The Role of Issuers' Credit Ratings in Warrants Pricing Errors

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Abstract

The paper provides evidence that the third-party issuer's crediting ratings relate to pricing errors for warrants traded in Taiwan, after considering market trading activities and improved pricing models. The results show that, other than the consideration of pricing models, the credit ratings of issuer and market transactions affect pricing errors as well.

Keywords: Covered **w**arrants, Credit ratings; Pricing errors

JEL Classification: F31, G13

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1. Introduction

Unlike U.S. warrants which are issued by the underlying stock companies and usually combined with a bond (warrant-linked bond), covered warrants, a kind of securitized option, (banked-issued warrants or third-party warrants, referred to warrants hereafter), in Taiwan are issued by a third party, a financial intermediary, on the shares of an unrelated company stock, a basket of companies' shares or an index.[1] Warrants are more appealing to security traders in terms of the volume of issues and transactions, when they were first allowed to be listed in the Taiwan Stock Exchange (TWSE) and introduced into the security market in 1997.[2]

Since (i) short-selling (i.e., issuing) warrants is impossible for individual investors, (ii) no margin accounts are required, and (iii) the size of the contract is much smaller than those in the options markets, warrants are more attractive to stock options for investors in Taiwan. Moreover, the crucial difference between warrants and options is that the former are issued by qualified securities intermediaries, overseen by the TWSE, and the later is offered by the Taiwan Futures Exchange (TAIFEX), who actively lists three (the next two quarterly months) or five (including the spot month and the next two calendar months) in-the-money and out-of-the-money series accompanied with the index or price level, respectively. In other words, the TAIFEX will regularly list options on the TWSE index and others, such as the TWSE electric or financial indexes and individual stock options, when specific options are approaching their maturity dates. In contrast, the issuers of warrants are financial institutions which not only play important roles in pricing and distributing an IPO of warrants but also act as a potential link between the before-market pricing and syndication functions with stabilization trading activities.

Warrant issuers are both the liquidity providers (the market-makers) accompanied with managing potential inventory risks, and the largest position owners

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[1] According to Article 4 of the "Taiwan Stock Exchange Corporation Rules Governing Review of Call (Put) Warrant Listings" announced in July, 30, 2007, any enterprise that simultaneously operates underwriting, trading for its own account, and brokerage or intermediary services may apply for approval as a qualified issuer of call (put) warrants.

[2] It is broadly accepted that these warrants are attractive investment vehicles for two reasons: (1). their leveraging effect and limited loss feature make them attractive to aggressive investors; and (2). they can serve as hedging instruments to reduce the risk exposures arising from other related investments. The numbers of warrants listed in the TWSE are from 7 in 1997 to 3,335 in 2007 and related traded volumes in terms of dollars are from 1.96 billion in 1997 to nearly 254 billion in 2007.

participants who could have superiorly asymmetric information relative to their counterparties, who are usually individual investors. However, the activities of warrant issuers before the IPOs and the market maker after warrants are listed are difficult to reconcile with the assumptions that issuers set the exercise price accurately before a warrant is listed and play the role of a market maker after the IPOs of the warrants. It is a challenge to quote the warrant fairly for the counterparty after the warrant is traded.

As a result, the trading activities of issuers may perform the following two opposite functions. One is to act as a market maker that provides immediacy to ensure smooth trading and distributes warrants to earn premiums to manage their inventory risk (Stoll, 1976; Ho and Stoll, 1983; Ho and Macris, 1984). The other is to proprietarily trade to make profit for themselves by their private information and the largest positions of the warrant in the market (Hasbrouck, 1988; Stoll, 1989; Madhaven and Smidt, 1991; Foster and Vishwanathen, 1993). Madhavan and Smidt (1993) find strong evidence of both the inventory and information effects in price dynamics. Recently, literature studies primarily using intra-day evidence have examined the specialists trading behavior.[3] Easley, O'Hara and Srinivas (1998) suggest that an options market with greater liquidity attracts traders to more frequently use this market. They show that the overall fraction of informed traders is high when the leverage implicit in options is large and when the liquidity in the stock market is high. However, Jameson and Wilhen (1992) emphasize the importance of risk management in market making for options specialists. Thus, two alternative trading patterns may appear when the market makers conduct negative or positive feedback trading. While clear evidence would be found in refuting the third objective, the first two objectives may not be mutually exclusive in nature. Moreover, Prior literature also suggests that very limited information trading can be found in the options market due to its relatively low liquidity (Chan, Chung, and Johnson, 1993; Chan, Chung and Fong, 2002).

