* | *0.101* | *0.094* | *0.098* | *0.093* | *0.096* | *0.097* | *0.095* | *0.095* |
| *Constant* | 0.721 | 0.904 | 0.826 | 0.857 | 0.741 | 0.824 | 0.702 | 1.219 | 1.081 |
| | *0.549* | *0.637* | *0.612* | *0.618* | *0.615* | *0.609* | *0.536* | *0.775* | *0.683* |
| | | | | | | | | | |
| $N$ | 7,740 | 7,740 | 7,740 | 7,740 | 7,740 | 7,740 | 7,742 | 7,740 | 7,742 |
| $R^2$ | 0.275 | 0.233 | 0.210 | 0.185 | 0.161 | 0.176 | 0.169 | 0.135 | 0.118 |
| $N_{wk}$ | 129 | 129 | 129 | 129 | 129 | 129 | 129 | 129 | 129 |

## Table C7 Fama-MacBeth (1973) Results for In-the-Money (ITM) Call Options

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for ITM calls. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.330* | 0.172 | 0.168 | 0.247 | 0.329 | 0.238 | 0.261 | 0.028 | 0.031 |
| | *0.186* | *0.201* | *0.204* | *0.220* | *0.219* | *0.218* | *0.208* | *0.288* | *0.269* |
| $lnssprop$ | -0.015 | 0.007 | 0.018 | 0.030 | 0.034 | 0.032 | | 0.008 | |
| | *0.081* | *0.077* | *0.078* | *0.078* | *0.081* | *0.077* | | *0.089* | |
| $\beta_{(dhg,rm)}$ | -0.296 | | | | | | | | |
| | *0.505* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | 0.044 | 0.043 | 0.043 | 0.052 | 0.054* | 0.052 | 0.051 | | |
| | *0.030* | *0.033* | *0.032* | *0.031* | *0.032* | *0.031* | *0.032* | | |
| $\beta_{(dhg,omliq)}$ | -0.025 | -0.018 | -0.021 | | | | | | |
| | *0.018* | *0.019* | *0.019* | | | | | | |
| $\beta_{(oliq,rm)}$ | -0.959 | -1.626 | -1.747 | -2.636 | | -2.488 | -2.924 | -0.720 | -0.799 |
| | *4.184* | *4.341* | *4.190* | *4.216* | | *4.292* | *4.269* | *4.755* | *4.804* |
| $\beta_{(oliq,smliq)}$ | 0.162 | 0.124 | 0.174 | 0.081 | 0.062 | 0.070 | 0.123 | 0.285 | 0.356 |
| | *0.283* | *0.289* | *0.270* | *0.285* | *0.290* | *0.290* | *0.288* | *0.323* | *0.337* |
| $\beta_{(oliq,omliq)}$ | -0.022 | -0.006 | 0.007 | -0.051 | -0.066 | | -0.047 | -0.119 | -0.111 |
| | *0.170* | *0.169* | *0.170* | *0.172* | *0.176* | | *0.167* | *0.174* | *0.170* |
| $\beta_{(sliq,rm)}$ | -2.010 | -1.921 | | | | | | | |
| | *2.969* | *2.998* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.073 | 0.115 | 0.099 | 0.014 | 0.018 | 0.023 | 0.021 | 0.316 | 0.298 |
| | *0.156* | *0.171* | *0.162* | *0.172* | *0.167* | *0.174* | *0.173* | *0.249* | *0.248* |
| $\beta_{(sliq,omliq)}$ | -0.16** | -0.18** | -0.187** | -0.18** | -0.184** | -0.189** | -0.15** | -0.234*** | -0.214** |
| | *0.079* | *0.078* | *0.077* | *0.078* | *0.079* | *0.077* | *0.077* | *0.082* | *0.083* |
| $Constant$ | -0.890 | -0.406 | -0.374 | -0.588 | -0.687 | -0.565 | -0.706 | 0.095 | 0.050 |
| | *0.606* | *0.670* | *0.685* | *0.743* | *0.699* | *0.737* | *0.642* | *0.980* | *0.854* |
| $N$ | 7,080 | 7,080 | 7,080 | 7,080 | 7,080 | 7,080 | 7,081 | 7,080 | 7,081 |
| $R^2$ | 0.285 | 0.243 | 0.222 | 0.191 | 0.172 | 0.176 | 0.175 | 0.144 | 0.126 |
| $N_{wk}$ | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 |

