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Does the Liquidity of Underlying Stocks Affect the Liquidity of Derivatives? Evidence from a Natural Experiment [*]

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Abstract
This paper documents a significant positive impact of the liquidity of underlying stocks on the liquidity of derivative securities on the basis of a sample of options and derivative warrants traded in Hong Kong. The study relies on an exogenous change in the liquidity of underlying stocks, namely, the tick size reduction implemented by the Hong Kong Stock Exchange (HKEx), which significantly reduces the bid-ask spreads of underlying stocks. The bid-ask spreads of derivative securities are also significantly reduced, especially those less liquid and with a greater inventory risk. The results of the paper are consistent with the derivative hedging theory of Cho and Engle (1999) and shed light on the sources of the liquidity of derivative securities.

Keywords: Liquidity, Options, Derivative Warrants, Hedging, Inventory Risk

标的资产的流动性影响衍生证券的流动性吗？基于自然试验的证据

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摘要
本文用香港期权和衍生认股权证的样本，阐明了标的股票的流动性对衍生证券的流动性有着显著正向的影响。该研究依赖于标的股票流动性的外生变化，即香港联交所实施的报价单位的减少。这项措施显著降低了标的股票的买卖价差。衍生证券的买卖价差也显著减少，特别是流动性差的及库存风险大的衍生证券。本文的结果与 Cho and Engle（1999）的衍生证券对冲理论一致，并揭示了衍生证券流动性的来源。

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I. Introduction

Studies on the liquidity of equity options are relatively sparse compared with the voluminous studies on the liquidity of underlying securities. Some early empirical studies document the stylised facts of the liquidity of derivative markets. Vijh (1990) finds that options traded on the Chicago Board Options Exchange have excellent market depth but large bid-ask spreads. George and Longstaff (1993) investigate the bid-ask spreads of the S&P 100 index options across exercise prices and maturities and find that market making cost can explain the cross-sectional variations of bid-ask spreads to a large extent. Mayhew *et al.* (1999) examine the relation between the characteristics of underlying stocks and the order flow in options and find that options are more liquid for stocks with higher prices, greater volatilities, higher trading volumes, and smaller sizes. On the basis of German data, Kalodera and Schlag (2004) find that the liquidity of options is positively related to the underlying stock's trading volume. In more recent studies, Cao and Wei (2010) document the covariation of liquidity measures among stock options and Wei and Zheng (2010) find that the option return volatility has a high explanatory power for the bid-ask spreads of stock options and that increased trading activities on options lead to smaller bid-ask spreads.

The main thrust of my investigation pertains to a distinctive determinant of the liquidity of derivatives: the hedging costs. It is well known that option traders use the underlying stocks extensively to hedge the risks in their option positions. In a frictionless market where traders can trade the underlying stocks continuously without transaction costs, options can be replicated by continuously rebalancing the position in the underlying stocks, as in Black and Scholes (1973). In this case, the market makers of options eliminate their inventory risks completely by hedging from the underlying stock market. However, when there are transaction costs in the underlying stock market and trading only takes place at discrete time intervals, the perfect replication no longer exists. Leland (1985) and Boyle and Vorst (1992) theoretically show that the bid-ask spread of the underlying stock and discrete trading lead to the differences in the costs of replicating a long option and a short option. Consider replicating a long call option. When the stock price increases, since the sensitivity of the option price to the stock price (i.e. delta) increases, replication would require the investor to purchase more shares of the stock at the ask price. When the stock price falls, the stock has to be sold at the bid price to maintain a delta neutral position. In this case, the cost of replicating a long call option will be higher than in a frictionless market. Similarly, the revenue from replicating a short call option will be lower than in a frictionless market. This implies that the option bid-ask spread is positively related to the spread of the underlying stock. Cho and Engle (1999) propose a derivative hedge theory and suggest that option market proportional spreads are inversely related to the option market maker's ability to hedge his/her positions in the underlying market, as measured by the liquidity of the latter market. Using S&P 100 index options, they find that the option bid-ask spread is positively related to the proportional spread of the underlying security. Jameson and Wilhelm (1992) empirically show that the inability to rebalance continuously explains the variations of bid-ask spreads quoted across options with different maturities and strike prices. Kaul *et al.* (2004), Petrella (2006), Engle and Neri (2010), and Wu *et al.* (2014) decompose the hedging costs into two components, the initial hedging costs and the rebalancing costs, and examine the role of each component in explaining the bid-ask spread of options. Wu *et al.* (2014) decompose the rebalancing costs further into those due to inventory changes and those due to delta changes and find that the former is far more important than the latter in determining the option spreads.

I contribute to this literature by utilising a unique setting in Hong Kong. I identify an exogenous change in the liquidity of underlying assets and examine how the liquidity of the derivative securities of these underlying assets is affected. Exogenous changes arise from the implementation of the tick size reduction by the Hong Kong Stock Exchange (HKEx) in 2005 and 2006, which affects underlying stocks only. This implementation reduces the quoted and effective bid-ask spreads of underlying stocks significantly. There are two types of option market in Hong Kong, the usual option market and the derivative warrant market. Call and put derivative warrants are similar to call and put options, but they are issued by financial institutions approved by regulators. The derivative warrant market has been very active in recent years. However, the option market in Hong Kong is not as liquid. There is a significant reduction in the bid-ask spreads of options after the tick size reduction; however, there is little change in the bid-ask spreads of derivative warrants.

The results suggest that the impact of the change in the liquidity of underlying assets on that of derivatives depends on the market makers' propensity to hedge in the underlying stock market. The derivative warrant market is more liquid, and market makers can manage their inventory risk by buying and selling warrants at low costs. The option market is relatively illiquid, and it is more costly for market makers to maintain an optimal level of inventory by trading in the option market. Market makers of options rely more on the underlying stocks to hedge against their inventory risk. As a result, the effect of the liquidity spillover from the underlying market to the option market is much stronger. I find that the reduction in the quoted spread of an option or derivative warrant with a higher vega, a lower trading volume, and a less stable level of inventory held by market makers is more sensitive to the tick size reduction of the underlying stock. A higher vega requires more shares of the underlying asset to be traded to hedge against the option or warrant position in the optimal hedging strategy, as shown by Leland (1985). A lower trading volume and a more unstable level of inventory holding imply that it is more difficult for the market makers of derivatives to find counterparts to trade with and to maintain an optimal level of inventory. I also find that the effect of the tick size reduction on the bid-ask spreads of derivative warrants is also stronger when the number of different derivative warrant contracts issued by the same issuer and on the same underlying stock is smaller. A small number of different derivative warrant contracts issued by the same issuer and on the same underlying stock indicates that the availability of other derivative warrant contracts as hedging instruments is low and that the propensity to hedge in the underlying market is high. The results are generally consistent with the derivative hedge theory and suggest that the degree of the liquidity spillover from the underlying market to the derivative markets is related to the propensity to hedge in the underlying market.

