Why are the prices of European-style derivatives over the American-style derivatives?

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Abstract

In Hong Kong, the prices of European-style derivative warrants are generally above those of American-style options with similar terms. Using high-frequency tick by tick data from the Hong Kong market during 2012-2016, we find that liquidity differences gain strong explanatory power for overpricing, especially for derivatives of low moneyness and long term. Also, factors considering counterparty credit risk, investors preference, information asymmetry, volatility discovery, exercise style, the behavior of market makers and investors sentiment do matter. Besides, we show a big gap of market-wide liquidity among two markets and find that strong day-of-the-week effects exist in derivative warrants market. To further compare the pricing efficiencies, we examine return predictability from order flows as well as variance ratios and the outcomes support lower liquidity resulting in weaker efficiency of option market relative to warrant market.

KEYWORDS

derivative warrants; exercise style; liquidity; price difference

JEL CLASSIFICATION

G12; G13; G14

1. INTRODUCTION

Derivative warrants, a kind of option-type derivatives, are actively traded in a few countries around Asian, European and Oceania. These warrants are quite similar to the traditional options traded in the U.S. and elsewhere in many respects, except for non-standard contract designs and issuing bank systems. Given the same payoff profiles, it's peculiar that the derivative warrants are generally more expensive than otherwise identical options in Hong Kong, which violates the law of one price in asset pricing. What is more remarkable is that for warrants and options written on individual stocks, their exercise styles are different. In Hong Kong, all derivative warrants are European-style but the options written on individual stocks are American-style. Thus, the individual stock options theoretically should have prices no less than the warrants with similar terms. This is in contradiction with reality. In this paper, we mainly aim to explore what cause the overpricing between the European derivative warrants and the American options traded in Hong Kong, with key features affecting values controlled.

Relatively little research has carried out on price differences between derivative warrants and options. The phenomenon, derivative warrants are more expensive than otherwise identical options, exists commonly around the regions where these two markets coexist such as Hong Kong (Duan and Yan, 1999; Li and Zhang, 2011; Fung and Zeng, 2012; Li and Zhang, 2019), Netherland (Horst and Veld, 2006) and Australian (Chan and Pinder, 2000). Using daily quote data of derivative warrants and options written on HSI stock index during 2002-2007, Li and Zhang (2011) find that the premiums of derivative warrants over options arise from the better liquidity in warrants and clientele effects explain how they can coexist in the markets. Fung and Zeng (2012) extend the work of Li and

Zhang (2011), indicating that derivative warrants are overpriced due to short-selling restriction and high proportion of unsophisticated investors with presenting overestimated implied volatility. Li and Zhang (2019) provide evidence that counterparty credit risk and investors' gambling preference can explain the price differences besides liquidity. Using data from Netherland, Horst and Veld (2006) find that call derivative warrants are priced higher than call options with same underlying stocks, strike price but longer maturity, which is mainly attributed to issuers' marketing strategy. Chan and Pinder (2000) use data from the Australian Exchange (ASX), showing that derivative warrants are more expensive than comparable options and liquidity differences can explain the overpricing. Using data of matched warrants and options with different exercise style from Germany markets, Bartram and Fehle (2007) find the competition between derivative warrants market and options market significantly improve liquidity in either market. Controlling exercise style of derivatives and other factors affecting prices the same, the greater part of the literature on price differences between derivative warrants and options acknowledges strong explanatory power of liquidity differences, but hardly any literature is concerned with whether the overpricing remains for different exercise-style derivatives, which really matters for testing the law of option pricing. Besides, there are imperfections in model specifications since some important variables are omitted.

The main thrust of this paper is to explain the phenomenon that the European-style derivative warrants are more expensive than the American-style options in Hong Kong. In Hong Kong, there are one of the most active derivative markets and option markets in the world. Owing to special markets and products design, the American options written on individual stocks traded in the Stock Options Exchange, have counterpart European-style derivative warrants traded in the Securities Market. Therefore, our high-frequency tick by tick data during

July 2012 to November 2016 from Hong Kong's markets have unique advantages when it comes to studying price differences of homogeneous derivatives with different exercise style. We address this puzzle by using a matched sample of derivative warrants and options both written on individual stocks, controlling strike price, maturity, underlying stock, trading time and the type of call or put. The whole sample is divided into several sub-samples according to moneyness, maturity and option type. Liquidity plays an important role both in stocks pricing (Amihud and Mendelson, 1986; Amihud et al., 1997; Hua et al., 2020; Amihud and Noh, 2021) and derivatives pricing (Brenner et al., 2001; Deuskar et al., 2011; Christoffersen et al., 2018; Muravyev and Pearson, 2020). Based on previous literatures, we account for the overpricing of derivative warrants with three high-frequency liquidity measures as our core explanatory variables. Besides liquidity, we add measures of counterparty credit risk and investors preference into our model, following Li and Zhang (2019). We then propose novel perspective by exploring more factors including information asymmetry, volatility discovery, exercise style, the behavior of market makers and investors sentiment, which will be discussed in Section 2.3 in detail.

We conduct main analysis in three steps. First, we document the overpricing and compare the differences of liquidity measures for each sub-sample. We find that European-style derivative warrants are apparently more expensive than the corresponding American-style options, performing higher proportions and values of premium. But it tends to be insignificant or even reversal in the sub-sample of in-the-money and short-term derivative pairs. In addition, derivative warrants present generally better liquidity than matched options. The results confirm the overpricing also exist between derivative warrants and options written on individual stocks in Hong Kong, consistent with findings in derivatives written on HSI stock index (Li and Zhang, 2011; Fung and Zeng, 2012). Next, we use linear panel regression to examine whether liquidity differences and other relevant factors could explain the overpricing. We suggest that liquidity differences provide strong explanatory power for overpricing, while variables including measures of counterparty credit risk, investors preference, information asymmetry, volatility discovery ability, exercise style, the behavior of market makers and investors sentiment also take significant impact on the price differences. Finally, we re-estimate our benchmark model with sub-samples divided by moneyness, maturity and type of call or put, showing that the model is robust except for the in-the-money group and provides stronger power for derivatives of low moneyness and long term. We also conduct Fama-Macbeth regression to ensure the robustness of our models, the results of which is close to our basic regression.

To further understand the liquidity differences of derivative warrants market and options market in Hong Kong, we conduct a series of additional analyses. Inspired by Chordia et al. (2001), we study aggregate market-wide liquidity and trading activity for derivative warrants market and options market. We construct daily time series indices of market-wide liquidity measures over the period July 2012 through November 2016, enabling to further compare the liquidity differences between derivative warrants and options from the perspective of the whole market. We find that there is a big gap in liquidity indicators——the market-wide liquidity of warrants market is much better than that of option market most of the time. Then, we consider several distinct major determinants of liquidity justified as the explanatory variables, reflecting inventory risk, underlying assets performance, investors liquidity needs, informed trading and trading frictions. Using time series regression, we find that the liquidity of derivative market is more sensitive to the change of interest rate and investors sentiment. The results indicate that the warrants market exhibits strong day-of-the-week effects that liquidity significantly increases on Tuesdays and decreases on Fridays, while the options market doesn't. We also discover there is more informed trading in option market.

The phenomenon that derivative warrants are more expensive don't necessarily mean they are overvalued (Fung and Zeng, 2012). Thus, we attempt to test their pricing efficiencies and explain what cause the difference of pricing efficiency between derivative warrants and options market. Following Chordia et al. (2008), we use return predictability from order flows as well as variance ratios to examine the efficiency of each market. As previous literatures emphasize on the relationship between liquidity and market efficiency (Chowdhry and Nanda, 1991; Amihud et al., 1997; Chordia et al., 2008), it's natural to ask if the liquidity differences impose impact on the efficiencies. Our matched derivative warrants and options samples offer us an ideal venue to examine the impact of liquidity differences on market efficiency since most variables affecting market efficiency are controlled, except liquidity differences between two markets. As a result, the degree of warrant market efficiency is better than option market owing to higher liquidity and the sub-sample for derivatives written on small-cap stocks performs weaker efficiency.

To the best of our knowledge, this paper is the first to discover and explain the phenomenon that European-style derivatives are in fact more expensive than American-style derivatives with nearly similar terms, contributing to existing literatures about option pricing. In addition, we extend studies concerned with the overpricing of derivative warrants over options in Hong Kong. Our samples cover derivative warrants and options written on individual stocks and most variables even measures of underlying stocks and futures market are constructed on the basis of high-frequency tick by tick data. To alleviate endogenous problems, we have a more comprehensive consideration of factors affecting the price difference and add several critical variables into the model. Besides, we intuitively compare market-wide liquidity differences between derivative warrants and options and quantitatively analyze the determinants of liquidity among the two markets. What's more, we use return predictability from order flows to examine the market efficiency of derivatives and confirm the positive relationship between liquidity and market efficiency, contributing to empirical studies about liquidity and market efficiency.

The remainder of this paper is organized as follows. Section 2 firstly compares the derivative warrants and options market in Hong Kong, then describes data and main variables used in the empirical analysis. Section 3 presents main empirical findings about the price differences between derivative warrants and options traded in HKEx and conducts robustness checks. Section 4 provides additional empirical results to better understand the liquidity differences. Section 5 concludes this paper.

2. MARKETS DESCRIPTION

2.1 Overview of the markets

To better understand the causes of price differences, it is necessary to have an overview of the derivative warrants market and options market in Hong Kong. Practically, both the trading of derivative warrants and options are conducted in the Hong Kong Exchange and Clearing Limited (HKEx) consist of two parts, the Securities Market and the Derivatives Market. The Derivatives Market is further composed by the Futures Exchange and the Stock Options Exchange. Securitized derivatives including derivative warrants are traded in the Securities Market like common stocks, the trading volume of which has been the largest in the world for more than ten years. According to the data from the World Federation of Exchanges, the trading volume of securitized derivatives on HKEx——more than half of them are derivative warrants, has reached 532.3 billion dollars, nearly 3 times the sum of the second to tenth place! An options market developing rapidly coexists with markets for derivative warrants in Hong Kong. Options written on index are traded in the Futures Exchange, while those written on individual stocks are traded in the Stock Options Exchange. For more than 20 years of development, there have been 107 types of stock options in Hong Kong, with an average daily contract turnover of more than 520,000.

The differences of design and structure between two markets can't be neglected, although the expected payoff of products is almost equal. As far as market participants, the market makers more actively provide liquidity in derivative warrants market since there are multiple competing issuers for each underlying stock while liquidity providers in options market face slack liquidity requirements; The investors structures are different, that is, the retail investors cluster in warrants market while institutional investors have occupied option market.

As for products traded in the two market, besides the differences of exercise style, derivative warrants contracts are more flexible with various underlying assets, maturity and strike prices while options contracts are standardized.

When it comes to the differences of trading rules, a central clearing house and margin system almost remove counterparty credit risk in options market while derivative warrants investors suffer from the credit risk of issuers; Short-selling restriction that only issuers of derivative warrants can take a short position exists in warrants market while options can be short at will once investor opens a margin account; The market doorsill for warrants market is lower than options market since for options trading, a futures account is demanded and the minimum trading size is higher. These differences help to comprehend the price gap between derivative warrants market and options market in Hong Kong.