**Table C8 Fama-MacBeth (1973) Results for At-the-Money (ATM) Call Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for ATM calls. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| *lnosprop* | 0.48*** | 0.371** | 0.380** | 0.409** | 0.503*** | 0.392** | 0.419** | 0.209 | 0.199 |
| | *0.127* | *0.172* | *0.173* | *0.178* | *0.176* | *0.176* | *0.172* | *0.303* | *0.298* |
| *lnssprop* | 0.0510 | 0.0717 | 0.0286 | -0.0040 | 0.0059 | 0.0148 | | -0.0402 | |
| | *0.074* | *0.074* | *0.075* | *0.073* | *0.073* | *0.070* | | *0.079* | |
| $\beta_{(dhg,rm)}$ | -0.2124 | | | | | | | | |
| | *0.486* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | 0.022 | 0.0285 | 0.0292 | 0.0482 | 0.0484 | 0.0467 | 0.0484 | | |
| | *0.036* | *0.040* | *0.040* | *0.040* | *0.040* | *0.040* | *0.040* | | |
| $\beta_{(dhg,omliq)}$ | 0.041* | 0.046** | 0.046** | | | | | | |
| | *0.022* | *0.021* | *0.021* | | | | | | |
| $\beta_{(oliq,rm)}$ | -9.84** | -10.43** | -10.5*** | -10.59** | | -10.73** | -11.23*** | -12.59*** | -13.55*** |
| | *4.027* | *4.085* | *4.025* | *4.061* | | *4.113* | *4.066* | *4.128* | *4.067* |
| $\beta_{(oliq,smliq)}$ | 0.2431 | 0.1462 | 0.1302 | 0.1402 | 0.0833 | 0.1451 | 0.1338 | 0.2045 | 0.2232 |
| | *0.300* | *0.324* | *0.326* | *0.325* | *0.333* | *0.322* | *0.321* | *0.326* | *0.319* |
| $\beta_{(oliq,omliq)}$ | -0.1600 | -0.1271 | -0.1180 | -0.1501 | -0.1878 | | -0.1342 | -0.1583 | -0.1339 |
| | *0.137* | *0.137* | *0.132* | *0.133* | *0.138* | | *0.127* | *0.137* | *0.132* |
| $\beta_{(sliq,rm)}$ | -2.3752 | -1.882 | | | | | | | |
| | *2.454* | *3.086* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.1558 | 0.1422 | 0.118 | 0.1203 | 0.2209 | 0.1235 | 0.0979 | 0.3123 | 0.2704 |
| | *0.135* | *0.134* | *0.131* | *0.136* | *0.142* | *0.137* | *0.132* | *0.207* | *0.193* |
| $\beta_{(sliq,omliq)}$ | -0.20** | -0.21** | -0.20** | -0.19** | -0.16** | -0.19** | -0.203** | -0.25*** | -0.28*** |
| | *0.081* | *0.085* | *0.081* | *0.081* | *0.080* | *0.081* | *0.080* | *0.090* | *0.093* |
| *Constant* | -1.7*** | -1.37** | -1.50** | -1.57** | -1.26** | -1.48** | -1.60*** | -1.021 | -0.9364 |
| | *0.436* | *0.582* | *0.590* | *0.604* | *0.607* | *0.602* | *0.538* | *0.990* | *0.962* |
| $N$ | 8,884 | 8,884 | 8,884 | 8,884 | 8,884 | 8,884 | 8,886 | 8,884 | 8,886 |
| $R^2$ | 0.334 | 0.286 | 0.265 | 0.224 | 0.203 | 0.213 | 0.209 | 0.165 | 0.149 |
| $N_{wk}$ | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 |

**Table C9 Fama-MacBeth (1973) Results for Out-the-Money (OTM) Call Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for OTM calls. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.4220*** | 0.285** | 0.288** | 0.337** | 0.328** | 0.321** | 0.345** | 0.285 | 0.246 |
| | *0.114* | *0.133* | *0.135* | *0.139* | *0.141* | *0.135* | *0.136* | *0.216* | *0.234* |
| $lnssprop$ | 0.028 | 0.048 | 0.010 | 0.006 | 0.053 | 0.011 | | -0.041 | |