The approach in this paper has several advantages over existing studies in the literature. First, the use of the exogenous change in the liquidity of underlying securities clearly identifies the causal effects. The setting in this study rules out the possibility of the reverse causality that the changes in the liquidity of the underlying stock market are caused by the changes in the liquidity of the derivative markets.[2] Second, I compare the changes in the liquidity variables of two samples of derivative securities, one affected by the change in the liquidity of underlying stocks and one not. This difference-in-differences approach offers a cleaner test of the effects of the liquidity of underlying stocks while controlling for other confounding factors that affect the liquidity of derivatives and underlying stocks simultaneously. Third, I examine changes in the bid-ask spreads in a short window, 5 days before and after the implementation of the tick size reduction. Since the liquidity of derivatives is likely related to their characteristics, such as moneyness and maturity, a short window keeps these characteristics approximately unchanged and I can focus on the effects of hedging costs in this study.

The rest of the paper is organised as follows. In Section II, I provide background information on the stock, option, and derivative warrant markets in Hong Kong and discuss the implementation of the tick size reduction of the underlying stocks. In Section III, I describe the sample used in the study and report the summary statistics of the liquidity variables of the three markets. In Section IV, I present the results on the effects of the change in the tick size of the underlying stocks on liquidity variables of the underlying stocks, options and derivative warrants. Section V concludes the paper.

II. Institutional Background

2.1 The Stock, Option, and Derivative Warrant Markets in Hong Kong

The trading of stocks, options, and derivative warrants is conducted on the HKEx, which is divided into the Securities Market and the Derivatives Market. Stocks and derivative warrants are traded on the Securities Market, and options are traded on the Derivatives Market.

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2 There is a literature on the effects of the introduction of derivative securities on the volatility, price level, and trading volume of the underlying stocks: for example, Conrad (1989), Chan and Wei (2001), and Draper *et al.* (2001).

The Hang Seng Index options started trading in Hong Kong in March 1993, and the trading of stock options started in September 1995. The index options are European style options and settled by cash, whereas the stock options are American style options with physical delivery of the underlying assets upon exercise. The contract specifications of the options are set by the exchange. A system of market makers has been implemented. For each underlying stock, the HKEx appoints a few market makers. The market makers are required to provide liquidity to the trading system. However, the requirements are not stringent. For stock options, market makers are required to select at least 12 (before July 2006) or 18 (since July 2006) series to provide continuous quotes, while for all other options, they only need to respond to requests for quotes.

There are two types of warrants in Hong Kong: equity warrants and derivative warrants. Equity warrants, issued by the underlying company itself, entitle holders to purchase equity securities from the underlying company at a predetermined price. Call and put derivative warrants are similar to call and put options, but they are issued by financial institutions approved by regulators. In Hong Kong, the trading of equity warrants started in 1977, whereas the trading of derivative warrants started in 1989. In recent years, the vast majority of the warrants traded in Hong Kong have been derivative warrants. By the end of 2007, the derivative warrant market in Hong Kong had become the largest in the world in terms of trading volume.[3] The underlying assets of derivative warrants are blue-chip stocks, stock indexes, baskets of stocks, and some commodities. All the derivative warrants are European style warrants. The issuers of derivative warrants are typically large- or medium-sized financial institutions. Several major European and Australian banks, such as Société Générale, KBC, Deutsche Bank, BNP Paribas, and Macquarie Bank, are among the most active issuers. Each underlying asset may have multiple issuers who compete with each other to offer more popular contract specifications, lower prices, and better liquidity. The HKEx requires that each issuer of derivative warrants appoints one liquidity provider (i.e. market maker) to provide liquidity by inputting bid and ask prices in the trading system, either continuously or on request. Since I examine derivative warrants only in this study, hereinafter, derivative warrants are referred to as warrants without causing any confusion.

2.2 The Tick Size Reduction

The reduction of the tick size (i.e. the minimum bid-ask spread) of the securities in the Securities Market was implemented in two phases. Starting from 4 July 2005, the tick sizes of securities with a price no less than 30 Hong Kong dollars (HKD) were reduced by 50 to 80 per cent. From 24 July 2006, the tick sizes of securities with a price range from 2 HKD to 20 HKD were reduced by 60 to 80 per cent. The details of the tick size reductions for various price levels are shown in Table 1. Since all the underlying stocks in my sample are

[3] Derivative warrants are traded in Germany, Switzerland, Italy, U.K., Australia, Hong Kong, Singapore, and Korea, among others.

traded above 2 HKD per share, whereas the majority of warrants are traded below 2 HKD per share, the implementation of the tick size reduction mainly affects the underlying stocks. The options are traded in the Derivatives Market, to which the tick size reduction is not applied. Therefore, the event is exogenous to options and warrants and provides an ideal setting to examine the effect of the liquidity of underlying stocks on that of derivative securities.

Table 1 Minimum Tick Sizes

This table reports the minimum tick sizes before and after the implementation of the tick size reduction in two phases in 2005 and 2006. The first column shows the levels of stock prices that the minimum tick sizes are applied to, and the next three columns show the tick sizes before and after the implementation of the tick size reduction. The unit is HKD.