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[3] For example, in the stock market, Hasbrouck and Sofianos (1993), Madhavan and Smidt (1993), and Madhavan and Sofianos (1998) use NYSE data; Hansch, Naik, and Viswanathan (1998), Reiss and Werner (1998), and Naik and Yadav (2003) hire LSE data; Mann and Manaster (1996) reference the futures market data; Garleanu, Pedersen, and Poteshman (2005) use the options market data; Lyons (2001) and Cao, Evans, and Lyons (2006) utilize foreign exchange data to explain the two effects.

In short, smooth trading in the warrant market may add to the depth of the market which eventually leads to the issuance of more warrants. Issuers who have charged a premium when the warrants were listed have inventory costs as liquidity providers after the warrants were issued. In contrast, issuers who could be viewed as informed traders gain abnormal profits since the market is a monopoly with a specific warrant between the issuer and other traders, especially to those who are individual investors. The structure of the Taiwan warrant market is similar to a monopolistic competition, a kind of imperfect competition, among the issuers for those warrants that target the same underlying stock with different exercise prices and time to maturity. Warrants, issued by many issuers, with similar contract-specific characteristics, such as the underlying stock, moneyness, remaining time to maturity and a multiplier, have distinctive turnover rates and premiums.

In the paper, we use the credit rating as proxying the warrants issues' quality to identify how the credit rating affects the warrant pricing errors underly controlling the characteristics of issuers, different pricing models and market activities. The "Issuers Quality" mentioned in the paper is similar to the analysts' positive or negative reports to one security. Quality, similar to other fields, such as (1) entrance exams of university, (2) papers are considered to be accepted or not, (3) a security can be open listed or not..., et., al., is defined based on many dimensions. In the paper, quality is proxied by just one factor, credit rating, which is evaluated (rating credit, scores, or quality) by the third parity, China Trust Evaluation Company. CTEC also evaluates all corporations listed and traded in the TWSE and provide the ratings to the banking systems as a reference to decide the loan is passed or not and what the loan interest rates is. Moreover, for the pricing errors, the variable, default risk, and another variable, credit ratings, both can measure the metaphysical the term "quality". Credit rating is evaluated by CTEC, who considers more factors, such as earnings, the ability to loans interests coverage rate, debt/assets ratio,...et, al.. Thus, default risk is included in the credit rates.

Based on the literature studies discussed above, we discover whether the issuers are more likely to buy (sell) calls or sell (buy) puts. Does the market go up (down), as a typical market stabilization reaction, by negative feedback trading rather than through witnessed positive feedback trading, or does it support a hypothesis that issuers are trading to provide immediacy to the market? Other than in the case of providing immediacy, they may trade in positive feedback either for information reasons or rather simply that they trade to manage their inventory risk. Thus we use other derivatives, the warrants which can contribute to the fields in this paper.

After reviewing the report of the listed warrants on the *Market Observation Post System* disclosed by the TWSE from 1999 to 2008, we found many interesting findings as follows. First, warrants, issued by qualified issuers, have distinct theoretical premiums and *ex ante* return patterns on the same underlying stock with a similar exercise price and maturities when all other conditions are equal. However, warrants issuers could act with a phenomenon of a hot issuing period viewed as a kind of herding effect, when the market atmosphere is favorable to them. We investigate the quality of liquidity in terms of the liquidity ratio of the warrant trades and other measureable proxies, and decompose the pricing errors from the contract-specific characteristics and functions of liquidity providers performed by issuers and issuer-specific identities. We also test how the degree of warrant pricing errors disturbed by the issuers' credit evaluations in the Black-Scholes model (1973, hereafter B-S) and modified B-S models, Hseton's (1993) stochastic volatility model (SV) and the Bates' SV with jumps model (1996, SVJ). Finally, we use a comprehensive sample of call and put warrants, accounting for 7089 warrants and value them up to 1.2 trillion N.T. dollars, traded in the TWSE from 2004 to 2008. We contribute to the academic literature on the options pricing algorithms[4] and to identify issues' asymmetric information problems among the counterparties of warrant traders.