| | *0.064* | *0.066* | *0.066* | *0.066* | *0.067* | *0.066* | | *0.074* | |
| $\beta_{(dhg,rm)}$ | -0.251 | | | | | | | | |
| | *0.448* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | -0.0067 | 0.0046 | 0.0036 | 0.0150 | 0.0171 | 0.0144 | 0.0128 | | |
| | *0.032* | *0.039* | *0.040* | *0.039* | *0.038* | *0.038* | *0.038* | | |
| $\beta_{(dhg,omliq)}$ | 0.0220 | 0.0271 | 0.0254 | | | | | | |
| | *0.021* | *0.020* | *0.020* | | | | | | |
| $\beta_{(oliq,rm)}$ | -6.842*** | -6.015** | -6.007** | -6.473*** | | -6.221** | -6.676*** | -8.374*** | -8.880*** |
| | *2.491* | *2.430* | *2.421* | *2.451* | | *2.396* | *2.481* | *2.566* | *2.542* |
| $\beta_{(oliq,smliq)}$ | 0.3219 | 0.2506 | 0.2389 | 0.2656 | 0.1096 | 0.2226 | 0.2344 | 0.3207* | 0.2951 |
| | *0.202* | *0.215* | *0.198* | *0.198* | *0.204* | *0.192* | *0.202* | *0.193* | *0.191* |
| $\beta_{(oliq,omliq)}$ | -0.224** | -0.172* | -0.179* | -0.164* | -0.119 | | -0.165* | -0.146 | -0.149 |
| | *0.094* | *0.098* | *0.096* | *0.095* | *0.092* | | *0.095* | *0.095* | *0.094* |
| $\beta_{(sliq,rm)}$ | -1.6823 | -1.0167 | | | | | | | |
| | *2.527* | *2.860* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.1217 | 0.0952 | 0.0790 | 0.1018 | 0.1584 | 0.1145 | 0.1252 | 0.2205 | 0.1886 |
| | *0.127* | *0.121* | *0.117* | *0.115* | *0.116* | *0.118* | *0.109* | *0.139* | *0.122* |
| $\beta_{(sliq,omliq)}$ | -0.0538 | -0.0511 | -0.0542 | -0.0355 | -0.0562 | -0.0344 | -0.0251 | -0.0393 | -0.0631 |
| | *0.079* | *0.080* | *0.082* | *0.082* | *0.082* | *0.082* | *0.078* | *0.084* | *0.086* |
| $Constant$ | -1.650*** | -1.103** | -1.203** | -1.359** | -0.880 | -1.272** | -1.381*** | -1.351* | -1.169 |
| | *0.432* | *0.524* | *0.538* | *0.544* | *0.546* | *0.541* | *0.497* | *0.728* | *0.834* |
| $N$ | 8,101 | 8,101 | 8,101 | 8,101 | 8,101 | 8,101 | 8,103 | 8,101 | 8,103 |
| $R^2$ | 0.363 | 0.313 | 0.288 | 0.241 | 0.216 | 0.227 | 0.226 | 0.180 | 0.163 |
| $N_{wk}$ | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 |

**Table C10 Fama-MacBeth (1973) Results for Deep-Out-the-Money (DOTM) Call Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for DOTM calls. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.210** | 0.2472* | 0.2662** | 0.3167** | 0.293** | 0.3177** | 0.3064** | 0.3137* | 0.2802* |
| | *0.099* | *0.126* | *0.128* | *0.132* | *0.131* | *0.129* | *0.128* | *0.165* | *0.167* |
| $lnssprop$ | 0.0024 | 0.0072 | -0.0060 | -0.0002 | 0.0438 | -0.0026 | | -0.0398 | |
| | *0.042* | *0.042* | *0.042* | *0.042* | *0.042* | *0.040* | | *0.051* | |
| $\beta_{(dhg,rm)}$ | 0.4140 | | | | | | | | |
| | *0.370* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | 0.0171 | -0.0086 | -0.0092 | 0.0108 | 0.0133 | 0.0097 | 0.0104 | | |
| | *0.030* | *0.031* | *0.032* | *0.032* | *0.032* | *0.032* | *0.032* | | |
| $\beta_{(dhg,omliq)}$ | 0.0253 | 0.0251 | 0.0262 | | | | | | |
| | *0.021* | *0.020* | *0.020* | | | | | | |