Price Range	Before 20050704	From 20050704 to 20060723	On and after 20060724
[0.01,0.25)	0.001	0.001	0.001
[0.25,0.50)	0.005	0.005	0.005
[0.50,2.00)	0.010	0.010	0.010
[2.00,5.00)	0.025	0.025	0.010
[5.00,10.00)	0.050	0.050	0.010
[10.00,20.00)	0.050	0.050	0.020
[20.00,30.00)	0.050	0.050	0.050
[30.00,50.00)	0.100	0.050	0.050
[50.00,100.00)	0.250	0.050	0.050
[100.00,200.00)	0.500	0.100	0.100
[200.00,500.00)	1.000	0.200	0.200
[500.00,1000.00)	1.000	0.500	0.500

III. Data

3.1 Data Description

I select 5 days before and after each phase of the implementation of the tick size reduction to examine the changes in the liquidity variables. The sample periods are 24 June 2005 to 8 July 2005 and 17 July 2006 to 28 July 2006. Since the liquidity of derivatives is likely related to their characteristics, such as moneyness and maturity, a relatively short window keeps these characteristics approximately unchanged. I select a sample of options and warrants written on individual stocks because the tick size reduction is applied to individual stocks only. The option and warrant samples are on the same underlying stocks so that the results from these two samples can be compared. The underlying stocks of options and warrants are all actively traded blue-chip stocks. The number of underlying stocks with warrants traded on them is slightly higher than the number of underlying stocks with options traded on them. About 10% of the warrants are excluded because they do not have matched options with the same underlying stocks. To eliminate the direct impact of the implementation of the tick size reduction, I also exclude 1.4% of the warrants whose prices ever reach 2 HKD or above during the sample period. I require the stocks, options, and warrants in my sample to have non-zero trading volume during the 5-day periods before and after the tick size reduction. I exclude options and warrants with a maturity of less than 7 days for liquidity reasons. After applying these sample selection criteria, I am left with 69 underlying stocks, 885 options, and 1,082 warrants observations. For both the warrants and options, the data include the intraday bid and ask quotes, the transaction prices and volumes, and the daily dollar volumes and numbers of trades. I also have the daily open interests of options and the daily average prices and share volumes of warrants traded by the liquidity providers. All the data are from the HKEx.

3.2 Liquidity Variables

I now examine the liquidity of underlying stocks before and after the tick size reduction. I identify the quoted bid and ask pair for a given time, and the bid and ask pair is updated when either the bid or ask is changed. The former bid and ask pair is defined as the prevailing bid and ask for the time interval between the updates. I calculate the daily quoted spread as the average proportional spread weighted by the time interval for which the prevailing bid and ask quotes apply. Let $QS_{i,j}^{u}$ be the 5-day average of the daily proportional spread of underlying stock *j* in period *i*, where *i* = 1 indicates the period before the tick size reduction and *i* = 2 indicates the post-reduction period. The average quoted spread across N^u underlying stocks, $QS_i^u = \sum_j^{N^u} QS_{i,j}^u / N^u$ for *i* = 1, 2, is shown in Table 2. The same stock appearing in 2005 and 2006 is treated as two separate observations. The spreads of these stocks are low because stocks with options and warrants traded on them are typically large and liquid stocks. The average quoted spread across the 69 stocks is only 0.437% before the implementation of the tick size reduction, and the standard deviation is 0.268%. The quoted spread is lowered significantly by about 1/3 after the tick size reduction. This suggests that spreads are binding before the tick size reduction.

Table 2 Summary Statistics of Liquidity Variables of Underlying Stocks

This table reports the mean, standard deviation, and 25th, 50th, and 75th percentiles of the liquidity variables of underlying stocks 5 days before and after the tick size reduction. QS^u is the average proportional quoted bid-ask spread as a percentage, weighted by the length of time that the spread applies. ES^u is the average proportional effective bid-ask spread as a percentage. The effective spread is defined as $2|p_t - q_t| \times 100/q_t$, where p_t is the transaction price at time *t* and q_t is the average prevailing bid and ask quotes at *t*. DV^u is the log of total dollar volume. NT^u is the log of total number of trades. *N*, the number of observations, is 69.

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^u	0.437	0.268	0.246	0.368	0.592	0.296	0.246	0.122	0.211	0.348
ES^u	0.427	0.270	0.233	0.341	0.588	0.286	0.245	0.118	0.193	0.341
DV^u	20.446	1.171	19.676	20.368	21.164	20.541	1.044	19.773	20.355	21.396
NT^u	8.114	0.762	7.521	8.090	8.615	8.249	0.737	7.667	8.112	8.630

Trades may not occur at the quoted bid or ask prices but inside the quoted spreads. In this case, the quoted spreads overestimate the actual transaction costs arising from the spreads. I therefore also calculate the effective spreads. Let p_t be the transaction price at time t and q_t be the midpoint of the prevailing bid and ask quotes applied at time t. The proportional effective spread at t is defined as $2|p_t - q_t| \times 100/q_t$. I take the equally weighted average across all the trades for a given day as the daily effective spread. $ES^u_{i,j}$ denotes the 5-day average of the proportional effective spread for stock j and period i for $i = 1, 2$. The average effective spread across N^u stocks is smaller than, but very close to, that of the quoted spread, suggesting that most of the trades occur at the best bid or ask prices. The effective spread is also reduced significantly after the tick size reduction.

Let $DV^u_{i,j}$ and $NT^u_{i,j}$ be the log of total dollar volume and the log of total number of trades for underlying stock j and period i for $i = 1, 2$, respectively. The results show that the dollar volume and the number of trades increase marginally after the tick size reduction.

The summary statistics for the liquidity variables of options are shown in Table 3. These variables are defined in the same way as for underlying stocks. The results for the sample of all options are reported in Panel A. The quoted spread is close to 20% on average, indicating that the transaction costs in the option market are quite high. The effective spread is much lower than the quoted spread, implying that many trades occur inside the best bid and ask quotes. The total dollar volume and number of trades are significantly lower than those of underlying stocks. They all indicate that the option market is much less liquid than the underlying stock market. The results also show that there are no obvious differences in the liquidity variables before and after the tick size reduction. Note that I include the options of underlying stocks both affected and unaffected by the tick size changes. I compare the changes in the liquidity variables of options of the two groups separately in the next section. Options with a maturity less than or equal to 90 days are classified as short maturity, and the rest are classified as long maturity. The summary statistics for these two subsamples are reported in Panel B and Panel C, respectively. The short maturity options have lower total dollar volume and higher quoted and effective spreads and number of trades than the long maturity options. Interestingly, the liquidity of the long maturity options is improved after the tick size reduction, as indicated by all the liquidity variables, whereas the liquidity of the short maturity options is reduced, as indicated by most of the liquidity variables.

Table 3 Summary Statistics of Liquidity Variables of Options

This table reports the mean, standard deviation, and 25th, 50th, and 75th percentiles of the liquidity variables of options 5 days before and after the tick size reduction. QS^o is the average proportional quoted bid-ask spread as a percentage, weighted by the length of time that the spread applies. ES^o is the average proportional effective bid-ask spread. The effective spread is defined as $2|p_t - q_t| \times 100/q_t$, where p_t is the transaction price at t and q_t is the average prevailing bid and ask quotes at t. DV^o is the log of total dollar volume. NT^o is the log of total number of trades. N is the number of observations. Panel A reports the results for the sample of all options, and Panel B and Panel C report the results for short maturity options and long maturity options, respectively.