2.2 Data

We use high-frequency tick by tick trade data for derivative warrants and options written on individual stocks listed on the Hong Kong Exchange and Clearing Limited (HKEx). Also, we have obtained tick by tick trade data for underlying stocks and futures to construct relevant variables. The full sample in this paper spans the period from July 03, 2012 to November 30, 2016. The high frequency data of our sample are provided by the Hong Kong Exchanges and Clearing Limited and other daily data are acquired at the Chinese Stock Market and Accounting Research (CSMAR) website. Warrants, options and underlying stocks trading records that are time-stamped before 9:30 a.m. or after 4:00 p.m. are excluded. The sampling frequency of high-frequency data is five minutes. This sampling frequency is the most commonly used choice (Hansen and Lunde, 2006), considering two aspects: increasing sample size and reducing market microstructure noise.

Derivative warrants and options are distinguished and matched by strike price, maturity, underlying asset, trading time, and option type (call or put). Warrants and options with the same characteristics mentioned above are regarded as the same product and constitute a set of derivative pairs. In the end, we got 266828 derivative pairs from 59 underlying individual stocks as Table A1 presented. Further, we divide our whole matched sample into eighteen sub-samples according to moneyness, maturity and option type refer to Li and Zhang (2011). Moneyness is divided into the groups of $k \leq -0.03$ (out-of-the-money (OTM)), $-0.03 < k \leq 0.03$ (at-the-money (ATM)), and $k > 0.03$ (in-the-money (ITM)).[1] Maturity is divided into the groups of short term (ST) with $m/360 \leq 60$ days, medium term (MT) with $60 < m/360 \leq 120$ days, and long term (LT) with $m/360 > 120$ days. Option type is divided into the groups of calls (C) and puts (P).

2.3 Variables

The price data of warrants and options is normalized by underlying stocks price S/100 to make it comparable across time. In addition, warrants price is multiplied by entitlement ratio[2] to make the prices of warrants and options comparable. Let P^w, P^o respectively denote warrants price and options price after normalization and adjustment, and let DP denote the price difference of each option pairs, then the price premium ratio of the i^{th} warrant and option pair at time t can be written as:

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[1] $k=1-X/S(t)$ for a call and $k=X/S(t)-1$ for a put. k, X, S(t) are denoted as moneyness, strike price and the price of underlying stock on business day t.

[2] The number of warrants is needed to buy one share of common stock.

$$DP_{i,t} = \frac{P_{i,t}^{w} - P_{i,t}^{o}}{P_{i,t}^{o}} \tag{1}$$

According to previous literature, liquidity plays an important role in the overpricing, therefore three variables to measure liquidity are our core explanatory variables. We quantified three dimensions of liquidity including market width, market depth and resiliency, which is respectively measured by Roll spread (Roll, 1984), trading volume and the Amihud (2002) illiquidity measure respectively.

Roll spread, used to measure market width, is employed as a substitute for the bid-ask spread since we couldn't precisely compute the bid-ask spread for lack of high frequency quote data. The Roll spread, $\text{Rolls}_{i,t}$[3], is defined as:

$$\text{Rolls}_{i,t} = \begin{cases} \dfrac{2\sqrt{-Cov(\Delta P_{i,t}, \Delta P_{i,t-1})}}{S_{i,t}/100}, Cov(\Delta P_{i,t}, \Delta P_{i,t-1}) < 0 \\ 0, Cov(\Delta P_{i,t}, \Delta P_{i,t-1}) \geq 0 \end{cases} \tag{2}$$

Similar to the price measure, the Roll spread is expressed in the percentage of the underlying stock price. Then, we use $DRolls_{i,t}$ to approximate the differences of bid-ask spread, which is given by:

$$DRolls_{i,t} = \frac{Rolls_{i,t}^{w} - Rolls_{i,t}^{o}}{Rolls_{i,t}^{o}} \tag{3}$$

The second liquidity measure we consider is trading volume measured by the shares of transactions. Let Vol^{w}, Vol^{o} respectively denote warrants trading volume and options trading volume, then the trading volume difference of the

[3] Rolls spread of warrants is computed by the price before the normalization and adjustment mentioned above.

i^{th} option pair at time t, $DVol_{i,t}$, can be written as:

$$DVol_{i,t} = Vol_{i,t}^{w} - Vol_{i,t}^{o} \quad (4)$$

As a popular measure of illiquidity, we use the Amihud (2002) illiquidity measure to scale resiliency. The Amihud (2002) measure, $A_{i,t}^{w}$ for warrants and $A_{i,t}^{o}$ for options, are both defined as:

$$A_{i,t} = \frac{1}{11}\sum_{i=-5}^{5}\frac{|R_{i,t}|}{Vol_{i,t}} \quad (5)$$

where $|R_{i,t}|$ is the 5 minutes level absolute percentage return on warrants or options. Thus, the difference of Amihud (2002) measure of the i^{th} option pair at time t $DA_{i,t}$, can be written as:

$$DA_{i,t} = Ln(A_{i,t}^{w}) - Ln(A_{i,t}^{o}) \quad (6)$$

We not only document the impact of illiquidity differences between warrants and options on their price differences, but also investigate if there are other possible factors that affect the price difference and add them as control variables to the model. For control variables, we first refer to Li and Zhang (2019), who identifies counterparty credit risk and behavioral biases besides liquidity as the major determinants of the price difference. Because compared to options, derivative warrants are subject to the credit risk of issuers or guarantors and the behavior of retail investors' lottery-like trading. We use daily iTraxx Asia ex-Japan CDS index in logarithm CDS_t to measure counterparty credit risk. The moneyness $k_{i,t}$, as well as the maturity $m_{i,t}$, controls for the investors preference. We then propose novel perspectives by considering more factors such as underlying stock's liquidity and volatility, theoretical price difference, liquidity providers behavior and investor sentiment to fully comprehend the cause of the price difference and make model more robust.

We use underlying stocks trading volume in 5 minutes interval, $Vol\_Ud_{i,t}$, to measure the trading activity of underlying stocks as a proxy for information asymmetry. According to Martens (2002), we compute daily volatility $\sigma_{i,t}$, measured by the sum of intraday squared 5-min returns, excluding the overnight return:

$$\sigma_{i,t} = (1 + \mathrm{c}) \sum_{n=1}^{N} (r_{t,n}^{i}) \tag{7}$$

where $r_{t,n}^{i}$ is 5-minute level absolute percentage return on i^{th} underlying stock. The constant is equal to $\frac{98}{81}$ in estimation following Martens (2002), which is attribute to one day consists of ninety-eight 5-minute intervals, of which 81 intervals are attributed to floor trading.

What is remarkable about warrants and options trading in HKEs, is that their exercise styles are different. For derivative warrants, they are all European-style; For individual stocks options, they are all American-style. It's necessary to control the differences of their theoretical prices, which reflects value differences due to different exercise styles. We use standard Black-Scholes-Merton Option Pricing Model to estimate the theoretical price of warrants denoted by $\hat{P}_{i,t}^{w}$. The method we employ to estimate the options theoretical value is a simplified American options pricing model (Alghalith, 2020). The theoretical price of options is given by:

$$\hat{P}_{i,t}^{o} = e^{0.5(e^{r_t m_{i,t}} - 1)(1 - r_t) m_{i,t}} \hat{P}_{i,t}^{BS} \tag{8}$$

where r_t is the risk-free interest rate at time t valued by the daily overnight Hibor and $\hat{P}_{i,t}^{BS}$ is the options theoretical price calculated by BSM model. As we can see, the American options price is always more expensive than the European options price in theory when we control other factors the same. Similarly, the theoretical price is expressed in the percentage of the underlying stock price. We define the difference of theoretical prices as:

$$D\hat{P}_{i,t} = \frac{\hat{P}_{i,t}^{w} - \hat{P}_{i,t}^{o}}{S_{i,t}/100} \tag{9}$$

Market makers behavior is another plausible causative candidate. Chae et al. (2012) find that, in Korean derivative warrant market, liquidity providers only provide limited liquidity and earn profits by information advantages. Baule et al. (2018) find warrants liquidity providers is inclined to step up their quotes relative to options markets to generate additional profits in German. SFC (2005a) find market markers in Hong Kong's derivative warrants market provide liquidity actively, contributing to 73% trading volume. Chow et al. (2007) suggest market makers of derivative warrants market in Hong Kong aren't always providing liquidity to market. Our proxy for liquidity providers behavior is constructed by the warrants/options order imbalance (OI) in the spirit of Christoffersen et al. (2018), which reflects the inventory risk of liquidity providers. The method to calculate OI refers to previous literature (Bernile et al., 2016 and Luo et al., 2020)[4]. Thus, the variables measuring liquidity providers behavior, $Lp_{i,t}^{w}$ and

[4] Since the data do not have the label of buyer- or seller-initiated, we use the tick rule classification algorithm to flag the direction, that is, a transaction is buyer (seller) initiated if the transaction price is higher (lower) than the latest price. If the price between the two transactions remains unchanged, the same trademark will be marked as the previous transaction.

$Lp^o_{i,t}$, are equally given by:

$$Lp_{i,t} = |OI_{i,t}| = \frac{|\sum_{n=1}^{N} Vol\$^{Buy}_{i,n} - \sum_{n=1}^{N} Vol\$^{Sell}_{i,n}|}{\sum_{n=1}^{N} Vol\$_{i,n}} \tag{10}$$

where $Vol\$^{Buy}_{i,n}$ and $Vol\$^{Sell}_{i,n}$ mean warrants/options trading volume by Hong Kong dollars. The time interval is 5 minutes and N is total number of trading records during t-1 to t. We use these indicators to measure the behavior of market makers. When market makers conduct negative feedback trading[5], $Lp_{i,t}$ goes up because market makers are providing liquidity to mitigate order imbalance; When market makers conduct positive feedback trading, $Lp_{i,t}$ goes down because market makers are trading to make profit or manage inventory risk thus aggravating order imbalance. Then, the difference of liquidity providers behavior $DLp_{i,t}$ is defined as:

$$DLp_{i,t} = Lp^w_{i,t} - Lp^o_{i,t} \tag{11}$$

Additionally, we include a measure of investors sentiment. Investors sentiment may affect the prices of the two markets heterogeneously since the investors structures of the two markets is different. Investors in the warrant market are mainly retail investors, while those in the option market are mainly institutional investors. Building on the work of Han (2008), we use the net position of speculators in futures written on individual stocks in Hong Kong to measure investors sentiment, which is constructed by the number of long contracts minus the number of short contracts, excluding hedging transactions. Let Ftp_t denotes the investors sentiment of derivative market at time t and the

[5] Negative feedback trading means selling calls/buying put when underlying price goes up/down, while positive feedback trading means buying calls/selling puts when underlying price goes up/down.

frequency of this measurement is also 5 minutes.

[Insert **Table 1** about here.]