| $\beta_{(oliq,rm)}$ | -6.12*** | -6.61*** | -6.614*** | -7.16*** | | -6.828*** | -7.214*** | -8.155*** | -8.184*** |
| | *2.129* | *2.088* | *2.090* | *2.180* | | *2.140* | *2.138* | *2.222* | *2.151* |
| $\beta_{(oliq,smliq)}$ | 0.0008 | 0.0730 | 0.0676 | 0.0638 | -0.0332 | 0.0490 | 0.0757 | 0.1119 | 0.1328 |
| | *0.141* | *0.174* | *0.173* | *0.172* | *0.173* | *0.165* | *0.173* | *0.174* | *0.174* |
| $\beta_{(oliq,omliq)}$ | -0.1633 | -0.1183 | -0.1207 | -0.1451 | -0.0662 | | -0.1412 | -0.1265 | -0.1117 |
| | *0.101* | *0.100* | *0.106* | *0.109* | *0.108* | | *0.106* | *0.113* | *0.114* |
| $\beta_{(sliq,rm)}$ | 0.2888 | -0.2612 | | | | | | | |
| | *1.752* | *1.759* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.0958 | 0.1132 | 0.1094 | 0.1025 | 0.1918** | 0.1272* | 0.1024 | 0.1517* | 0.1347 |
| | *0.073* | *0.072* | *0.073* | *0.074* | *0.086* | *0.074* | *0.074* | *0.090* | *0.086* |
| $\beta_{(sliq,omliq)}$ | -0.0623 | -0.0283 | -0.0285 | -0.0183 | 0.0130 | -0.0141 | -0.0176 | -0.0208 | -0.0273 |
| | *0.054* | *0.066* | *0.069* | *0.070* | *0.069* | *0.071* | *0.070* | *0.071* | *0.071* |
| *Constant* | -1.113** | -1.313** | -1.418** | -1.618*** | -1.105* | -1.575*** | -1.581*** | -1.706** | -1.499** |
| | *0.433* | *0.554* | *0.566* | *0.581* | *0.564* | *0.557* | *0.527* | *0.699* | *0.705* |
| $N$ | 8,473 | 8,473 | 8,473 | 8,473 | 8,473 | 8,473 | 8,475 | 8,473 | 8,475 |
| $R^2$ | 0.363 | 0.307 | 0.289 | 0.253 | 0.226 | 0.231 | 0.240 | 0.189 | 0.173 |
| $N_{wk}$ | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 |

**Table C11 Fama-MacBeth (1973) Results for Deep-In-the-Money (DITM) Put Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for DITM puts. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.2051 | 0.2812 | 0.2579 | 0.2442 | 0.2650 | 0.3227* | 0.2793 | 0.6657** | 0.6763** |
| | *0.164* | *0.182* | *0.183* | *0.179* | *0.178* | *0.188* | *0.177* | *0.276* | *0.277* |
| $lnssprop$ | -0.1043 | -0.0655 | -0.0449 | -0.0017 | 0.0080 | 0.0418 | | 0.0085 | |
| | *0.080* | *0.084* | *0.083* | *0.085* | *0.082* | *0.086* | | *0.086* | |
| $\beta_{(dhg,rm)}$ | 0.5304 | | | | | | | | |
| | *0.406* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | -0.09*** | -0.13*** | -0.13*** | -0.118*** | -0.116*** | -0.123*** | -0.113*** | | |
| | *0.033* | *0.037* | *0.037* | *0.039* | *0.038* | *0.039* | *0.039* | | |
| $\beta_{(dhg,omliq)}$ | -0.0450* | -0.0198 | -0.0198 | | | | | | |
| | *0.024* | *0.024* | *0.024* | | | | | | |
| $\beta_{(oliq,rm)}$ | 8.466** | 8.634** | 8.162** | 7.8164** | | 4.4535 | 6.690* | 6.503* | 5.470 |
| | *3.868* | *3.956* | *3.903* | *3.899* | | *3.742* | *3.774* | *3.808* | *3.657* |
| $\beta_{(oliq,smliq)}$ | -0.4766 | -0.4985 | -0.5153* | -0.5502* | -0.4823 | -0.5128 | -0.5687* | -0.6321* | -0.6415* |
| | *0.301* | *0.305* | *0.308* | *0.318* | *0.317* | *0.317* | *0.318* | *0.326* | *0.327* |