We believe that all participants, including the issuers and other investors, are well-behaved. This is especially valid for the issuers who are viewed as an informed audience and are those who own the largest position of the warrants that they themselves have issued. But, if the issuers have a motivation to own the most "chips"

[4] One of the most important concerns is to find the formulated-issue price set by the issuers before the warrant is allowed to be listed in the market. Empirical evidence of the literature related to the options pricing models, basing on Black-Scholes type and extending to those whose volatility are stochastic (SV), SV with jumps in the returns process (SVJ) and SV with stochastic interest rates (SVSI), have been shown to have largely improved performance both for in-sample pricing fitness and for out-of-sample forecasting. This applies although the empirical results of the deep out-of-money cases, especially on shorter period to maturity are still slightly disappointing. (Melino and Turnbull, 1990; Day and Lewis, 1992; Rubinstein, 1994; Bakshi, Cao, and Chen, 1997; Nandi, 1998; Bates, 1996 and 2000; Lin, Strong and Xu, 2001; Bates, 2003; Chen and Gau; 2008, and among others)

in this game with their counterparts, they usually are individual investors. It is doubtful that the warrant markets are fair. This proposition is proven by this paper. We find that when the credit ratings of warrant issuers are evaluated from the B to A class, the pricing errors will reduce from 1.9% (in the Rubber Industry, 21) to 8.3% (in the Food Industry, 12), and on average 6.32% falling of the errors in terms of the total markets under controlling the characteristics of the warrants and trading activities in warrant market. Moreover, we find that the issues of options pricing errors from the asymmetric information problem perspective for the counterparties of warrant traders. Finally, the paper provides academic practices to learn about the quality of liquidity providers of warrant issuers through a conscientious and careful empirical methodology and carries the achievements beyond the typical options pricing models.

This paper proceeds as follows. Section 2 presents the sample and related data selected criteria. Section 3 describes the empirical methodology. Section 4 is our empirical results. Section 5 provides the conclusions.

2. Data Descriptions and Sample Selection Criteria

We access the daily-closed prices of warrants and the related underlying stocks traded in the TWSE from 2004 to 2008 as our samples.[5] A brief summary of the preliminary data is shown in Table 1. We can find that the warrants market exhibits higher action from 1999 to 2008 in terms of (i) trade volume, measured by values and units, (ii) the numbers of issues and (iii) the ratio on the values of warrants to the total security market. The total traded values of warrants occupy .22% and .77% for the market in 1999 and 2008, which shows that the warrants market is flourishing in trades.

< Insert Table 1 about here>

In terms of the accuracy of the empirical studies, we discard the uninformative options records through the following criteria. First, we use the daily traded warrants

[5] Since the numbers of listed warrants are 7 and 14 in 1996 and 1997 and the related trade volumes occupied is less compared to those after 2004, we exclude the samples of these years.

with maturities greater than five calendar days to expiration as our samples. This is appropriate since the price of the warrants; especially for the deep out-of-money cases whose maturity date is less than five calendar days is erratic. Second, warrants violate the European-style boundary conditions. For example, the condition is $C < S - Ke^{-r\tau}$ for all call warrants. And finally, the daily warrants with the strike/spot price ratio (moneyness, denoted as S/K for call warrants, K/S for put warrants) are from 0.5 to 1.5. After discarding data by the criteria discussed above and considering the underlying stocks listed and traded in the TWSE market, the total sample includes 1,122 warrants, issued by 19 financial institutions, with 493,613 daily trading records in our study.

As for the risk-free rates, similar to the popularly cited literature (for example, Bodurtha and Courtadon, 1987; Bates, 1996; and Sarwar and Krehbiel, 2000), we use the yield on the U.S. treasury bills with maturity closest to the option maturity date as the risk-free interest rates. We use the monthly deposit interest rate averaged from the one-month Board Rate[6] (rolled over each month), calculated from the average on the five major commercial banks including, The Bank of Taiwan, Taiwan Cooperative Bank, First Bank, Hua Nan Commercial Bank and Chang Hua Bank which are disclosed on the website for the Central Bank of the R.O.C. from 2004 to 2008 as the proxy for a risk-free rate. Credit ratings of the issuers are collected from the reports disclosed by the Taiwan Ratings Corporation and the Fitch Ratings Limited Taiwan Branch, respectively. The daily percentage liquidity ratio of warrants, trade volume in terms of ten thousand NTD, and moneyness are collected from the Taiwan Economic Journal (TEJ) database and calculated based on the empirically operated definition discussed in detail for the next section. In order to verify the pricing errors and warrants to obtain an initial view, we first show the warrant pricing errors, and the difference between the daily closed price and theoretical option price estimated from the B-S model, on eighteen industries in Table 2.