3. EMPIRICAL RESULTS

3.1 Overpricing and Liquidity difference

This subsection will attempt to test whether the derivative warrants written on individual stocks are more expensive than the matched options and document their liquidity differences. As a result, the prices of derivative warrants are significantly higher than the corresponding options but it tends to be insignificant or even reversal in the ITM-ST group. As for liquidity differences, liquidity of derivative warrants is generally better than matched options.

[Insert **Table 2** about here.]

Table 2 shows the overpricing of derivative warrants in comparison to options. In panel A of Table 2, we document the proportion of the observations for which the trading price of warrants are higher than those of the relative options. A large number of warrants are more expensive than options, of which average premium proportion reaches 73.5% for full sample. The highest group is OTM-LT which reaches 94.3% and 98% for calls and puts respectively, indicating almost all OTM-LT warrants have higher prices relative to options. The lowest is ITM-ST which reaches 42.8% and 50.5% for calls and puts respectively. The price premium proportions of the LT groups are higher than the ST groups and those of the OTM groups are higher than the ITM groups, which is consistent with previous finding based on warrants and options written on HSI[6] (Li and Zhang, 2011; Fung and Zeng, 2012). However, the proportions should have been zero since the American options price is always more expensive than the European options price in theory when we control other factors the same. Our empirical results are inconsistent with the theory of option pricing.

In panel B and panel C of Table 2, we separately display the average price premium and the average percentage price premium for each moneyness and maturity group. No matter the average price premium in value or in percentage, they're all significantly greater than 0 at the 5 percent level, except for the ITM-ST. On the whole, the overpricing of the puts group is more obvious than the calls group, which is inconsistent with Li and Zhang (2011). Panel D displays the number of observations of the matched warrant and option pairs for each group[7].

In panel A of Table 3, we document the proportion of the observations for which the liquidity of derivative warrants is better than those of the relative options. The proportion is over 50% for all groups for all liquidity measures. Panel B of Table 3 shows the average liquidity differences for each moneyness and maturity group. Overall, Table 3 presents that derivative warrants' liquidity is generally better than matched options. There are only one insignificant t-statistic in premiums among all groups.

[Insert **Table 3** about here.]

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[6] The HSI is the benchmark index in the Hong Kong stock market, those of the warrants and options written on HSI are both of European style as mentioned above.

[7] To maintain sample size, derivative warrants and options are matched within one-hour intervals. We also conduct the price and liquidity comparison using the synchronous trading records to ensure robustness.

3.2 Regression results

We empirically test the effects of the liquidity differences between derivative warrants and options on their price differences, employing a series of panel regression models. The benchmark model is specified as:

$$DP_{i,t} = \alpha_i + \beta_1 DRolls_{i,t} + \beta_2 DVol_{i,t} + \beta_3 DA_{i,t} + \beta_4 CDS_t + \beta_5 k_{i,t} + \beta_6 m_{i,t} + \beta_7 Vol\_Ud_{i,t} + \beta_8 \sigma_{i,t-1} + \beta_9 D\hat{P}_{i,t} + \beta_{10} DLp_{i,t} + \beta_{11} Ftp_{t-1} + \varepsilon_{i,t} \quad (12)$$

where $DP_{i,t}$ is the price difference in percentage between matched warrants and options; $DRolls_{i,t}$, $DVol_{i,t}$ and $DA_{i,t}$ are the differences in liquidity measures indicating the differences of Roll spread, trading volume and Amihud (2002) illiquidity measure, respectively. CDS_t measures the counterparty credit risk of the warrant. $k_{i,t}$ is moneyness and $m_{i,t}$ is maturity, which control for investor preference. $Vol\_Ud_{i,t}$ and $\sigma_{i,t-1}$ are the underlying stock trading volume and 1-lag volatility respectively, controlling for asymmetric information and volatility discovery ability. $D\hat{P}_{i,t}$ is the theoretical value difference between matched warrants and options, controlling the effect of different exercise style, European for warrants and American for options. $DLp_{i,t}$ reflecting the different order imbalance level between derivative warrants market and option market, controls the difference of liquidity providers behavior. Ftp_{t-1} is the 1-lag net position of speculators in futures written on individual stocks listed on HKEx, controlling the investors sentiment in Hong Kong's derivative market. In addition, both individual and time effects[8] are controlled in regression.

[8] The time variables are monthly because CDS is daily frequency and equal for i^{th} pair, meanwhile our panel data is extremely imbalanced. When adjust the time variables to 5 minutes level, the robustness of liquidity measures is unchanged.

The regression results are shown in Table 4. Model (1) to (3) are univariate regressions to test the impact of each liquidity indicator on the price differences. Model (4) adds three liquidity indicators together. Model (5) is based on Model (4), with all control variables added. Each liquidity indicator is statistically and economically significant and has the expected sign whatever in univariate regression or multivariate regression. The results indicate the liquidity differences also explain the price differences between derivative warrants and options written on individual stocks to a certain extent, which extends the results of previous literature. The coefficients of DRolls and DA are negative and those of DVol are positive, suggesting the better liquidity leads to a premium on warrant price. CDS is negatively and significantly related to DP, consistent with the finding in Li and Zhang (2019), indicating the counterparty credit risk of warrant leads to a discount on warrant price. Moneyness k and maturity m are both significant, suggesting the warrant investors preference exists likewise. The coefficient of k is negative but the coefficient of m is positive contrary to the previous literatures (Li and Zhang, 2011; Li and Zhang, 2019).

The coefficient of Vol_Ud is negatively and significantly related to DP, suggesting the liquidity and trading activity on the underlying stock explain DP to a certain extent. One possible explanation is that warrant investors have less information than option investors and this information asymmetry is mitigated when trading on stocks with high liquidity. The coefficient of volatility σ is significantly negative, indicating the price of options is more sensitive to volatility changes. According to Baule (2018), options market plays a leading role in volatility discovery in comparison to warrants market in German, which in a way explains the difference of volatility sensitivity. $D\widehat{P}$ is significant and has expected sign, which mean the differences of exercise style explain the price differences and the European-style warrants should have been cheaper than the

American-style options. DLp, a proxy for behavior of market makers, is negatively and significantly related to DP, suggesting the market makers in warrants market trade more actively to provide liquidity to market to mitigate order imbalance whereby improving warrant market price relative to option. Ftp measures the investors sentiment of derivative market and its positive and significant relationship with DP, indicates the investors in derivative warrants market are more susceptible to market sentiment. Ftp together with Vol_Ud implies the different investor structures between derivative warrants market and option market, as the warrant market is designed for retail investors, and the option market is dominated by institutional investors.

[Insert **Table 4** about here.]

3.3 Robustness check

In this section, we conduct several robustness checks to ensure the robustness of the benchmark model when samples choice or model specification changing. First, we re-estimate our model with different samples choices, considering the critical factors which may at the same time influence the price and liquidity of the warrants and options. Besides, we run Fama-Macbeth regression to repeat the analysis to address the concern about our results being dependent on the choice of model specification.

As we show there are obvious overpricing and liquidity difference among groups in Section 3.1, it's natural to ask if the empirical result stay robust when we focus our analysis on each group. Table 5 reports our subsamples panel regression results. Model (1)-(3) concentrate on the out-of-the-money, at-the-money and in-the-money groups respectively. The results indicate the level effects of moneyness among groups. The three liquidity measures in the out-of-the-money group gain the strongest explanatory power, with the absolute average value of t reaching 14.31 and model's R^2 above 10%. However, they loses explanatory power in the in-the-money group but the theoretical value difference $D\widehat{P}$ in that is mostly significant and negatively related to DP, which suggests that in the case of warrants or options in the money, the investors are more sensitive to the gap of exercise opportunities resulting from exercise style so that the price of option is incline to exceed warrant. The sub-sample results for maturity are estimated as Model (4)-(6) for the long term, medium term and short term successively. The results are similar to each other and the core explanatory variables remain significant and keep sign of coefficient unchanged. The explanatory power of model is strongest in LT group, with a 0.27 R^2. Model (7) and Model (8) focus on the calls and the puts groups respectively. It shows liquidity measures are useful in explaining price differences no matter for calls or puts. Maturity m loses explanatory power and its sign turns to negative, suggesting long-term European-style put warrants aren't very preferred by investors and the likely positive Theta may explain it. $D\widehat{P}$ also loses power in puts group. Ftp is negatively and significantly related to DP, which can make sense since when market sentiment goes up, warrants market investors will remarkably reduce the purchases of put warrants for their optimistic expectations.

[Insert **Table 5** about here.]

To further address the concern about the dependency on model specification, we run monthly Fama-Macbeth regressions to repeat our analysis in Section 3.2.

The regression results are reported on Table 6. All variables remain the explanatory power, except for maturity m and the proxy of exercise style difference $D\widehat{P}$. The Fama-Macbeth regression explains a larger proportion of variation in DP than panel regression, indicated by generally larger R^2.

[Insert **Table 6** about here.]

4. UNDERSTANDING LIQUIDITY DIFFERENCES

4.1 Aggregate market liquidity

In previous chapters, we concentrate on the individual warrants or options and use data on short time intervals. Then, we will move on to explore aggregate market liquidity from three dimensions of width, depth and resiliency for derivative warrants and options market over 1-day time intervals samples for each other. Our work here is inspired by Chordia et al. (2001), who have studied aggregate liquidity and trading activity for U.S. equities.

For either warrants market or options market, we define the following liquidity measures roughly the same to the previous chapters:

Rolls: the daily market-wide average Roll spread

A: the daily market-wide average Amihud (2002) illiquidity measure

Vol: the daily market-wide aggregate trading volume by the Hong Kong dollars

AveVol: the daily market-wide aggregate trading volume (Vol) divided by the daily trading numbers of warrants or options

We winsorize the trading records at 2% for both warrants and options samples.[9] The time spans from July 3 2012 to November 30 2016, and April 2016 is eliminated for missing data. To filling the time series, we adopt the following principles: (i) For trading volume or average trading volume, non-trading dates are assigned to a value of zero. (ii) For Roll spread or Amihud (2002) measure, non-trading dates are filled in an average value from the past ten trading days. Figure 1-4 illustrates the time-series averages of the cross-sectional average liquidity differences. Figure 5 illustrates the daily trading numbers difference. Panel A and Panel B of Table 7 reports descriptive statistics for derivative warrants market sample and options market sample, respectively.

[Insert **Figure 1-5** about here.]

The summary statistics of market-wide liquidity measures of derivative warrants and options are reported in the Panel A and Panel B of Table 7, respectively. Figure 1 through 5 plot the market-wide liquidity and trading activity differences between warrants market and options market. As can be obviously seen, though the number of products available for trading of two markets are close, there is a big gap in liquidity indicators, with the daily average trading volume of warrants roughly 26 times larger than options, Roll spread roughly 4 times smaller and Amihud (2002) measure roughly 26 times smaller. However, the liquidity differences in average daily changes between two markets are small. Figure 1-4 illustrates the positive correlation between the daily changes of liquidity in the two markets exists. The correlation coefficients of Roll spread, Amihud (2002) measure and trading volume between the two

[9] On the level of 5-minute time intervals, there are approximately 8.6 million transaction records for warrants and 1.2 million transaction records for options.

markets are 0.59, 0.25, 0.21 respectively. Means are quite close to the medians, suggesting none of variables exhibit significant skewness.