| $\beta_{(oliq,omliq)}$ | -0.54*** | -0.66*** | -0.633*** | -0.63*** | -0.573*** | | -0.61*** | -0.875*** | -0.846*** |
| | *0.198* | *0.203* | *0.199* | *0.201* | *0.192* | | *0.202* | *0.222* | *0.225* |
| $\beta_{(sliq,rm)}$ | -0.4852 | -0.3758 | | | | | | | |
| | *2.980* | *2.926* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.1428 | 0.0841 | 0.0725 | 0.1083 | 0.1775 | 0.2447* | 0.1107 | -0.2179 | -0.2267 |
| | *0.126* | *0.152* | *0.147* | *0.154* | *0.146* | *0.147* | *0.156* | *0.212* | *0.211* |
| $\beta_{(sliq,omliq)}$ | -0.0268 | 0.0071 | -0.0022 | -0.0249 | -0.0142 | -0.0147 | -0.0366 | -0.0295 | -0.0372 |
| | *0.112* | *0.127* | *0.125* | *0.132* | *0.133* | *0.132* | *0.131* | *0.140* | *0.140* |
| $Constant$ | -0.6414 | -0.7738 | -0.6748 | -0.5306 | -0.5548 | -0.5495 | -0.6110 | -1.812** | -1.859** |
| | *0.474* | *0.521* | *0.528* | *0.524* | *0.514* | *0.536* | *0.444* | *0.798* | *0.779* |
| $N$ | 8,416 | 8,416 | 8,416 | 8,416 | 8,416 | 8,416 | 8,419 | 8,416 | 8,419 |
| $R^2$ | 0.357 | 0.294 | 0.280 | 0.245 | 0.234 | 0.230 | 0.231 | 0.174 | 0.159 |
| $N_{wk}$ | 133 | 133 | 133 | 133 | 133 | 133 | 133 | 133 | 133 |

**Table C12 Fama-MacBeth (1973) Results for In-the-Money (ITM) Put Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for ITM puts. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.366** | 0.401** | 0.408** | 0.462*** | 0.554*** | 0.572*** | 0.432** | 0.546** | 0.506* |
| | *0.158* | *0.174* | *0.173* | *0.171* | *0.169* | *0.168* | *0.170* | *0.259* | *0.264* |
| $lnssprop$ | -0.0801 | -0.0744 | -0.0700 | -0.0810 | -0.0503 | -0.0891 | | -0.0612 | |
| | *0.084* | *0.086* | *0.086* | *0.086* | *0.084* | *0.086* | | *0.088* | |
| $\beta_{(dhg,rm)}$ | 0.1992 | | | | | | | | |
| | *0.452* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | -0.0246 | -0.0339 | -0.0332 | -0.0456 | -0.0497 | -0.0543 | -0.0427 | | |
| | *0.034* | *0.039* | *0.040* | *0.039* | *0.039* | *0.038* | *0.039* | | |
| $\beta_{(dhg,omliq)}$ | 0.0102 | 0.0273 | 0.0278 | | | | | | |
| | *0.026* | *0.022* | *0.022* | | | | | | |
| $\beta_{(oliq,rm)}$ | 11.725*** | 11.731*** | 10.671** | 10.131** | | 8.5** | 9.857** | 12.59*** | 11.93*** |
| | *4.285* | *4.191* | *4.111* | *4.176* | | *4.101* | *4.085* | *4.423* | *4.427* |
| $\beta_{(oliq,smliq)}$ | -0.0833 | -0.0424 | -0.0355 | -0.0394 | -0.0848 | -0.0128 | 0.032 | 0.0037 | 0.0661 |
| | *0.237* | *0.242* | *0.238* | *0.240* | *0.237* | *0.242* | *0.236* | *0.245* | *0.241* |
| $\beta_{(oliq,omliq)}$ | -0.47*** | -0.47*** | -0.45*** | -0.41*** | -0.349** | | -0.409*** | -0.64*** | -0.62*** |
| | *0.172* | *0.157* | *0.153* | *0.152* | *0.148* | | *0.152* | *0.158* | *0.156* |
| $\beta_{(sliq,rm)}$ | -0.9942 | -1.1949 | | | | | | | |
| | *3.340* | *3.129* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.1462 | 0.2174 | 0.2051 | 0.2080 | 0.2239 | 0.2244 | 0.235* | 0.0931 | 0.1212 |