A. All Options (N = 885)

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^o	19.321	21.984	5.245	12.477	24.143	19.286	23.562	4.813	10.191	22.762
ES^o	8.305	12.727	1.693	4.255	9.706	9.255	14.343	1.999	4.528	10.526
DV^o	11.357	2.020	9.980	11.524	12.954	11.518	2.092	10.086	11.804	13.155
NT^o	1.710	0.868	1.099	1.609	2.303	1.935	0.949	1.099	1.792	2.565

B. Short Maturity Options (N = 450)

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^o	20.422	22.943	5.617	12.097	25.541	22.616	26.205	5.171	11.798	31.300
ES^o	8.669	12.377	2.242	4.830	10.112	11.126	16.391	2.260	5.575	13.410
DV^o	11.334	2.056	9.893	11.461	13.031	11.315	2.208	9.645	11.571	13.122
NT^o	1.859	0.958	1.099	1.792	2.565	2.048	1.011	1.099	1.946	2.833

C. Long Maturity Options (N = 435)

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^o	18.182	20.912	4.683	12.739	21.526	15.841	19.923	4.539	8.911	18.563
ES^o	7.929	13.083	1.340	3.978	8.889	7.319	11.561	1.682	3.767	8.536
DV^o	11.381	1.985	10.048	11.590	12.798	11.728	1.944	10.575	11.983	13.206
NT^o	1.557	0.735	1.099	1.386	2.079	1.819	0.867	1.099	1.792	2.485

The summary statistics for the liquidity variables of warrants are shown in Table 4. The liquidity variables are defined in the same way as for the underlying stocks and options. The results for the sample of all warrants are reported in Panel A. The bid-ask spreads of the warrants are much lower than those of the options. The average quoted spread is less than 5%, and the average effective spread is about 1% lower than the average quoted spread. The total dollar volume and number of trades are all greater than those of options, suggesting that the warrant market is more liquid. A new variable, the trading by liquidity providers, which measures how actively the liquidity providers provide liquidity to the warrant market, is included. The trading by liquidity providers $LT_{i,j}^{w}$ is defined as the ratio of dollar volume traded by the liquidity provider for warrant j in period i to the total dollar volume for warrant j in period i. The average trading by liquidity providers is greater than 80%, suggesting that liquidity providers are actively engaged in providing liquidity and that most of the trades involve liquidity providers. Interestingly, the warrant market becomes slightly less liquid after the tick size reduction, as evidenced by increases in the quoted and effective spreads, and decreases in total dollar volume and number of trades. The trading by the liquidity providers increases slightly. The summary statistics for short maturity and long maturity warrants are reported in Panel B and Panel C, respectively. The results show that long maturity warrants are more liquid than short maturity warrants, as indicated by all the liquidity variables except for the number of trades. The liquidity providers are also more active in providing liquidity to long maturity warrants than to short maturity warrants.

Table 4 Summary Statistics of Liquidity Variables of Derivative Warrants

This table reports the mean, standard deviation, and 25th, 50th, and 75th percentiles of the liquidity variables of derivative warrants 5 days before and after the tick size reduction. QS^w is the average proportional quoted bid-ask spread as a percentage, weighted by the length of time that the spread applies. ES^w is the average proportional effective bid-ask spread. The effective spread is defined as $2|p_t - q_t| \times 100/q_t$, where p_t is the transaction price at t and q_t is the average prevailing bid and ask quotes at t. NT^w is the log of total number of trades. LT^w is the ratio of the dollar volume traded by liquidity providers to the total dollar volume. N is the number of observations. Panel A reports the results for the sample of all warrants, and Panel B and Panel C report the results for short maturity warrants and long maturity warrants, respectively.

A. All Warrants (N = 1082)

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^w	4.779	7.483	1.495	2.227	4.759	4.818	8.579	1.452	2.049	4.788
ES^w	3.632	5.243	1.356	1.857	3.620	3.899	7.680	1.294	1.794	3.384
DV^w	14.461	2.614	12.615	14.579	16.503	14.225	2.633	12.352	14.310	16.203
NT^w	3.953	2.012	2.398	3.839	5.403	3.848	2.029	2.197	3.676	5.338
LT^w	0.820	0.271	0.746	0.962	1.000	0.828	0.268	0.776	0.973	1.000

B. Short Maturity Warrants (N = 276)

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^w	9.328	12.122	2.214	4.811	10.451	9.616	14.315	2.106	4.837	10.111
ES^w	6.680	8.279	1.927	3.598	7.302	7.825	13.141	1.780	3.349	8.205
DV^w	14.052	2.662	12.089	14.035	15.890	13.693	2.758	11.643	13.913	15.545
NT^w	4.203	2.126	2.485	3.989	5.613	4.020	2.137	2.250	3.951	5.418
LT^w	0.683	0.336	0.442	0.821	0.993	0.695	0.343	0.444	0.873	0.999

C. Long Maturity Warrants (N = 806)

	Before					After				
	mean	std	p25	p50	p75	mean	std	p25	p50	p75
QS^w	3.222	3.934	1.407	1.902	3.429	3.174	4.268	1.343	1.828	3.159
ES^w	2.589	3.036	1.276	1.690	2.653	2.555	3.623	1.198	1.638	2.488
DV^w	14.602	2.584	12.779	14.788	16.661	14.407	2.565	12.556	14.400	16.400
NT^w	3.868	1.965	2.303	3.784	5.347	3.789	1.988	2.197	3.611	5.323
LT^w	0.867	0.227	0.844	0.981	1.000	0.873	0.220	0.856	0.985	1.000

IV. Empirical Results

4.1 Effects of the Tick Size Reduction on the Liquidity of Underlying Stocks

I now examine the effects of the tick size reduction on the liquidity of underlying stocks by comparing the two subsamples, one affected by the reduction and one not. I calculate the change in the proportional quoted spreads after the implementation of the tick size reduction for the underlying stock *j* as $\Delta QS_j^u = QS_{2,j}^u - QS_{1,j}^u$. The averages across the underlying stocks and the t-statistics are shown in Table 5. I also report the proportions of increases and decreases in the quoted spreads among the sample of underlying stocks. The impact of the tick size reduction on the quoted spreads of the underlying stocks is economically significant: on average, the spreads are reduced by more than three quarters of the original spreads in the sample affected by the tick size reduction. In the unaffected sample, the reduction of the quoted spreads is also statistically significant; however, the magnitude is only 2% of the original spreads. The small decrease in the unaffected sample is due to other factors unrelated to the tick size reduction. To test the effects of the tick size reduction while controlling for other factors, I test the difference in the average ΔQS_j^u between the affected and unaffected samples. The result indicates a significant effect of the tick size reduction. The changes in the effective spread, ΔES_j^u; the total dollar volume, ΔDV_j^u; and the number of trades, ΔNT_j^u, for the underlying stock *j* are defined in the same way as for ΔQS_j^u. The effective spread is also significantly lowered after the tick size reduction. However, the effects of the tick size reduction on the total dollar volume and the number of trades are insignificant.