[Insert **Table 7** about here.]

4.2 Determinants of liquidity

In this subsection, we construct a series of variables to explain the daily change of liquidity both in warrants market and options market, employing time-series regressions. Considering the time series stationarity, we use the daily changes of liquidity measures as dependent variables. Then, several distinct major determinants of liquidity are justified as the explanatory variables, including inventory risk, underlying assets performance, investors liquidity needs, informed trading and trading frictions.

Inventory models suggest that liquidity depends on inventory risks (Ho and Stoll, 1983), and it is positively related to the bid-ask spread (Biais, 1993). We consider interest rate as a proxy variable for market-wide inventory risk. An increase in interest rates could decrease market liquidity, by increasing the cost of financing inventory. The trading frictions such as constraints on short-selling and the hedging cost could be also reflected by interest rate. Actually, it's more difficult to short warrants than to short options and the uptrend interest rate could aggravate the cost difference. We decompose the interest rate into two parts, risk-free risk and risk premium, measured by the daily change of overnight Hibor, Δrf and the daily change of iTraxx Asia ex-Japan CDS index, ΔCDS, respectively.

Underlying assets performance is another possible influencing factor. We use the HSI market index, HSI, the trading volume of HSI constituent stocks, HSI_vol and the concurrent daily return on the HSI index, HSI_r, to measure the concurrent daily performance of underlying stock market. We use a five-day moving average of past returns for the HSI index, HSI_r5, to measure historical performance and use a five-day trailing average of daily absolute returns for the HSI index, HSI_σ to measure the volatility of stocks market.

Liquidity might also be affected by investor sentiment. Chordia et al. (2001) find strong day-of-the-week effects on U.S. stock market due to the fluctuations in investors sentiment over the week. Thus, we construct several dummy variables for days of the week as well as days for the start of holiday and the end of holiday. The investor sentiment variables are defined as follows:

ΔFtp: the daily change of the net position of futures, calculated by the same method mentioned in Section 2.3.

Monday-Thursday: the dummy variables, are 1.0 when the trading day is a Monday, Tuesday, Wednesday, or Thursday, otherwise zero.

Holiday: the dummy variable, is 1.0 when the trading day is on the one day preceding or following a holiday, otherwise zero.[10]

Holiday_f: the dummy variable, is 1.0 when the trading day is on the one day following a holiday, otherwise zero.

Holiday_p: the dummy variable, is 1.0 when the trading day is on the one day preceding a holiday, otherwise zero.

Previous literatures conclude the important impact of informed trading on the liquidity in option markets (Easley et al., 1998; Pan and Poteshman, 2006; Christoffersen et al., 2018). To examine the influence of the market-wide informed trading, we use measures constructed by macroeconomic announcement information, which are defined as:

Gdppro: the dummy variable, is 1.0 when the trading day is on the GDP

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[10] If the transaction record interval is greater than or equal to 1 day, we will define a holiday except for the weekends.

announcement day, otherwise zero.

Gdppro_p: the dummy variable, is 1.0 when the trading day is one or two days prior to GDP announcement day, otherwise zero.

Gdppro_f: the dummy variable, is 1.0 when the trading day is one or two days following GDP announcement day, otherwise zero.

Table 8 reports the time-series regression results for the ΔRolls, ΔA, ΔVol and ΔAveVol of warrants market and options market. First, we show that the coefficients of the lagged terms are all negative, suggesting every series exhibits negative first-order autocorrelation. Second, for the warrants market, Hibor is positively and significantly related to the change of Roll spread and Amihud (2002) measure as we expect, but loses explanatory power for the options market. The result indicates the liquidity level of warrants market is more sensitive to the change of interest rate, which could be explained by the reason that the market makers in warrants market rebalance their portfolio and provide liquidity more actively, besides the constraints on short-selling bring about higher hedging cost for warrants. The underlying stock market measures, HSI_vol, HSI_r and HSI_σ explain the liquidity change to a certain extent. Further, investors sentiment matters for the warrants market, with ΔFtp being more significant than options market. The warrants market exhibits strong day-of-the-week effects, while the options market doesn't. The dummy, Tuesday is significantly related to liquidity measures and has the largest absolute coefficients and t-statistics for the warrants sample, compelling strong evidence that warrants market liquidity increases on Tuesday. Meanwhile, the dummies for Monday, Tuesday, Wednesday and Thursday are generally negatively related to Roll spread and Amihud (2002) measure and positively related to the measures of trading volume, indicating Friday effect that the warrants market liquidity decreases on Friday exists. The finding of day-of-the-week effects in warrants market is consistent with the day-of-the-week effects in U.S. equity market discovered by Chordia et al. (2001). What's more, the coefficients of Gdppro_p is positively correlated with Roll spread and Amihud (2002) measure for the warrants sample as well as the measures of trading volume for the option sample. The results indicate that there is more informed trading in option market, which implies the traders in option market get information earlier than those in warrant market and reflect them in the market price through transactions.

[Insert **Table 8** about here.]

4.3 Liquidity and Market efficiency

Market efficiency may be strongly related to liquidity. Chowdhry and Nanda (1991) show theoretically that the benefits of liquidity will endogenously improve the market efficiency. Chordia et al. (2008) empirically examine the changes in market efficiency of the New York Stock Exchange after in a more liquid decimal regime and find the improvement of liquidity will enhance market efficiency. Amihud et al. (1997) also show empirically that liquidity is positively correlated with market efficiency using the data from the Tel Aviv Stock Exchange. In this subsection, we try to test the differences of market efficiency between the derivative warrants market and the options market following the methodology of Chordia et al. (2008). Using the matched sample of warrants and options constructed above, we can simply focus on the interaction between liquidity and market efficiency for the two markets, with other factors affecting market efficiency controlled.

Firstly, we use return predictability from order flows to test the level of the market efficiency. The models to estimate return predictability are specified as

$$r_t = \alpha + \beta_1 OI_{t-1} + \beta_2 OI_{t-1} * ILQ \quad (13)$$

$$r_t = \alpha + \beta_1 OI_{t-1} + OI_{t-1} * wo + \beta_2 OI_{t-1} * ILQ \quad (14)$$

where r_t denotes the 5-minute returns of warrants or options at time t, and OI_{t-1} is one-period lagged order imbalance calculated above. The low-liquidity dummy, ILQ, measuring the market-wide liquidity, is 1.0 if the two markets' daily Roll spread is at least one standard deviation above the average level at the same time and otherwise zero. The dummy wo, indicates a warrant when equal to 1.0 and an option when equal to 0. Then, we separately test return predictability from order flows of the warrants sample and the options sample, using Model (13). Model (14) is employed to examine the performance of full sample. Considering positive relationship between efficiency and firm size or liquidity and firm size, we stratify the samples into three firm size groups by market value of firms. Due to high leverage characteristics of derivative warrants and options trading, firm size might pose a much bigger impact on information efficiency for the investors.

Table 9 reports the results for the return predictability from order flows. First, we show that both for warrant market and option market, one-period lagged OI positively and significantly predicts 5 minutes ahead returns, since the coefficients of OI_{t-1} are all positively and significantly related to return r_t in Regression (1). Second, we find the degree of warrant market efficiency is better than option market owing to higher liquidity. The coefficients of $\mathrm{OI}_{t-1} * ILQ$ are positive and highly significant for full sample and options sample, indicating that the return predictability of OI improves during periods of illiquidity. Therefore, illiquidity weakens market efficiency, consistent with the finding of Chordia et al. (2008). The significance and explanatory power of the OI for options samples are stronger than warrants samples, because of larger coefficients, t-statistics and R^2. The significantly negative coefficients on $\mathrm{OI}_{t-1} * wo$ indicate the weaker predictability of the OI in the warrant market than those in the option market. Besides, we suggest that the degree of market efficiency is greater for warrants and options written on the stocks of larger firms. As can we see from the regressions results, the explanatory power of the OI increases accompanied by the shrink in the market value of firms.

[Insert **Table 9** about here.]

Further, we use variance ratios and autocorrelations to ensure robustness of the results above by suggesting that the warrants prices are closer to a random walk benchmark than the options. Table 10 reports our results. Five minutes/daily variance ratios are calculated as the variance of 5-minute returns plus q divided by the variance of daily returns, where q is the number of 5-minute intervals in one day horizon. This measure would converge to 1 for a random walk. Thus, Panel A of Table 10 suggests that the warrants price is closer to a random walk than options. Per hour open/close variance ratios are constructed as (per hour) open-close return variances divided by (per hour) close-open ones. The higher level of this measures, the prices reflect more private information. Panel B of Table 10 shows these ratios are higher for the warrants sample, suggesting the stronger efficiency for the warrant market. Panel C of Table 10 indicates that the one-period lagged price change gains stronger explanatory power in the option markets so that the efficiency of option market is inferior to those of warrant market.

[Insert **Table 10** about here.]

5. CONCLUSIONS

This study set out to explain the paradox that European-style derivative warrants are more expensive than the American-style options given that other elements affecting prices are controlled by using a matched sample of warrants and options written on the individual stocks listed in Hong Kong. The samples of previous research exclude the derivative warrants and options with different exercise-style and concentrate on those written on the stocks index. We use high-frequency tick by tick trade data of the individual stocks warrants and options to explain the paradox thereby making a supplement to the field.

The results demonstrate that the liquidity differences significantly explain the overpricing of the different exercise-style derivatives and the explanatory power is stronger for the out-of-the-money and long-term derivatives group. Many other variables provide explanatory powers, indicating the price differences between derivative warrants and options reflect at least following factors: counterparty credit risk, investors preference, information asymmetry, volatility discovery ability, exercise style, the behavior of market makers and investors sentiment. Our findings add to the literature on the price determinants of derivative assets.

Besides, we conduct additional empirical analyses to further understand the liquidity differences between derivative warrants market and option market. We compare the liquidity differences from daily market-wide perspective, suggesting that no matter in market width, depth or resiliency, the liquidity of derivative warrants market is far better than those of options market for most of the time. Then, we analyze the determinants of market liquidity and find the stronger impact of the interest rate and investors sentiment on the liquidity of derivative warrants market than those of option. The regression results that liquidity and trading volume significantly increase on Tuesdays while Fridays display the opposite pattern indicate that there are strong day-of-the-week effects in derivative warrants market. Furthermore, we use return predictability from order flows and variance ratios to empirically confirm that the degree of derivative warrants market efficiency is better than those of options market owing to higher liquidity.