| | *0.143* | *0.147* | *0.143* | *0.144* | *0.139* | *0.146* | *0.142* | *0.175* | *0.172* |
| $\beta_{(sliq,omliq)}$ | -0.1174 | -0.1262 | -0.1427 | -0.1243 | -0.1389 | -0.1466 | -0.1286 | -0.1132 | -0.1175 |
| | *0.114* | *0.124* | *0.121* | *0.121* | *0.121* | *0.121* | *0.122* | *0.133* | *0.136* |
| $Constant$ | -1.38*** | -1.43*** | -1.43*** | -1.63*** | -1.62*** | -1.79*** | -1.38*** | -2.01** | -1.79** |
| | *0.498* | *0.534* | *0.538* | *0.532* | *0.521* | *0.516* | *0.465* | *0.811* | *0.810* |
| $N$ | 7,896 | 7,896 | 7,896 | 7,896 | 7,896 | 7,896 | 7,899 | 7,896 | 7,899 |
| $R^2$ | 0.375 | 0.323 | 0.309 | 0.270 | 0.256 | 0.255 | 0.253 | 0.182 | 0.164 |
| $N_{wk}$ | 132 | 132 | 132 | 132 | 132 | 132 | 132 | 132 | 132 |

**Table C13 Fama-MacBeth (1973) Results for At-the-Money (ATM) Put Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for ATM puts. First, at each week ‘$t$’, a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.487*** | 0.377** | 0.393** | 0.391** | 0.435** | 0.47*** | 0.394** | 0.424 | 0.429 |
| | *0.139* | *0.177* | *0.177* | *0.175* | *0.174* | *0.180* | *0.174* | *0.363* | *0.356* |
| $lnssprop$ | -0.0253 | -0.0137 | -0.0079 | -0.0307 | 0.0027 | -0.0060 | | 0.0007 | |
| | *0.069* | *0.072* | *0.070* | *0.070* | *0.071* | *0.070* | | *0.074* | |
| $\beta_{(dhg,rm)}$ | 0.0005 | | | | | | | | |
| | *0.473* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | -0.0207 | -0.0171 | -0.0173 | -0.0276 | -0.0256 | -0.0328 | -0.0252 | | |
| | *0.029* | *0.041* | *0.041* | *0.042* | *0.042* | *0.042* | *0.042* | | |
| $\beta_{(dhg,omliq)}$ | 0.0047 | 0.0149 | 0.0140 | | | | | | |
| | *0.028* | *0.027* | *0.027* | | | | | | |
| $\beta_{(oliq,rm)}$ | 10.749*** | 10.201*** | 9.833*** | 9.982*** | | 7.916** | 10.236*** | 6.984* | 6.900* |
| | *3.580* | *3.792* | *3.712* | *3.726* | | *3.604* | *3.753* | *3.931* | *3.967* |
| $\beta_{(oliq,smliq)}$ | 0.0551 | 0.1341 | 0.1374 | 0.1352 | 0.0695 | 0.1632 | 0.1317 | 0.3167 | 0.3385 |
| | *0.214* | *0.213* | *0.212* | *0.219* | *0.215* | *0.222* | *0.216* | *0.254* | *0.250* |
| $\beta_{(oliq,omliq)}$ | -0.433*** | -0.456*** | -0.448*** | -0.45*** | -0.42*** | | -0.458*** | -0.542*** | -0.535*** |
| | *0.117* | *0.122* | *0.121* | *0.125* | *0.121* | | *0.125* | *0.135* | *0.133* |
| $\beta_{(sliq,rm)}$ | 1.1245 | 0.8347 | | | | | | | |
| | *2.571* | *2.562* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.417*** | 0.515*** | 0.516*** | 0.506*** | 0.578*** | 0.54*** | 0.510*** | 0.555*** | 0.5538** |
| | *0.137* | *0.155* | *0.151* | *0.141* | *0.143* | *0.144* | *0.139* | *0.208* | *0.214* |
| $\beta_{(sliq,omliq)}$ | -0.1152 | -0.1051 | -0.1106 | -0.0998 | -0.1339 | -0.0973 | -0.0951 | -0.0838 | -0.0756 |
| | *0.110* | *0.132* | *0.132* | *0.133* | *0.132* | *0.132* | *0.132* | *0.135* | *0.135* |
| *Constant* | -1.766*** | -1.403** | -1.424** | -1.502** | -1.240** | -1.571** | -1.439** | -1.554 | -1.579 |