Table 5 Changes in Liquidity Variables of Underlying Stocks

This table reports the changes in the liquidity variables of underlying stocks after the tick size reduction. ΔQS^u is the change in the average proportional quoted bid-ask spread as a percentage. ΔES^u is the change in the average proportional effective bid-ask spread. ΔDV^u is the change in the log of total dollar volume. ΔNT^u is the change in the log of total number of trades. *N* is the number of observations. The average changes, associated t-statistics, and proportions of increases (up) and decreases (dw) for affected and unaffected underlying stocks are reported. The last two columns report the differences in the average changes between the affected and unaffected samples and the associated t-statistics.

	Affected ($N=28$)				Unaffected ($N=41$)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^u	-0.335	(-10.96)	0.000	1.000	-0.010	(-3.24)	0.293	0.707	-0.325	(-4.25)
ΔES^u	-0.337	(-10.94)	0.000	1.000	-0.008	(-2.97)	0.341	0.659	-0.329	(-4.28)
ΔDV^u	0.011	(0.15)	0.357	0.643	0.153	(2.38)	0.659	0.341	-0.142	(-0.38)
ΔNT^u	0.145	(2.32)	0.679	0.321	0.127	(2.58)	0.683	0.317	0.018	(0.07)

4.2 Effects of the Liquidity of Underlying Stocks on the Liquidity of Derivatives

In this subsection, I examine whether the changes in the spreads of underlying stocks affect the liquidity of derivative securities. First, I examine the changes in the liquidity variables of options after the tick size change. Let $\Delta QS_j^o = QS_{2,j}^o - QS_{1,j}^o$ be the change in the proportional quoted bid-ask spread for option j after the implementation of the tick size reduction. The change in the effective spread, ΔES_j^o; the total dollar volume, ΔDV_j^o; and the number of trades, ΔNT_j^o, are defined similarly. The averages for these variables across options are shown in Table 6. The quoted spread is reduced significantly for the affected sample (i.e. the sample of options on the underlying stocks affected by the tick size reduction), whereas it is increased significantly for the unaffected sample. The difference-in-differences test suggests that controlling for other factors, the quoted spreads of options are significantly positively affected by the spreads of underlying stocks. Since the best quotes are very likely from the market makers of options, the reduction of the quoted spreads implies a lower compensation required from option market makers. When the bid-ask spreads of underlying stocks are lower, it is less costly for the market makers to hedge their derivative inventory using the underlying stocks, allowing them to quote narrower bid-ask spreads for options to compensate for their hedging costs. The reduction of quoted spreads is consistent with the derivative hedging theory. The effective spread is also reduced, but only marginally significantly, for the affected sample, whereas it is significantly increased for the unaffected sample. The difference-in-differences test indicates that the effective spread is significantly reduced by the tick size reduction. The results suggest that the reduction in the spreads of underlying stocks benefits the option traders because their transaction costs become lower. In addition, the increases in the total dollar volume and number of trades of the affected sample are significantly higher than those of the unaffected sample. The reduction of the spreads of options induces investors to trade options more frequently because of lower trading costs. The results from Panel B and Panel C indicate that the effects of the improved liquidity of underlying stocks on the long maturity options are stronger than those on the short maturity options.

The changes in the liquidity variables of warrants after the tick size reduction are reported in Table 7. The results for warrants are in sharp contrast to those for options. There is a decrease in the quoted spread for warrants of the affected underlying stocks; however, the decrease is statistically insignificant. There is also no significant difference between the warrants of the affected and unaffected underlying stocks. Similar results are found for the effective spread. Since the warrant market is more liquid than the option market, it is less costly for market makers of warrants to maintain an optimal level of inventory by trading in the warrant market, and they rely less on the underlying stock market to hedge their derivative positions. As a result, the effect of the liquidity spillover from the underlying

Table 6 Changes in Liquidity Variables of Options

This table reports the changes in the liquidity variables of options after the tick size reduction. ΔQS^o is the change in the average proportional quoted bid-ask spread as a percentage. ΔES^o is the change in the average proportional effective bid-ask spread. ΔDV^o is the change in the log of total dollar volume. ΔNT^o is the change in the log of total number of trades. *N* is the number of observations. The average changes, associated t-statistics, and proportions of increases (up) and decreases (dw) for affected and unaffected underlying stocks are reported. The last two columns report the differences in the average changes between the affected and unaffected samples and the associated t-statistics. Panel A reports the results for the sample of all options, and Panel B and Panel C report the results for short maturity options and long maturity options, respectively.

A. All Options

	Affected (N=329)				Unaffected (N=556)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^o	-4.901	(-5.71)	0.271	0.729	2.845	(5.41)	0.599	0.401	-7.746	(-3.41)
ΔES^o	-1.200	(-1.78)	0.371	0.626	2.222	(4.13)	0.606	0.387	-3.422	(-2.69)
ΔDV^o	0.448	(4.48)	0.596	0.404	-0.009	(-0.14)	0.491	0.507	0.458	(2.31)
ΔNT^o	0.400	(7.83)	0.620	0.264	0.122	(3.45)	0.480	0.369	0.278	(3.07)

B. Short Maturity Options

	Affected (N = 160)				Unaffected (N = 290)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^o	-1.712	(-1.21)	0.406	0.594	4.350	(4.92)	0.610	0.390	-6.062	(-1.70)
ΔES^o	1.523	(1.60)	0.463	0.538	2.972	(3.16)	0.614	0.376	-1.449	(-0.77)
ΔDV^o	-0.080	(-0.59)	0.488	0.513	0.014	(0.14)	0.528	0.472	-0.094	(-0.33)
ΔNT^o	0.152	(2.10)	0.538	0.338	0.210	(4.13)	0.541	0.328	-0.058	(-0.42)