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APPENDIX A

Table A1 List of the observations and premium proportions of matched warrant and option pairs written on each individual stock

UnderlyCode	Prod_name	Obs	Prem%
700	Tencent Holdings Limited	58692	73.26%
941	China Mobile Ltd.	51297	72.21%
5	HSBC Holdings Plc	37058	75.44%
388	Hong Kong Exchanges & Clearing Ltd	33383	72.30%
2318	Ping An Insurance (Group) Co. of China Ltd.	32292	71.45%
2628	China Life Insurance Company Ltd.	14389	75.68%
1299	AIA Group Limited	7178	74.99%
27	Galaxy Entertainment Group Limited	6513	78.17%
939	China Construction Bank Corp	4797	68.79%
1928	Sands China Ltd.	4438	86.89%
16	Sun Hung Kai Properties Ltd.	2376	84.43%
386	China Petroleum & Chemical Corp.	2271	72.26%
857	Petrochina Company Limited	1863	72.25%
1	CK Hutchison Holdings Ltd.	1858	73.20%
1398	Industrial and Commercial Bank	1517	65.59%
3988	Bank of China Ltd.	956	66.63%
688	China Overseas Land & Investment Limited	770	79.87%
3323	China National Building Material Company Limited	735	64.90%
267	CITIC Ltd.	476	72.69%
914	Anhui Conch Cement Company Limited	429	89.28%
3968	China Merchants Bank Co.	395	56.46%
1088	China Shenhua Energy Company Limited	379	91.03%
1988	China Minsheng Banking Corp.	344	50.29%
1211	BYD Company Limited	281	53.38%
3888	Kingsoft Corporation Ltd.	222	85.14%
1171	Yanzhou Coal Mining Company Limited	214	84.11%
3328	Bank of Communications Co.	174	43.10%
992	Lenovo Group Ltd.	162	90.74%
998	China CITIC Bank Corporation Limited	127	61.42%
2601	China Pacific Insurance (Group) Co.	117	94.02%
728	China Telecom Corporation Ltd.	115	82.61%
2388	BOC Hong Kong (Holdings) Limited	107	74.77%
358	Jiangxi Copper Company Limited	103	90.29%
2888	Standard Chartered PLC	76	82.89%
6837	Haitong Securities Co.	69	100.00%

Table A1, continued			
UnderlyCode	**Prod_name**	**Obs**	**Prem%**
762	China Unicom (Hong Kong) Limited	68	91.18%
902	Huaneng Power International Inc.	63	93.65%
1898	China Coal Energy Company Limited	56	55.36%
1800	China Communications Construction Company Limited	54	90.74%
1359	China Cinda Asset Management Co.	50	36.00%
12	Henderson Land Development Co. Ltd.	45	97.78%
17	New World Development Co. Ltd.	41	53.66%
2333	Great Wall Motor Company Ltd.	38	89.47%
6030	CITIC Securities Co. Ltd.	37	100.00%
1288	Agricultural Bank of China Ltd.	33	78.79%
2328	PICC Property and Casualty Company Limited	26	100.00%
19	Swire Pacific Ltd. - A	22	100.00%
1339	People's Insurance Co. (Gp) of China Ltd	22	63.64%
11	Hang Seng Bank Ltd.	20	80.00%
1186	China Railway Construction Corporation Limited	17	100.00%
6	Power Assets Holdings Ltd.	13	100.00%
66	MTR Corporation Limited	12	100.00%
2	CLP Holdings Ltd.	11	100.00%
135	Kunlun Energy Co. Ltd.	8	62.50%
494	Li & Fung Limited	6	100.00%
23	The Bank of East Asia Ltd.	4	100.00%
2899	Zijin Mining Group Company Limited	4	75.00%
1113	Cheung Kong Property Holdings Ltd.	3	33.33%
1109	China Resources Land Ltd.	2	50.00%

Notes: This is the list of the underlying stocks of matched warrant and option pairs in our samples, which shows the code of underlying stocks, the name of underlying firms, the observations and premium proportions for matched warrant and option pairs written on each individual stock.

Table 1 Summary Statistics

	Mean	*St. Dev.*	*Median*	*Min*	*Max*	*N*
DP	0.206	0.331	0.159	-0.396	1.212	266,828
DRolls	-0.066	0.267	-0.018	-22.608	5.981	266,828
DVol	0.149	0.456	0.020	-0.200	2.582	266,828
DA	-2.826	2.218	-2.756	-14.060	8.142	266,828
CDS	4.785	0.134	4.759	4.561	5.086	266,625
k	-0.056	0.054	-0.048	-0.209	0.043	266,828
m	0.196	0.120	0.178	0.022	0.561	266,828
Vol_Ud	12.715	1.198	12.680	10.150	15.658	266,828
σ	0.171	0.177	0.111	0.020	0.891	260,061
D$\hat{P}$	0.042	0.077	0.012	0.000	0.393	266,824
DLp	-0.103	0.321	0	-1	1	266,828
Ftp	0.025	0.575	0.010	-17.890	16.960	240,620

Notes: Table 1 reports the descriptive statistics of the variables constructed in Section 2.3. We winsorize the variables at the 2% and 98% levels. DP denotes the price premium ratio of derivative pair; DRolls, DVol and DA used to measure liquidity differences represent differences of Roll spread, trading volume and Amihud (2002) measure, respectively. CDS is the measure of counterparty credit risk. k is moneyness and m is maturity, both measuring investors preference. Vol_Ud and σ is the trading volume and volatility of underlying stock, measuring information asymmetry and volatility discovery ability, respectively. D$\hat{P}$ denotes theoretical value differences for derivative pairs. DLp, measuring behavior of market makers, is the difference of absolute order imbalance. Ftp denotes markets' investors sentiment, measured by the net position of futures. The sample period is from July 03, 2012 to November 30, 2016.

Table 2 Overpricing

Panel A: Proportion						
		Calls			*Puts*	
Group	ST	MT	LT	ST	MT	LT
OTM	0.681	0.849	0.943	0.821	0.906	0.980
ATM	0.523	0.668	0.879	0.628	0.729	0.871
ITM	0.428	0.528	0.728	0.505	0.644	0.740
Panel B: Average Premium						
		Calls			*Puts*	
Group	ST	MT	LT	ST	MT	LT
OTM	0.184	0.445	0.882	0.340	0.533	0.877
ATM	0.079	0.329	0.879	0.234	0.495	1.075
ITM	-0.069*	0.157	0.463	0.055*	0.379	0.777
Panel C: Percentage Premium						
		Calls			*Puts*	
Group	ST	MT	LT	ST	MT	LT
OTM	0.223	0.285	0.311	0.399	0.379	0.410
ATM	0.064	0.106	0.121	0.110	0.116	0.142
ITM	-0.014*	0.015	0.045	0.008*	0.048	0.053
Panel D: Observations						
		Calls			*Puts*	
Group	ST	MT	LT	ST	MT	LT
OTM	53103	71404	19840	9749	14932	4054
ATM	47985	24188	4674	4710	2557	730
ITM	5731	1767	551	529	194	130

Notes: Table 2 shows the overpricing of derivative warrants in comparison to options in each moneyness-maturity group, for calls and puts separately. OTM, ATM, and ITM denote out-of-the-money, at-the-money, and in-the-money, respectively. ST, MT, and LT denote short term, medium term, and long term, respectively. Panel A reports the premium proportion of the observations. Panel B and Panel C respectively display the average price premium and average price premium in percentage. Panel D displays the number of observations of the matched derivative pairs.

Table 3 Liquidity difference

Panel A: Proportion							
			Calls			*Puts*	
	Group	ST	MT	LT	ST	MT	LT
$Rolls_{i,t}^{w} < Rolls_{i,t}^{o}$	OTM	0.538	0.608	0.656	0.548	0.597	0.627
	ATM	0.529	0.611	0.682	0.545	0.664	0.564
	ITM	0.563	0.664	0.673	0.573	0.572	0.573
$Vol_{i,t}^{w} > Vol_{i,t}^{o}$	OTM	0.717	0.759	0.716	0.748	0.776	0.736
	ATM	0.665	0.688	0.619	0.672	0.675	0.599
	ITM	0.616	0.599	0.579	0.522	0.546	0.504
$A_{i,t}^{w} < A_{i,t}^{o}$	OTM	0.810	0.905	0.938	0.833	0.952	0.985
	ATM	0.823	0.917	0.936	0.767	0.892	0.962
	ITM	0.875	0.954	0.962	0.908	0.961	0.980
Panel B: Average							
			Calls			*Puts*	
	Group	ST	MT	LT	ST	MT	LT
$-(Rolls_{i,t}^{w} - Rolls_{i,t}^{o})$	OTM	0.061	0.136	0.294	0.059	0.172	0.323
	ATM	0.076	0.192	0.473	0.089	0.335	0.593
	ITM	0.230	0.549	0.648	0.201	0.311	0.531
$Vol_{i,t}^{w} - Vol_{i,t}^{o}$	OTM	0.073	0.281	0.249	0.074	0.120	0.150
	ATM	0.053	0.166	0.144	0.051	0.060	0.045
	ITM	0.027	0.056	0.048	0.018	0.032	0.029*
$-(A_{i,t}^{w} - A_{i,t}^{o})$	OTM	0.041	0.044	0.067	0.043	0.062	0.088
	ATM	0.023	0.033	0.066	0.029	0.063	0.105
	ITM	0.029	0.051	0.105	0.038	0.086	0.108

Notes: Table 3 shows the liquidity difference of derivative warrants in comparison to options in each moneyness-maturity group, for calls and puts separately. OTM, ATM, and ITM denote out-of-the-money, at-the-money, and in-the-money, respectively. ST, MT, and LT denote short term, medium term, and long term, respectively. Superscripts w and o denote warrants and options, respectively. DRolls, DVol and DA measuring the liquidity differences are the differences of Roll spread, trading volume and Amihud (2002) measure, respectively. Panel A and Panel B respectively reports the proportion and the average value of which the warrant liquidity measure is greater than the identical option. $*$ denotes insignificant different from 0 in 5% level.

Table 4 Basic panel regressions

	(1)	(2)	(3)	(4)	(5)
DRolls	-0.077***			-0.071***	-0.057***
	(-12.02)			(-11.01)	(-8.83)
DVol		0.040***		0.029***	0.026***
		(29.65)		(21.75)	(19.60)
DA			-0.014***	-0.012***	-0.008***
			(-28.49)	(-24.72)	(-17.73)
CDS					-0.291***
					(-10.56)
k					-1.892***
					(-44.79)
m					0.454***
					(9.25)
Vol_Ud					-0.010***
					(-10.82)
σ					-0.025***
					(-3.52)
$D\widehat{P}$					-0.092**
					(-2.54)
DLp					-0.005***
					(-3.28)
Ftp					0.005***
					(7.47)
Individual effect	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes
Observations	266,828	266,828	266,828	266,828	234,380
R^2	0.010	0.008	0.018	0.031	0.142

Notes: Table 4 reports the results of basic panel regressions:

$DP_{i,t} = \alpha_i + \beta_1 DRolls_{i,t} + \varepsilon_{i,t}$ (1)

$DP_{i,t} = \alpha_i + \beta_1 DVol_{i,t} + \varepsilon_{i,t}$ (2)

$DP_{i,t} = \alpha_i + \beta_1 DA_{i,t} + \varepsilon_{i,t}$ (3)

$DP_{i,t} = \alpha_i + \beta_1 DRolls_{i,t} + \beta_2 DVol_{i,t} + \beta_3 DA_{i,t} + \varepsilon_{i,t}$ (4)

$$DP_{i,t} = \alpha_i + \beta_1 DRolls_{i,t} + \beta_2 DVol_{i,t} + \beta_3 DA_{i,t} + \beta_4 CDS_t + \beta_5 k_{i,t} + \beta_6 m_{i,t} + \beta_7 Vol\_Ud_{i,t} + \beta_8 \sigma_{i,t-1} + \beta_9 D\widehat{P}_{i,t} + \beta_{10} DLp_{i,t} + \beta_{11} Ftp_{t-1} + \varepsilon_{i,t} \quad (5)$$

DP denotes the price premium ratio of derivative pair; DRolls, DVol and DA used to measure liquidity differences represent differences of Roll spread, trading volume and Amihud (2002) measure, respectively. CDS is the measure of counterparty credit risk. k is moneyness and m is maturity, both measuring investors preference. Vol_Ud and σ is the trading volume and volatility of underlying stock, measuring information asymmetry and volatility discovery ability, respectively. $D\hat{P}$ denotes theoretical value differences for derivative pairs. DLp, measuring behavior of market makers, is the difference of absolute order imbalance. Ftp denotes markets' investors sentiment, measured by the net position of futures. The sample period is from July 03, 2012 to November 30, 2016. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The t-statistics (in parentheses) are adjusted for 12-period lags of autocorrelation using the Newey-West (1987) procedure.