| | *0.477* | *0.612* | *0.613* | *0.599* | *0.562* | *0.605* | *0.561* | *1.192* | *1.156* |
| $N$ | 9,147 | 9,147 | 9,147 | 9,147 | 9,147 | 9,147 | 9,150 | 9,147 | 9,150 |
| $R^2$ | 0.372 | 0.316 | 0.302 | 0.264 | 0.252 | 0.250 | 0.250 | 0.197 | 0.182 |
| $N_{wk}$ | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 |

**Table C14 Fama-MacBeth (1973) Results for Out-the-Money (OTM) Put Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for OTM puts. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.582*** | 0.539*** | 0.531*** | 0.507*** | 0.480*** | 0.5*** | 0.507*** | 0.634** | 0.636* |
| | *0.116* | *0.146* | *0.149* | *0.154* | *0.153* | *0.155* | *0.154* | *0.319* | *0.323* |
| $lnssprop$ | -0.0180 | -0.0316 | -0.0164 | -0.0099 | 0.0036 | 0.0122 | | 0.0170 | |
| | *0.061* | *0.064* | *0.064* | *0.066* | *0.067* | *0.066* | | *0.071* | |
| $\beta_{(dhg,rm)}$ | 0.0136 | | | | | | | | |
| | *0.409* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | -0.0320 | -0.0359 | -0.0347 | -0.0455 | -0.0421 | -0.0438 | -0.0453 | | |
| | *0.030* | *0.037* | *0.037* | *0.038* | *0.038* | *0.038* | *0.038* | | |
| $\beta_{(dhg,omliq)}$ | 0.0168 | 0.0164 | 0.0179 | | | | | | |
| | *0.020* | *0.019* | *0.019* | | | | | | |
| $\beta_{(oliq,rm)}$ | 8.90*** | 8.131*** | 7.719*** | 8.282*** | | 8.04*** | 8.650*** | 5.626** | 5.544** |
| | *2.708* | *2.685* | *2.611* | *2.697* | | *2.723* | *2.723* | *2.674* | *2.679* |
| $\beta_{(oliq,smliq)}$ | 0.1389 | 0.1880 | 0.1827 | 0.2115 | 0.2388 | 0.1317 | 0.2342 | 0.2493 | 0.3009* |
| | *0.146* | *0.149* | *0.148* | *0.147* | *0.149* | *0.143* | *0.145* | *0.161* | *0.162* |
| $\beta_{(oliq,omliq)}$ | -0.263** | -0.31*** | -0.314*** | -0.299*** | -0.288*** | | -0.327*** | -0.335*** | -0.358*** |
| | *0.102* | *0.105* | *0.106* | *0.106* | *0.107* | | *0.104* | *0.110* | *0.108* |
| $\beta_{(sliq,rm)}$ | 0.4883 | 0.4176 | | | | | | | |
| | *2.045* | *2.116* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.378*** | 0.386*** | 0.3853*** | 0.364*** | 0.462*** | 0.35*** | 0.371*** | 0.3163 | 0.3316* |
| | *0.113* | *0.126* | *0.121* | *0.120* | *0.125* | *0.117* | *0.118* | *0.194* | *0.187* |
| $\beta_{(sliq,omliq)}$ | -0.0797 | -0.1045 | -0.1106 | -0.0966 | -0.1275 | -0.0917 | -0.0902 | -0.1172 | -0.1107 |
| | *0.087* | *0.101* | *0.101* | *0.099* | *0.097* | *0.099* | *0.100* | *0.100* | *0.101* |
| *Constant* | -2.18*** | -2.02*** | -1.957*** | -1.945*** | -1.49*** | -2.04*** | -1.934*** | -2.316** | -2.369** |
| | *0.450* | *0.538* | *0.548* | *0.586* | *0.554* | *0.593* | *0.563* | *1.096* | *1.126* |
| $N$ | 8,511 | 8,511 | 8,511 | 8,511 | 8,511 | 8,511 | 8,513 | 8,511 | 8,513 |
| $R^2$ | 0.388 | 0.326 | 0.314 | 0.272 | 0.262 | 0.255 | 0.257 | 0.207 | 0.190 |
| $N_{wk}$ | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 |