C. Long Maturity Options

	Affected (N = 169)				Unaffected (N = 266)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^o	-7.920	(-8.44)	0.142	0.858	1.203	(2.36)	0.586	0.414	-9.123	(-3.29)
ΔES^o	-3.778	(-4.13)	0.284	0.710	1.404	(3.06)	0.598	0.398	-5.182	(-3.10)
ΔDV^o	0.948	(7.01)	0.698	0.302	-0.035	(-0.38)	0.451	0.545	0.983	(3.68)
ΔNT^o	0.634	(9.44)	0.698	0.195	0.026	(0.54)	0.414	0.414	0.608	(5.40)

stock market to the warrant market is much weaker. In addition, the total dollar volume and number of trades are significantly lowered for the affected sample, whereas these variables increase significantly for the unaffected sample, and the increases are mainly from the long maturity warrants shown in Panel B and Panel C. This may be due to the substitution effect that some warrant investors shift to the option market because the transaction cost in the option market is lower than before. The results also show that after the tick size reduction, warrant market makers provide liquidity more actively than before for the affected sample, whereas for the unaffected sample, the level of liquidity provision is unchanged. This suggests that the reduction of hedging costs encourages market makers to provide liquidity: however, the magnitude is small.

Table 7 Changes in Liquidity Variables of Derivative Warrants

This table reports the changes in the liquidity variables of derivative warrants after the tick size reduction. ΔQS^w is the change in the average proportional quoted bid-ask spread as a percentage. ΔES^w is the change in the average proportional effective bid-ask spread. ΔDV^w is the change in the log of total dollar volume. ΔNT^w is the change in the log of total number of trades. ΔLT^w is the change in the ratio of the dollar volume traded by liquidity providers to the total dollar volume. *N* is the number of observations. The average changes, associated t-statistics, and proportions of increases (up) and decreases (dw) for affected and unaffected underlying stocks are reported. The last two columns report the differences in the average changes between the affected and unaffected samples and the associated t-statistics. Panel A reports the results for the sample of all warrants, and Panel B and Panel C report the results for short maturity warrants and long maturity warrants, respectively.

A. All Warrants

	Affected ($N = 602$)				Unaffected ($N = 480$)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^w	-0.172	(-0.66)	0.455	0.545	0.302	(1.30)	0.481	0.519	-0.474	(-0.69)
ΔES^w	0.276	(1.21)	0.457	0.543	0.256	(0.93)	0.485	0.515	0.020	(0.04)
ΔDV^w	-0.530	(-7.18)	0.349	0.651	0.132	(1.93)	0.544	0.456	-0.663	(-2.93)
ΔNT^w	-0.294	(-6.54)	0.367	0.596	0.131	(2.73)	0.556	0.421	-0.426	(-2.44)
ΔLT^w	0.024	(3.14)	0.478	0.337	-0.013	(-1.39)	0.392	0.444	0.037	(1.56)

B. Short Maturity Warrants

	Affected ($N = 147$)				Unaffected ($N = 129$)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^w	-0.329	(-0.32)	0.449	0.551	0.992	(1.24)	0.481	0.519	-1.320	(-0.59)
ΔES^w	1.052	(1.26)	0.490	0.510	1.253	(1.32)	0.488	0.512	-0.201	(-0.11)
ΔDV^w	-0.655	(-4.68)	0.333	0.667	-0.021	(-0.16)	0.488	0.512	-0.634	(-1.38)
ΔNT^w	-0.357	(-4.02)	0.367	0.612	0.014	(0.16)	0.550	0.450	-0.371	(-1.02)
ΔLT^w	0.050	(2.33)	0.510	0.327	-0.032	(-1.23)	0.442	0.450	0.082	(1.42)

C. Long Maturity Warrants

	Affected ($N = 455$)				Unaffected ($N = 351$)				Dif	
	mean	t-stat	up	dw	mean	t-stat	up	dw	mean	t-stat
ΔQS^w	-0.122	(-1.21)	0.457	0.543	0.048	(0.40)	0.481	0.519	-0.170	(-0.40)
ΔES^w	0.025	(0.19)	0.446	0.554	-0.111	(-0.82)	0.484	0.516	0.136	(0.40)
ΔDV^w	-0.490	(-5.66)	0.354	0.646	0.189	(2.35)	0.564	0.436	-0.679	(-2.64)
ΔNT^w	-0.274	(-5.26)	0.367	0.591	0.175	(3.02)	0.558	0.410	-0.449	(-2.27)
ΔLT^w	0.015	(2.14)	0.468	0.341	-0.006	(-0.70)	0.373	0.442	0.021	(0.93)

4.3 Regression Analysis

The effect of the liquidity spillover from the underlying market to the option market is much stronger than that to the warrant market. I argue that this is because the warrant market is more liquid and warrant market makers rely more on warrants and less on the underlying stocks to hedge their derivative positions. In this subsection, I provide additional evidence to show that the propensity to hedge in the underlying stock market is related to the degree of liquidity spillover from the underlying stocks to derivatives.

I use regression analysis since it captures not only differences between options and warrants as two groups, as in the previous analysis, but also the variations among individual options and warrants observations. The regression is specified as

$$QS_{i,j}^{d} = \beta_0 + \beta_1 T_i + \beta_2 T_i \times I_j^d + \beta_3 T_i \times PH_j^d + \beta_4 T_i \times I_j^d \times PH_j^d + \eta_j^d + \varepsilon_{i,j}^d, \quad (1)$$

where $QS_{i,j}^{d}$ is the average proportional quoted bid-ask spread for option ($d = o$) or warrant ($d = w$) j as a percentage in period i, and $i = 1$ ($i = 2$) indicates the period before (after) the tick size reduction. The quoted spread measures the difference between the prices at which the market makers are willing to buy and sell, which represent the compensation required by the market makers. T_i is the dummy variable for the post-reduction period and takes the value of one for $i = 2$ and zero otherwise. I_j^d with $d = o$ or w is one if the underlying stock of the option or warrant j is affected by the tick size reduction and zero otherwise. PH_j^d with $d = o$ or w is a measure of the propensity to hedge against option or warrant j in the underlying market, which is explained below. η_j^d with $d = o$ or w is the fixed effects for option or warrant j, and is intended to capture the unobserved variations in the warrant and option bid-ask spreads that are not related to the propensity to hedge. I use the interaction term $T_i \times I_j^d \times PH_j^d$ to examine whether the degree of liquidity spillover from the underlying stock market to the derivative markets is related to the propensity to hedge in the underlying stock market. I adopt this difference-in-differences approach, similar to the univariate analysis in the previous subsections, to control for unobserved confounding factors that may affect the liquidity of both derivatives and underlying stocks.