Table 5 Group panel regressions

	OTM (1)	ATM (2)	ITM (3)	LT (4)	MT (5)	ST (6)	Calls (7)	Puts (8)
DRolls	-0.066***	-0.042***	-0.030**	-0.036*	-0.058***	-0.066***	-0.052***	-0.089***
	(-12.09)	(-3.91)	(-2.20)	(-1.67)	(-17.47)	(-6.61)	(-8.17)	(-4.99)
DVol	0.024***	0.022***	-0.003	0.012***	0.014***	0.038***	0.026***	0.014***
	(16.67)	(9.26)	(-0.50)	(6.09)	(11.83)	(8.54)	(18.68)	(3.37)
DA	-0.008***	-0.006***	0.000	-0.004***	-0.006***	-0.006***	-0.008***	-0.007***
	(-14.18)	(-8.76)	(0.13)	(-3.90)	(-11.82)	(-7.70)	(-16.46)	(-5.75)
CDS	-0.437***	-0.029	0.003	-0.248***	-0.387***	-0.150***	-0.258***	-0.507***
	(-11.78)	(-0.70)	(0.04)	(-4.18)	(-11.16)	(-3.50)	(-8.40)	(-8.01)
k	-2.075***	-2.381***	-1.753***	-2.090***	-2.079***	-1.817***	-1.843***	-1.561***
	(-33.66)	(-21.71)	(-2.80)	(-22.80)	(-35.01)	(-24.80)	(-38.23)	(-14.15)
m	0.513***	0.213**	0.412***	0.375***	0.898***	0.653***	0.564***	-0.049
	(7.87)	(2.57)	(3.44)	(3.34)	(12.20)	(6.01)	(10.27)	(-0.46)
Vol_Ud	-0.010***	-0.007***	-0.005**	-0.006***	-0.009***	-0.010***	-0.009***	-0.014***
	(-8.91)	(-5.45)	(-2.06)	(-3.01)	(-7.90)	(-7.21)	(-9.24)	(-6.99)
σ	-0.056***	0.000	0.019**	-0.045***	-0.038***	-0.029***	-0.017**	-0.037*
	(-5.96)	(0.02)	(2.06)	(-3.06)	(-4.20)	(-2.65)	(-2.15)	(-1.82)
$D\widehat{P}$	0.045	0.065	-0.362***	0.038	0.039	0.413	-0.199***	-0.003
	(0.99)	(0.99)	(-3.14)	(0.89)	(0.78)	(1.38)	(-5.02)	(-0.04)
DLp	-0.005***	-0.004**	-0.004	-0.001	-0.002	-0.005**	-0.005***	-0.005
	(-2.76)	(-2.18)	(-1.03)	(-0.45)	(-1.40)	(-2.47)	(-3.20)	(-1.39)
Ftp	0.003***	0.009***	0.001	0.000	0.003***	0.009***	0.007***	-0.011***
	(3.84)	(9.12)	(0.51)	(0.00)	(3.89)	(7.62)	(9.73)	(-5.12)
Individual effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	151,488	74,836	8,056	25,099	100,630	108,651	201,752	32,628
R^2	0.119	0.069	0.019	0.271	0.196	0.093	0.130	0.128

Notes: Table 5 reports the results of group panel regressions:

$$DP_{i,t} = \alpha_i + \beta_1 DRolls_{i,t} + \beta_2 DVol_{i,t} + \beta_3 DA_{i,t} + \beta_4 CDS_t + \beta_5 k_{i,t} + \beta_6 m_{i,t} + \beta_7 Vol\_Ud_{i,t} + \beta_8 \sigma_{i,t-1} + \beta_9 D\hat{P}_{i,t} + \beta_{10} DLp_{i,t} + \beta_{11} Ftp_{t-1} + \varepsilon_{i,t}$$

We repeat the benchmark regression in different moneyness and maturity groups, for calls and puts separately. OTM, ATM, and ITM denote out-of-the-money, at-the-money, and in-the-money, respectively.

ST, MT, and LT denote short term, medium term, and long term, respectively. DP denotes the price premium ratio of derivative pair; DRolls, DVol and DA used to measure liquidity differences represent differences of Roll spread, trading volume and Amihud (2002) measure, respectively. CDS is the measure of counterparty credit risk. k is moneyness and m is maturity, both measuring investors preference. Vol_Ud and σ is the trading volume and volatility of underlying stock, measuring information asymmetry and volatility discovery ability, respectively. D$\hat{P}$ denotes theoretical value differences for derivative pairs. DLp, measuring behavior of market makers, is the difference of absolute order imbalance. Ftp denotes markets' investors sentiment, measured by the net position of futures. The sample period is from July 03, 2012 to November 30, 2016. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The t-statistics (in parentheses) are adjusted for 12-period lags of autocorrelation using the Newey-West (1987) procedure.

Table 6 Fama-Macbeth regressions

	(1)	(2)	(3)	(4)	(5)
DRolls	-0.179***			-0.144***	-0.112***
	(-11.73)			(-8.60)	(-2.74)
DVol		0.061***		0.026***	0.024***
		(5.96)		(5.96)	(4.11)
DA			-0.025***	-0.023***	-0.014***
			(-4.92)	(-5.16)	(-4.86)
CDS					-0.597***
					(-5.02)
k					-2.551***
					(-7.46)
m					-0.248
					(-0.75)
Vol_Ud					-0.015***
					(-3.22)
σ					-0.053**
					(-2.10)
$D\widehat{P}$					0.001
					(0.00)
DLp					-0.012***
					(-5.08)
Ftp					0.006*
					(1.79)
Constant	0.227***	0.233***	0.167***	0.156***	3.129***
	(15.75)	(13.46)	(6.93)	(8.06)	(4.85)
Observations	266,828	266,828	266,828	266,828	234,380
R^2	0.030	0.013	0.054	0.080	0.260

Notes: Table 6 reports the results of monthly Fama-Macbeth regressions:

$DP_t = \alpha + \beta_1 DRolls_t + \varepsilon_t$ (1)

$DP_t = \alpha + \beta_1 DVol_t + \varepsilon_t$ (2)

$DP_t = \alpha + \beta_1 DA_t + \varepsilon_t$ (3)

$DP_t = \alpha + \beta_1 DRolls_t + \beta_2 DVol_t + \beta_3 DA_t + \varepsilon_t$ (4)

$$DP_t = \alpha + \beta_1 DRolls_t + \beta_2 DVol_t + \beta_3 DA_t + \beta_4 CDS_t + \beta_5 k_t + \beta_6 m_t + \beta_7 Vol\_Ud_t + \beta_8 \sigma_{t-1} + \beta_9 D\widehat{P}_t + \beta_{10} DLp_t + \beta_{11} Ftp_{t-1} + \varepsilon_t \quad (5)$$

DP denotes the price premium ratio of derivative pair; DRolls, DVol and DA used to measure liquidity differences represent differences of Roll spread, trading volume and Amihud (2002) measure, respectively. CDS is the measure of counterparty credit risk. k is moneyness and m is maturity, both measuring investors preference. Vol_Ud and σ is the trading volume and volatility of underlying stock, measuring information asymmetry and volatility discovery ability, respectively. $D\hat{P}$ denotes theoretical value differences for derivative pairs. DLp, measuring behavior of market makers, is the difference of absolute order imbalance. Ftp denotes markets' investors sentiment, measured by the net position of futures. The sample period is from July 03, 2012 to November 30, 2016. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The t-statistics (in parentheses) are adjusted for 12-period lags of autocorrelation using the Newey-West (1987) procedure.

Table 7 Summary statistics for market-wide liquidity

Panel A: Warrants Market					
	Mean	*St. Dev.*	*Min*	*Median*	*Max*
Rolls	0.030	0.007	0.020	0.028	0.086
ΔRolls	0.010	0.141	-0.292	-0.004	0.499
A	0.002	0.0005	0.001	0.002	0.006
ΔA	0.012	0.153	-0.281	0.003	0.411
Vol	3,876.599	1,841.178	66.659	3472.71	9,378.99
ΔVol	0.025	0.185	-0.453	0.005	0.864
AveVol	514.151	236.804	105.757	429.1	1,121.712
ΔAveVol	0.009	0.147	-0.325	-0.002	0.532
NumPdt	817.272	299.757	4	852	1,583
Panel B: Options Market					
	Mean	*St. Dev.*	*Min*	*Median*	*Max*
Rolls	0.121	0.035	0.029	0.113	0.205
ΔRolls	0.019	0.194	-0.292	-0.006	0.499
A	0.052	0.011	0.018	0.051	0.076
ΔA	0.015	0.166	-0.281	-0.001	0.411
Vol	150.212	92.826	66.659	124.7	982.611
ΔVol	0.044	0.310	-0.453	-0.0004	0.864
AveVol	28.56	8.86	18.584	26.35	75.635
ΔAveVol	0.021	0.202	-0.325	-0.013	0.532
NumPdt	502.359	152.529	94	470	1,380

Notes: Table 7 reports the descriptive statistics of the market-wide liquidity and trading activity. Rolls, A, Vol are Roll spread, Amihud (2002) measure and trading volume, standing for market width, resiliency and depth respectively. NumPdt stands for daily trading number of products. The prefixes Δ denote the daily change in percentage. Panel A and Panel B report for warrant market and option market separately.