**Table C15 Fama-MacBeth (1973) Results for Deep-Out-the-Money (DOTM) Put Options**

This table reports the results obtained from the Fama-MacBeth (1973) regression analysis for DOTM puts. First, at each week '$t$', a cross-sectional regression is estimated as given in Equation 6.5. Second, the average coefficients across time and their significance (p-value) are reported. This table also reports the total number of observations in the sample ($N$), average R-square ($R^2$) and the total number of weekly regressions ($N_{wk}$). Specifications (1) to (9) are reported after careful selection of variables based on the correlations, the stability of coefficient sign, and the significance.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $lnosprop$ | 0.234** | 0.313** | 0.315*** | 0.294** | 0.233* | 0.297** | 0.321** | 0.278 | 0.306 |
| | *0.094* | *0.120* | *0.121* | *0.139* | *0.139* | *0.137* | *0.135* | *0.244* | *0.250* |
| $lnssprop$ | 0.0821** | 0.0739* | 0.0627 | 0.0641 | 0.0899** | 0.0690 | | 0.0444 | |
| | *0.040* | *0.041* | *0.040* | *0.042* | *0.042* | *0.042* | | *0.045* | |
| $\beta_{(dhg,rm)}$ | 0.4537 | | | | | | | | |
| | *0.395* | | | | | | | | |
| $\beta_{(dhg,smliq)}$ | 0.0357 | 0.0088 | 0.0074 | 0.0003 | 0.0002 | 0.0005 | -0.0033 | | |
| | *0.030* | *0.037* | *0.037* | *0.038* | *0.038* | *0.038* | *0.038* | | |
| $\beta_{(dhg,omliq)}$ | 0.0050 | 0.0195 | 0.0175 | | | | | | |
| | *0.022* | *0.023* | *0.023* | | | | | | |
| $\beta_{(oliq,rm)}$ | 6.529** | 6.663*** | 6.815*** | 5.115* | | 4.966* | 5.805** | 5.129* | 5.480** |
| | *2.524* | *2.501* | *2.539* | *2.666* | | *2.575* | *2.659* | *2.654* | *2.679* |
| $\beta_{(oliq,smliq)}$ | 0.264* | 0.291** | 0.282* | 0.402*** | 0.4576*** | 0.400*** | 0.337** | 0.373** | 0.321** |
| | *0.145* | *0.147* | *0.144* | *0.134* | *0.132* | *0.134* | *0.133* | *0.149* | *0.152* |
| $\beta_{(oliq,omliq)}$ | -0.0442 | -0.0249 | -0.0271 | -0.0246 | 0.0115 | | -0.0281 | -0.0149 | -0.0160 |
| | *0.078* | *0.081* | *0.080* | *0.083* | *0.079* | | *0.084* | *0.096* | *0.096* |
| $\beta_{(sliq,rm)}$ | -0.4695 | -0.9582 | | | | | | | |
| | *1.636* | *1.613* | | | | | | | |
| $\beta_{(sliq,smliq)}$ | 0.1930** | 0.1816* | 0.1546* | 0.1513 | 0.2265* | 0.1444 | 0.1696 | 0.1781 | 0.1830 |
| | *0.089* | *0.100* | *0.091* | *0.106* | *0.116* | *0.107* | *0.106* | *0.157* | *0.152* |
| $\beta_{(sliq,omliq)}$ | -0.0492 | -0.0371 | -0.0351 | -0.0246 | -0.0438 | -0.0260 | -0.0128 | -0.0250 | -0.0130 |
| | *0.067* | *0.070* | *0.071* | *0.075* | *0.076* | *0.074* | *0.074* | *0.075* | *0.075* |
| $Constant$ | -1.086*** | -1.398*** | -1.439*** | -1.338** | -0.851 | -1.331** | -1.589*** | -1.344 | -1.558 |
| | *0.389* | *0.476* | *0.477* | *0.552* | *0.576* | *0.547* | *0.511* | *0.966* | *1.008* |
| $N$ | 8,787 | 8,787 | 8,787 | 8,787 | 8,787 | 8,787 | 8,790 | 8,787 | 8,790 |
| $R^2$ | 0.387 | 0.338 | 0.325 | 0.276 | 0.254 | 0.259 | 0.261 | 0.219 | 0.202 |
| $N_{wk}$ | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 |