Market makers of derivatives use the underlying stock as the hedging instrument to manage the risk of their derivatives inventory. When the inventory risk is higher, it is more likely that the market makers need to hedge. Leland (1985) and Boyle and Vorst (1992) theoretically show that in the case of discrete trading of the hedging instrument with transaction costs, the dollar bid-ask spread of an option is an increasing function of its vega, the sensitivity of the option price to the volatility of the underlying stock. This is the case because more shares of the underlying stock are expected to be traded to hedge against the option with a higher vega. Jameson and Wilhelm (1992) use this measure to capture the inventory risk in an empirical study of option bid-ask spreads. I adopt a similar measure, $VG_{1,j}^{d}$ with $d = o$ or w, defined as the average vega of option or warrant j divided by its average price during the 5 days before the tick size change, as the first propensity to hedge measure. Since I examine the proportional bid-ask spreads, normalising the vega by the price of the option or warrant is needed to conform to the theoretical results.

My other measures of the propensity to hedge are not only related to the inventory risk but also capture the important differences between the option and warrant markets in my sample. The second variable measures the volatility of inventory, defined as

$OV_{1,j}^{d} = \frac{\overline{\left|\Delta SO_{1,j}^{d}\right|}}{\overline{SV_{1,j}^{d}}}$ with $d = o$ or w, where $\overline{\left|\Delta SO_{1,j}^{d}\right|}$ is the average absolute change in the number of shares outstanding for warrant *j* or the average absolute change in the net open interests for option *j* during the 5 days before the tick size change, and $\overline{SV_{1,j}^{d}}$ is the average share volume for option or warrant *j* for the same period. In the derivative warrant market, since only market makers can sell short, shares outstanding for warrants is the short position (i.e. the inventory) of the market makers. The net open interests of options are calculated by netting the long and short positions of each investor and then summing up across all investors.[4] Since everyone can sell short options, the net open interests overestimate the inventory held by the market makers. Nevertheless, a high value of $OV_{1,j}^{d}$ suggests that it is difficult for the market makers of derivatives to absorb the demand shocks by trading derivatives with other market participants without changing their inventory level significantly. As a result, the market makers of derivatives may rely more on the underlying stocks to hedge.

The third measure is $DV_{1,j}^{d}$ with $d = o$ or w, the log of total dollar volume of option or warrant *j* during the 5 days before the tick size change. If the volume of the derivatives is low, it is difficult for the market makers of derivatives to find counterparts to trade with and maintain an optimal level of inventory. For those derivatives, market makers tend to rely more on the underlying stocks to hedge.

Another plausible type of hedging behaviour is that the market makers hedge the derivatives on the same underlying stock as a whole or hedge one derivative contract using others on the same underlying stock. In the option market, the market makers are required to provide liquidity to all the options on the same underlying stock. Since contract specifications are set by the exchange, the numbers of options that the market makers are responsible to provide liquidity to are more or less the same. Instead, the warrant issuers can choose the contract specifications and the number of warrants to issue. There turns out to be large cross-sectional differences in the number of warrants issued by the same issuer on the same underlying stock. I also include NW_j, the number of different warrant contracts issued by the same issuer on the same underlying stock as warrant *j*, as a measure of the availability of other warrant contracts for hedging. When NW_j is lower, it is more difficult for the market makers to hedge one warrant contract with other warrant contracts on the same underlying stock, so they tend to rely more on the underlying stock for hedging.[5]

The correlations among the main variables used in the regressions and their t-statistics are shown in Table 8. The results suggest that the quoted spreads of options or warrants are positively related to VG^d, as documented in the existing literature. The quoted spreads are also positively related to other measures of propensity to hedge in the underlying market.

[4] The open interests data of the market makers alone in the option market are not available.
[5] The warrant issuers typically act as the market makers to provide liquidity to the market.

Note that a lower value of DV^d or NW indicates a greater propensity to hedge. The measures of propensity to hedge are positively correlated in general; however, an exception is the VG^d and NW pair for the warrant sample.

Table 8 Correlations among Derivative Bid-Ask Spreads and Measures of Propensity to Hedge in the Underlying Market

This table reports the correlations between $QS^d_{i,j}$ and measures of propensity to hedge in the underlying market, where $QS^d_{i,j}$ is the average proportional quoted bid-ask spread for option ($d = o$) or warrant ($d = w$) j as a percentage in period i, and $i = 1$ ($i = 2$) indicates the period before (after) the tick size reduction. The measures of propensity to hedge include $VG^d_{1,j}$, $OV^d_{1,j}$, $DV^d_{1,j}$, and NW_j, where $VG^d_{1,j}$ with $d = o$ or w is the average vega of option or warrant j divided by its average price before the tick size change; $OV^d_{1,j}$ with $d = o$ or w is the ratio of the average absolute change in the number of shares outstanding to the average share volume for warrant j or the ratio of the average absolute change in the net open interests to the average share volume for option j before the tick size change; $DV^d_{1,j}$ with $d = o$ or w is the log of total dollar volume of option or warrant j before the tick size change, and NW_j is the number of different warrant contracts issued by the same issuer on the same underlying asset for warrant j. The t-statistics are reported in parentheses. N is the number of observations. Panel A reports the results for the sample of options and warrants, and Panel B reports the results for the sample of warrants.