Table 8 Market-wide Time Series Regressions

	Warrants				Options			
	ΔRolls	ΔA	ΔVol	ΔAveVol	ΔRolls	ΔA	ΔVol	ΔAveVol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lag_1	-0.312***	-0.202***	-0.005	-0.272***	-0.361***	-0.269***	-0.326***	-0.377***
	(-10.846)	(-6.674)	(-0.152)	(-9.213)	(-12.586)	(-9.155)	(-11.321)	(-12.984)
Δrf	0.100**	0.138***	-0.026	-0.062	-0.047	-0.008	0.151	0.075
	(2.301)	(2.827)	(-0.442)	(-1.394)	(-0.793)	(-0.151)	(1.582)	(1.184)
ΔCDS	-0.082	0.046	0.066	-0.159	-0.045	0.274	0.339	0.342
	(-0.459)	(0.229)	(0.274)	(-0.871)	(-0.184)	(1.259)	(0.865)	(1.317)
HSI	-0.084	-0.120*	-0.020	0.085	-0.087	-0.038	-0.297**	-0.040
	(-1.540)	(-1.950)	(-0.276)	(1.534)	(-1.164)	(-0.570)	(-2.486)	(-0.505)
HSI_vol	0.107***	0.113***	0.091***	-0.011	0.093***	-0.046**	0.299***	0.051**
	(6.778)	(6.297)	(4.332)	(-0.705)	(4.331)	(-2.380)	(8.604)	(2.213)
HSI_r	-0.280	0.064	-1.358**	-2.016***	-2.343***	-3.136***	-0.148	0.208
	(-0.555)	(0.112)	(-2.008)	(-3.897)	(-3.391)	(-5.103)	(-0.133)	(0.283)
HSI_r5	0.366	-1.166	0.965	2.649***	-0.268	0.851	-0.136	-0.880
	(0.396)	(-1.114)	(0.779)	(2.801)	(-0.212)	(0.756)	(-0.067)	(-0.656)
HSI_σ	-2.631**	-5.100***	-1.256	3.068**	-2.019	-1.420	-7.695***	-0.956
	(-2.065)	(-3.541)	(-0.736)	(2.358)	(-1.158)	(-0.917)	(-2.752)	(-0.518)
ΔFtp	-0.022	0.126*	-0.165**	-0.175***	0.073	0.168**	0.206	0.047
	(-0.372)	(1.923)	(-2.125)	(-2.939)	(0.920)	(2.388)	(1.623)	(0.559)
Monday	0.031**	-0.018	0.098***	0.062***	0.060***	-0.028*	0.032	-0.002
	(2.356)	(-1.227)	(5.618)	(4.658)	(3.379)	(-1.799)	(1.115)	(-0.100)
Tuesday	-0.048***	-0.068***	0.107***	0.096***	-0.025	-0.027*	0.083***	0.053***
	(-3.771)	(-4.722)	(6.227)	(7.318)	(-1.418)	(-1.753)	(2.949)	(2.839)
Wednesday	-0.022*	-0.027*	0.053***	0.056***	-0.024	-0.036**	0.074***	0.029
	(-1.735)	(-1.857)	(3.117)	(4.323)	(-1.380)	(-2.355)	(2.651)	(1.553)
Thursday	-0.003	-0.022	0.052***	0.050***	0.007	-0.027*	0.081***	0.035*
	(-0.270)	(-1.504)	(3.067)	(3.806)	(0.413)	(-1.726)	(2.905)	(1.904)
holiday	0.016	-0.004	-0.103	0.024	-0.067	-0.020	-0.044	-0.005
	(0.173)	(-0.038)	(-0.811)	(0.244)	(-0.512)	(-0.173)	(-0.212)	(-0.038)
holiday_f	0.065	0.023	0.131	0.007	0.154	-0.028	0.188	0.063
	(0.701)	(0.218)	(1.048)	(0.070)	(1.208)	(-0.251)	(0.921)	(0.463)
holiday_p	0.045	0.071	-0.076	-0.156*	0.061	0.085	-0.096	-0.070
	(0.482)	(0.674)	(-0.611)	(-1.647)	(0.477)	(0.749)	(-0.468)	(-0.521)
gdppro	-0.034	-0.045	-0.028	-0.013	-0.083*	-0.049	0.007	-0.009
	(-1.089)	(-1.282)	(-0.670)	(-0.406)	(-1.934)	(-1.287)	(0.106)	(-0.196)
gdppro_p1	0.037*	0.063**	0.033	0.030	0.043	0.037	0.128***	0.072**
	(1.691)	(2.541)	(1.119)	(1.332)	(1.450)	(1.392)	(2.657)	(2.255)
gdppro_f1	0.014	0.018	-0.010	-0.010	-0.034	-0.037	0.011	0.017
	(0.626)	(0.731)	(-0.326)	(-0.466)	(-1.139)	(-1.363)	(0.235)	(0.530)
Constant	-0.404	-0.072	-0.916	-0.783	-0.214	0.979	-0.540	-0.195
	(-0.764)	(-0.120)	(-1.292)	(-1.449)	(-0.296)	(1.522)	(-0.465)	(-0.255)
Observations	1,046	1,046	1,046	1,046	1,046	1,046	1,046	1,046
R^2	0.189	0.122	0.130	0.213	0.197	0.137	0.196	0.171

Notes: The results of daily market-wide time series regressions for the daily change of Roll spread ΔRolls, Amihud (2002) measure ΔA, trading volume ΔVol and average trading volume ΔAveVol separately in warrant market and option samples. Lag_1 denotes the one-period lagged terms. Δrf and ΔCDS are the daily change of overnight Hibor and iTraxx Asia ex-Japan CDS index, respectively. The HSI market index, HSI, the trading volume of HSI constituent stocks, HSI_vol and the concurrent daily return on the HSI index, HSI_r, measure the concurrent daily performance of underlying stock market. Five-day moving average of past returns for the HSI index, HSI_r5, and five-day trailing average of daily absolute returns for the HSI index, HSI_σ, measure historical performance and volatility of underlying stock market. ΔFtp is the daily change of the net position of futures. The dummy variables Monday-Thursday, are 1.0 when the trading day is a Monday, Tuesday, Wednesday, or Thursday, otherwise zero. The dummy variable Holiday, is 1.0 when the trading day is on the one day preceding or following a holiday, otherwise zero. Holiday_f: 1.0 when the trading day is on the one day following a holiday, otherwise zero. Holiday_p: 1.0 when the trading day is on the one day preceding a holiday, otherwise zero. Gdppro: 1.0 when the trading day is on the GDP announcement day, otherwise zero. Gdppro_p: 1.0 when the trading day is one or two days prior to GDP announcement day, otherwise zero. Gdppro_f: 1.0 when the trading day is one or two days following GDP announcement day, otherwise zero. The sample period is from July 03, 2012 to November 30, 2016. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9 Regressions of Return Predictability

Panel A: Warrants sample

	All	Large-Cap	Mid-Cap	Small-Cap
	(1)	(2)	(3)	(4)
OI_{t-1}	0.001***	0.001*	0.001***	0.002***
	(6.862)	(1.740)	(4.116)	(5.656)
$OI_{t-1} * ILQ$	0.000	-0.002*	0.002**	0.000
	(0.681)	(-1.817)	(2.401)	(0.215)
Constant	0.002***	0.001***	0.002***	0.004***
	(15.590)	(4.552)	(9.344)	(12.573)
Observations	266,828	88,936	88,931	88,961
R^2	0.0002	0.00001	0.0004	0.0004

Panel B: Options sample

	All	Large-Cap	Mid-Cap	Small-Cap
	(1)	(2)	(3)	(4)
OI_{t-1}	0.004***	-0.001	0.003***	0.009***
	(10.092)	(-1.106)	(4.829)	(11.943)
$OI_{t-1} * ILQ$	0.009***	0.004***	0.009***	0.015***
	(11.391)	(2.935)	(7.230)	(8.596)
Constant	0.005***	0.004***	0.005***	0.007***
	(15.596)	(7.317)	(9.321)	(10.194)
Observations	266,828	88,936	88,931	88,961
R^2	0.002	0.00001	0.002	0.004

Panel C: Full sample

	All	Large-Cap	Mid-Cap	Small-Cap
	(1)	(2)	(3)	(4)
OI_{t-1}	0.005***	-0.000	0.004***	0.010***
	(16.184)	(-0.508)	(7.684)	(18.530)
$OI_{t-1} * wo$	-0.004***	0.000	-0.003***	-0.010***
	(-10.639)	(0.550)	(-4.626)	(-12.804)
$OI_{t-1} * ILQ$	0.006***	0.002**	0.007***	0.008***
	(11.623)	(2.105)	(8.293)	(8.451)
Constant	0.004***	0.002***	0.004***	0.005***
	(20.638)	(8.521)	(12.497)	(14.260)
Observations	533,656	177,872	177,862	177,922
R^2	0.001	0.000	0.001	0.003

Notes: The results of return predictability from order flows:

$r_t = \alpha + \beta_1 OI_{t-1} + \beta_2 OI_{t-1} * ILQ$ (i)

$r_t = \alpha + \beta_1 OI_{t-1} + OI_{t-1} * wo + \beta_2 OI_{t-1} * ILQ$ (ii)

Model (i) is used for estimations of warrants or options sample. Model (ii) is used for full sample estimations. we stratify the samples into three firm size groups by market value of firms as large-cap, mid-cap and small-cap samples. Dependent variable is the 5-minute return of warrants or options at time t. OI_{t-1} is one-period lagged order imbalance. ILQ is 1.0 if the two markets' daily Roll spread is at least one standard deviation above the average level at the same time and otherwise zero. The dummy variable wo is 1.0 for warrants and zero for options. Panel A, Panel B and Panel C report respectively for samples of warrants, options and both. The sample period is from July 03, 2012 to November 30, 2016. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 10 Variance ratios and autoregressions

Panel A: Five minutes/daily variance ratios			
	Large-Cap	Mid-Cap	Small-Cap
Warrants	7.16	6.19	5.72
Options	32.06	33.16	43.40
Panel B: Per hour open/close variance ratios			
	Large-Cap	Mid-Cap	Small-Cap
Warrants	7.82	10.98	7.36
Options	1.68	1.58	1.28
Panel C: First order autoregressions of daily price change			
	Coefficient	t-statistics	R^2
Warrants	-0.21	-6.79	0.04
Options	-0.27	-8.99	0.07

Notes: Table 10 shows the variance ratios and autoregressions results of derivative warrants and options in each firm size group. Panel A reports the ratio of five-minute return variance to open-to-close return variance. Panel B presents (open-to-close)÷(close-to-open) per hour return variance ratios. Panel C reports the regression outcome of first order autoregressions of daily price change.

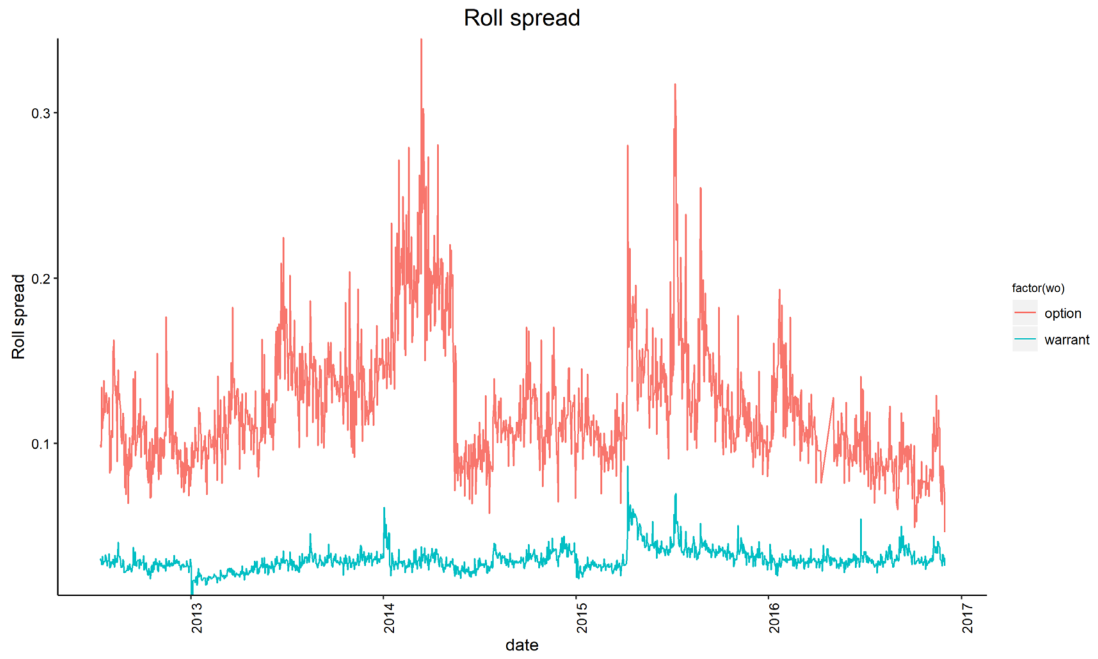

Figure 1 Market-wide Roll spread differences

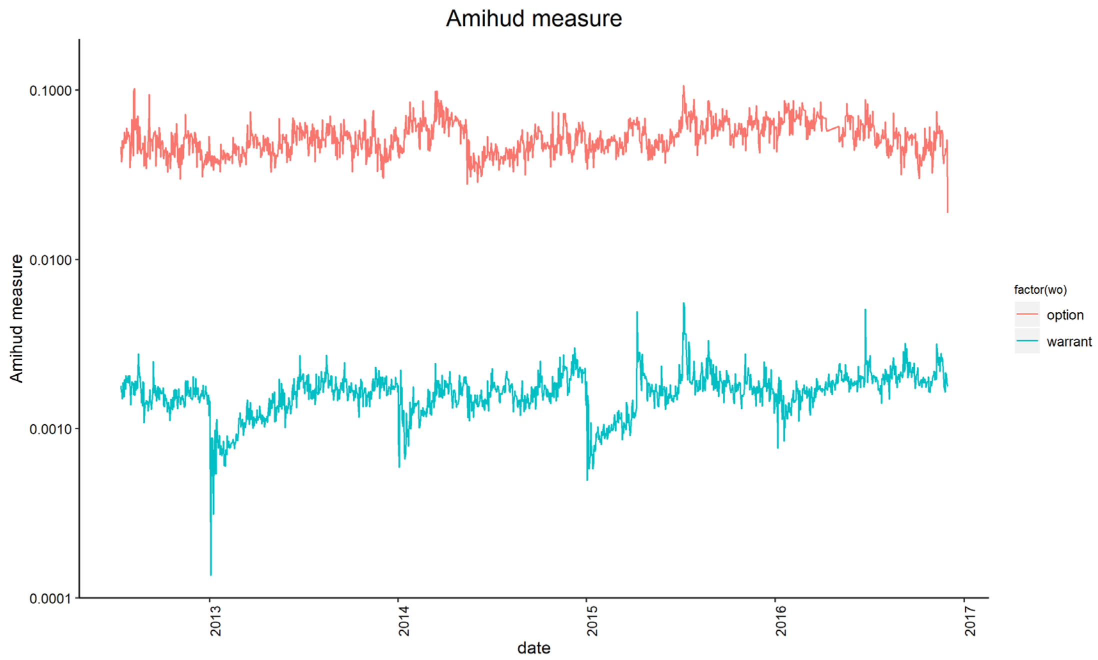

Figure 2 Market-wide Amihud (2002) measure differences

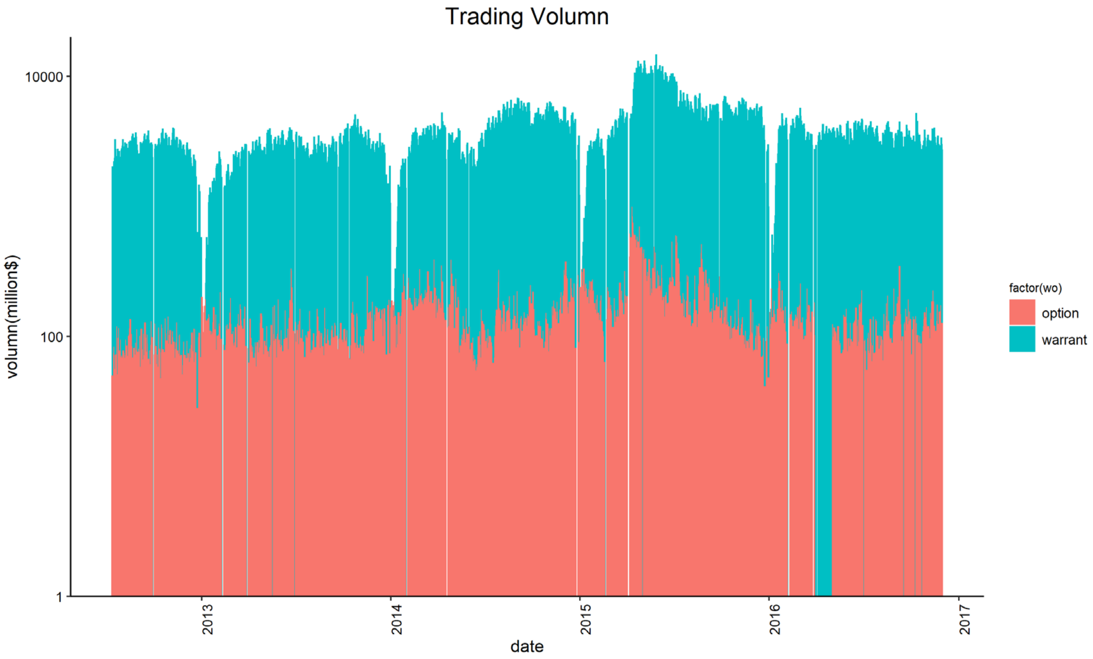

Figure 3 Market-wide trading volume differences in millions of Hong Kong Dollars

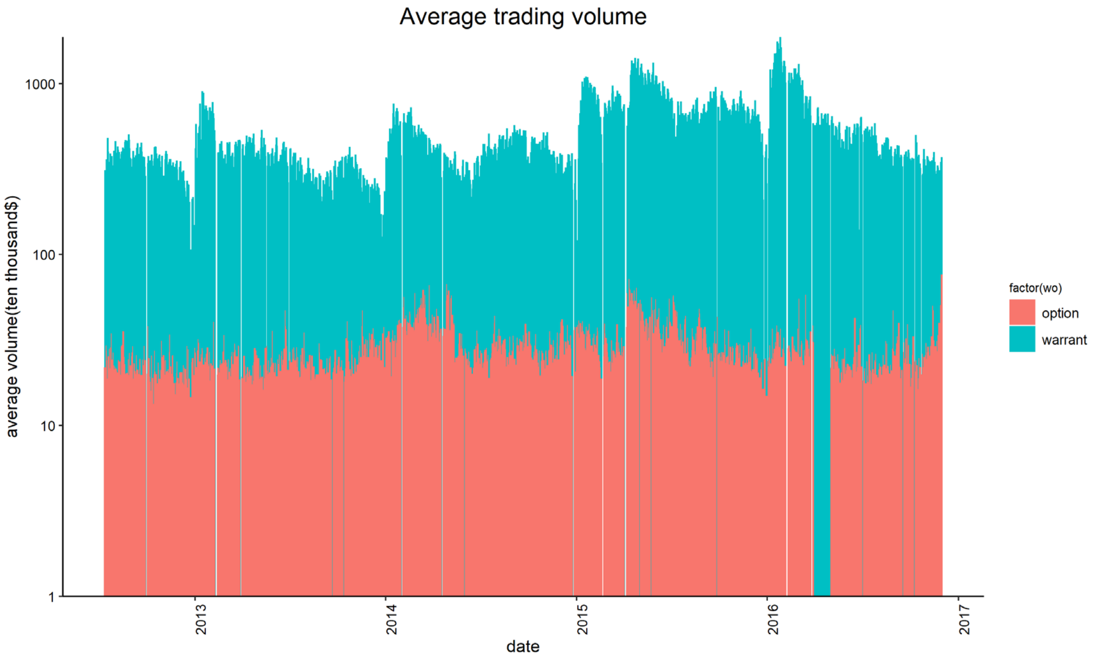

Figure 4 Market-wide average trading volume differences in ten thousand of Hong Kong Dollars

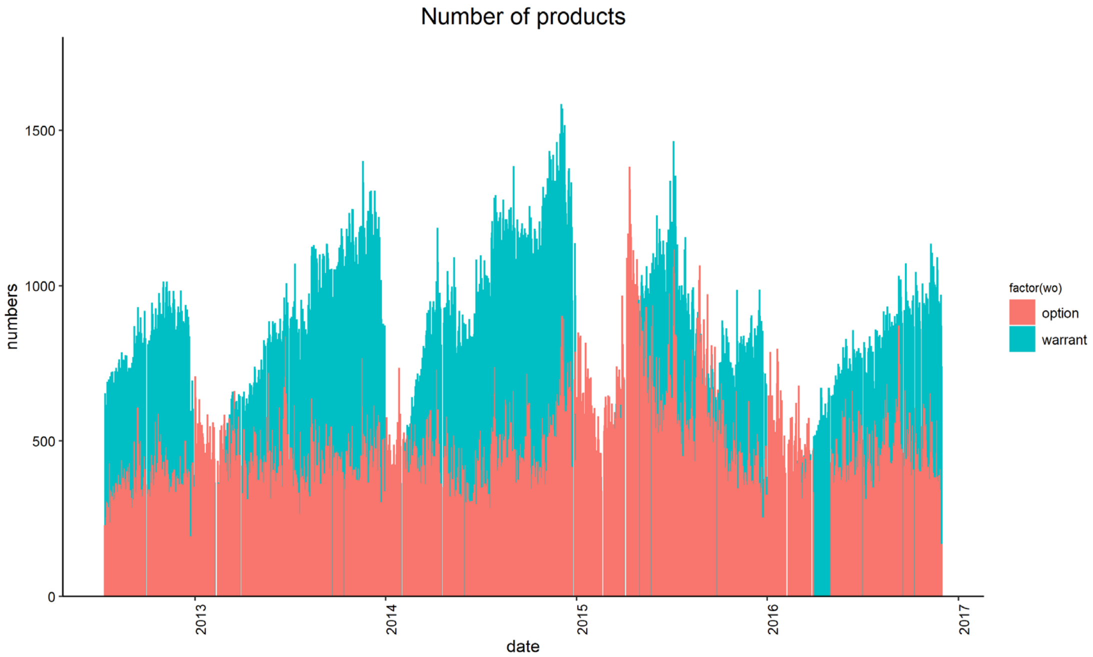

Figure 5 Difference of daily trading number of products