A. Options and Derivative Warrants ($N = 3934$)

	QS^d	VG^d	OV^d
VG^d	0.534		
	(39.56)		
OV^d	0.230	0.080	
	(14.80)	(5.04)	
DV^d	-0.553	-0.319	-0.547
	(-41.59)	(-21.08)	(-40.95)

B. Derivative Warrants ($N = 2164$)

	QS^d	VG^d	OV^d	DV^d
VG^d	0.341			
	(16.85)			
OV^d	0.212	-0.001		
	(10.09)	(-0.04)		
DV^d	-0.386	-0.156	-0.698	
	(-19.48)	(-7.36)	(-45.30)	
NW	-0.044	0.125	-0.124	0.221
	(-2.05)	(5.88)	(-5.80)	(10.52)

Table 9 reports the regression results. The numbers in parentheses are the t-statistics adjusted for heteroscedasticity. For the sample of options and warrants reported in Panel A, the interaction terms $T \times I^d \times PH^d$ for all three PH^d measures are significant, with negative signs for VG^d and OV^d and a positive sign for DV^d, suggesting that the effect of the tick size reduction on the quoted spread of a derivative with a higher propensity to hedge in the underlying market is stronger. To understand the magnitude of the coefficient estimate, I calculate the standardised coefficient, the coefficient of $T \times I^d \times \mathrm{PH}^d$ multiplied by the standard deviation of PH^d. The standardised coefficient indicates that the marginal impacts of the tick size reduction on the bid-ask spreads of the sample of options or warrants are -4.58%, -1.33%, and 3.68% for a one standard deviation increase in VG^d, OV^d, and DV^d, respectively. The magnitudes of the estimates are economically significant, suggesting that the propensity to hedge captures the important cross-sectional variations of the impacts of the tick size reduction. For the warrant sample, reported in Panel B, $T \times I^d \times \mathrm{VG}^d$ has a wrong sign; however, it is insignificant. The interaction terms with OV^d and DV^d have the expected signs and are significant. However, the significance levels are lower than those for the whole sample. In addition, the interaction term with the unique measure for the warrant sample, NW, is positive and significant, suggesting that when the number of different warrant contracts issued by the same issuer on the same underlying stock is lower, the liquidity spillover effect is stronger. The standardised coefficients of the interaction terms with OV^d, DV^d, and NW are -0.77, 0.83, and 0.84, respectively. The magnitudes of these numbers are smaller than their counterparts in Panel A, but they are still economically meaningful. The results suggest that although the liquidity spillover effect in the warrant market is weak on average, as shown in Table 7, there are cross-sectional variations among warrants. Those with higher OV^d or lower DV^d and NW are more affected by the tick size reduction. Overall, the results suggest that the degree of the liquidity spillover effect increases with the propensity to hedge in the underlying stock market.

Table 9 Derivative Bid-Ask Spreads and Propensity to Hedge in the Underlying Market

This table reports the results for the following regression:

$$QS_{i,j}^d = \beta_0 + \beta_1 T_i + \beta_2 T_i \times I_j^d + \beta_3 T_i \times PH_j^d + \beta_4 T_i \times I_j^d \times PH_j^d + \eta_j^d + \varepsilon_{i,j}^d,$$

where $QS_{i,j}^d$ is the average proportional quoted bid-ask spread for option ($d = o$) or warrant ($d = w$) j as a percentage in period i; $i = 1$ ($i = 2$) indicates the period before (after) the tick size reduction; $T_i = 1$ for $i = 2$, and $T_i = 0$ otherwise; I_j^d with $d = o$ or w is one if the underlying stock of option or warrant j is affected by the tick size reduction and zero otherwise; PH_j^d with $d = o$ or w is a measure of the propensity to hedge against option or warrant j in the underlying market; and η_j^d with $d = o$ or w is the fixed effects for option or warrant j. PH_j^d includes $VG_{1,j}^d$ with $d = o$ or w, the average vega of option or warrant j divided by its average price before the tick size change; $OV_{1,j}^d$ with $d = o$ or w, the ratio of the average absolute change in the number of shares outstanding to the average share volume for warrant j or the ratio of the average absolute change in the net open interests to the average share volume for option j before the tick size change; $DV_{1,j}^d$ with $d = o$ or w, the log of total dollar volume of option or warrant j before the tick size change; and NW_j, the number of different warrant contracts issued by the same issuer on the same underlying asset for the warrant *j*. The numbers in parentheses are the t-statistics adjusted for heteroscedasticity. *N* is the number of observations. Panel A reports the results for the sample of options and warrants, and Panel B reports the results for the sample of warrants.

A. Options and Derivative Warrants ($N = 3934$)					
PH^d	T	$T \times I^d$	$T^d \times PH^d$	$T \times I^d \times PH^d$	R^2
VG^d	0.044	1.594	0.253	-0.752	0.922
	(0.13)	(2.40)	(3.77)	(-6.11)	
OV^d	1.123	-1.863	1.041	-3.469	0.918
	(3.23)	(-3.90)	(1.64)	(-3.86)	
DV^d	9.309	-20.591	-0.595	1.304	0.920
	(6.06)	(-9.15)	(-5.66)	(8.68)	
B. Derivative Warrants ($N = 2164$)					
PH^d	T	$T \times I^d$	$T^d \times PH^d$	$T \times I^d \times PH^d$	R^2
VG^d	0.330	-0.867	-0.010	0.073	0.868
	(1.74)	(-2.16)	(-0.19)	(0.74)	
OV^d	0.319	0.282	-0.045	-2.141	0.869
	(1.85)	(1.06)	(-0.10)	(-3.15)	
DV^d	0.471	-5.106	-0.012	0.319	0.869
	(0.41)	(-2.68)	(-0.17)	(2.74)	
NW	0.174	-1.774	0.018	0.142	0.870
	(0.63)	(-4.00)	(0.63)	(3.32)	

V. Conclusion

In this paper, I study whether the liquidity of underlying stocks affects that of derivatives. I examine the differences in the liquidity variables of underlying stocks, options, and derivative warrants in Hong Kong around an exogenous change, the tick size reduction of underlying stocks. The results show that the bid-ask spreads of the underlying stocks are reduced significantly after the tick size reduction. The changes in the liquidity of the underlying market spill over to the option market; however, the effect on the derivative warrant market is much weaker. The results are consistent with the derivative hedging theory of Cho and Engle (1999) which suggests that the bid-ask spreads of derivatives are inversely related to the ability of derivative market makers to hedge their positions in the underlying market, as measured by the liquidity of the latter market. When the liquidity of the underlying market is improved, the bid-ask spreads of derivatives are narrowed. This paper also shows that the effect of liquidity spillover from the underlying market to the derivative market depends on the propensity to hedge in the underlying market. For derivatives that are illiquid and have a high inventory risk, the propensity to hedge in the underlying market is high, and as a result, the effect of liquidity spillover from the underlying market to the derivative market is strong.

This paper not only sheds light on the sources of the liquidity of derivative securities but also has important policy implications. The results suggest that the liquidity of derivative securities can be improved by enhancing the liquidity of underlying stocks, such as by lowering the tick size of underlying stocks. This approach is especially effective when the liquidity of the derivative market is low and the inventory risk of the derivative market makers is high.

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