< Insert Table 2 about here >

From Table 2, we can find that the warrant underlying “the electronic parts or

[6] Interest rates are published on the Central Bank website.

semiconductor industries (the first two SIC codes 23 and 24)" occupied approximately 30.29%, and "the financial and insurance industries (the first SIC code 28)" which occupied about 11.45%, are the most favorable industries that issuers are interested in. The average pricing error of the total market is about 0.301 NTD with a standard deviation of 0.555. The results of the options pricing errors, with a difference between the daily closed price and a theoretical option price estimated from the B-S model, is similar to when the literature shows that pricing errors have a skewing to the right, an estimated value of 6.735 and lepto-kurtosis, an estimated value of 122.973 in the studies, which are both a mostly contributed by the "the electronic parts or semiconductor industry" with a skewness value of 7.530 and a kurtosis value of 134.578. Table 2 shows that the B-S model could be a biased estimator when we calculate the theoretical price of a warrant, since most of the sample are the out-of-money type which shows a right-skewness pattern. An unconsidered fact is that the volatility pattern of underlying assets is stochastic and the volatility clusters could have a jump-phenomenon in which the kurtosis of pricing errors is loptic. Thus, we use another two SV and SVJ models in this study for the sake of controlling for the pricing errors caused from the third and fourth moments and then focus on discussing how the credit rating and related microstructure variables affect the pricing errors of the warrants.

3. Methodology

To investigate how the credit rating and the functions of the liquidity provider of warrant issuers affect the warrant pricing errors, we control the major cause of option pricing error sources from the underlying asset price dynamics and volatility pattern based on the studies of alternative option pricing models.

Option pricing models first originated with the B-S (1973) have witnessed an explosion of new approaches. Since many literature studies show the B-S model is subject to systematic biases originated from the violation of the normal distribution assumption on the underlying returns. The negative implicit skewness will cause the out-of-the-money option price bias, whereas the implicit leptokurtosis will raise the prices of deeply in-the-money and out-of-money options and lower the prices of the near-the-money options. The first innovation of the underlying price process is induced of the stochastic volatility (SV) option pricing models, such as Hull and While (1987), Scott (1987), Wiggins (1987), Melino and Turnbull (1990), and Heston (1993), who incorporate the leptokurtosis or excess kurtosis of the underlying asset returns by allowing the volatility process to behave randomly.[7] Moreover, unlike the viewpoint of Merton (1976a) who assumes that the jump risk is diversifiable and therefore nonsystematic, Bates (1991) deals with the jump risk as systematic and provides a European options pricing model which can capture stochastic skewness by randomizing the mean jump size parameter and the correlation parameter between the return and the stochastic volatility process. This is offered in an empirical study based on the closed form solution of Heston (1993) with a diffusion-jump stochastic volatility process (SVJ).

Bakshi, Cao and Chen (1997) evaluated the relative in-sample fitness, out-of-sample pricing and hedging performances for the S&P 500 index options among various options pricing models, including the SV, the SVJ, and the SV with stochastic interest option pricing models and suggest that the options pricing model of the SVJ performs best with the SV and the SV with the stochastic interest model. They argued that jumps included in the return processes play important roles in pricing options, although the jump effect is not a significant factor in option hedging strategies. Thus, for the sake of accurateness of theoretically estimated prices of warrants we use three approaches to estimate the pricing errors of warrant i in day t, $e_{i,t}$, defined by the difference between the market and model prices, among alternative pricing models, stated as B-S, SV and SVJ. We investigate how the issuers' credit ratings and trading activities disturb the pricing accuracy under the above three theoretical models.

B-S (1973) assumed that the volatility of the returns is constant and used the concept of hedging portfolios formed by options and their underlying stocks to derive the non-dividend European options theoretical valuation-formula as,

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[7] Black and Scholes (1973) assumed that the source of volatility risk comes from stochastic returns, however, the SV option pricing models allow the pricing risk to come from both the stochastic process of price and the stochastic process of volatility. To model the stochastic process of volatility in the SV option price, one has to specify the market price of volatility risk, the volatility of variance, and the correlation between underlying price (return) and related volatility.

$$C(S,\tau) = SN(d_1) - Ke^{-r\tau}N(d_2), \tag{1}$$

where $d_1 = \dfrac{\ln(S/K) + [r + 0.5\sigma^2]\tau}{\sigma\sqrt{\tau}}$; $d_2 = d_1 - \sigma\sqrt{\tau}$; S, K, σ , and $\tau \equiv T - t$ represent the spot rate, exercise price, the constant volatility of the spot return, and the time to maturity, respectively. According to the put-call parity, the European style put option can be obtained as follows:

$$P(S,\tau) = Ke^{-r\tau}N(-d_2) - SN(-d_1). \tag{2}$$

Many studies, such as Bollerslev, Chou, and Kroner (1992), Heieh (1989), Taylor and Xu (1994) and Poon and Granger (2003), have argued that the volatility of returns on underlying assets follows a stochastic process. Specifically, the tails of the distribution computed with intraday or daily market prices are fatter than those of the lognormal distribution, exhibiting leptokurtosis (Gesser and Poncet, 1997). Thus, the estimated implied volatility from the constant volatility assumption from the B-S model has been shown a biased estimate. Various stochastic volatility option pricing models, such as those derived from Hull and While (1987), Scott (1987), Wiggins (1987), Melino and Turnbull (1991), Heston (1993), and Bates (1996), were developed to release the unrealistic assumptions and the constant return volatilities. The return distributional assumption that includes stochastic volatility and the jump process for stocks by Bakshi, Cao and Chen (1997) and for currency prices in Bates (1996), offers a sufficiently versatile structure that can accommodate most of the desired features. Releasing the assumption that the correlation between volatility and the spot return is zero, Heston (1993) obtained a closed-form solution for the European options on an asset, including stocks, currencies and bonds, with a mean-reverting square-root stochastic volatility (SV model).[8] The derivation relies on properties of the conditional distribution and involves numerical integration of the characteristic function of the probability process. The European call options on currency follow:

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[8] Heston (1993) asserted that the correlation between underlying asset returns and its volatility affects the skewness and leptokurtosis of the distribution of the underlying asset returns which follow the risk-neutral pricing probabilities derived by Cox, Ingersoll, and Ross (1985)

$$
\begin{aligned}
C &= e^{-r\tau} E^* \max(S_\tau - K, 0) \\
&= e^{-r\tau} \left[\int_X^\infty (S_\tau - K) f^*(S_\tau) dS_\tau \right] \\
&= S e^{-r_F \tau} P_1 - K e^{-r_D \tau} P_2
\end{aligned} \tag{3}
$$

C, S, and *K* have the same meaning in the Black-Scholes model. In order to get a closed-form solution, Heston (1993) used the Fourier transformation and derived the probability density function P_j :

$$
P_j(x, v, t; \ln[K]) = \frac{1}{2} + \frac{1}{\pi} \int_0^\infty \mathrm{Re}\left[\frac{e(-i\varphi \ln(K)) f_j(x, v, t; \varphi)}{i\varphi} \right] d\varphi, \tag{4}
$$

where j=1, 2, Re indicates the real part of the square bracket, $i = \sqrt{-1}$, $f_j(x, v, t; \varphi)$ represents the characteristic functions of the conditional probability P_j.

$$
P_j = \frac{1}{2} + \frac{1}{\pi} \int_0^\infty \mathrm{Re}\left[\frac{\exp\left(-i\varphi \ln(K)\right) \cdot f_j}{i\varphi} \right] d\varphi, \quad j = 1, 2 \tag{5}
$$

where f_j, $j = 1, 2$ is the characteristic function of the parameters set, $\varphi = \{\kappa^*, \theta^*, \sigma_v, \rho\}$.[9]

Under the risk-neutral measure, Bates (1996) proposed a model which combined the concept of stochastic volatility (Heston, 1993) to catch the “skewness premium” with the jumps process (Merton, 1976) to price the possibility of the jump risk in security price dynamics. The Bates’ (1996) stochastic volatility with the jumps option pricing models (SVJ) and can also use the Fourier transformation and derive the probability density function P_j :[10]

$$
P_j(x, v, t; \ln[K]) = \frac{1}{2} + \frac{1}{\pi} \int_0^\infty \mathrm{Re}\left[\frac{e(-i\Phi \ln(K)) f_j(x, v, t; \Phi)}{i\Phi} \right] d\Phi, \tag{6}
$$

where j=1, 2, Re indicates the real part of the square bracket, $f_j(x, v, t; \Phi)$ represents

[9] See Heston (1993) for more details on the derivation of the characteristic functions.
[10] See Bates (1996), and the proof in appendix of Bakshi, Cao, and Chen (1997) for more details on the derivation of the characteristic functions.

the characteristic functions of the conditional probability P_j and $\Phi = \{\lambda, \mu_J, \sigma_v^J, \kappa_J^*, \theta_J^*, \sigma_v, \rho_J\}$ are the set of parameters. Given the no-arbitrage condition and the price of a call option, C, we can use the put-call parity to obtain the European put option price as follows,

$$P = C - S + Ke^{-r\tau}. \tag{7}$$

In short, we use the SV (Heston, 1993) and the SVJ (Bates, 1996) models to explore the stock price processes implicit in the options and their relative effect of volatility and jumps in the option pricing literature, against the B-S model to study how the extra potential sources, specifically from the aspects of the market microstructure, disturb the warrants prices. Since some of the warrants traded in the TWSE are American style options, we employ the quadratic approximation method of Barone-Adesi and Whaley (1987) to adjust the early exercise premium to derive a more accurate empirical study.[11] To explore and obtain the warrant pricing errors caused from other sources not discussed in the option pricing models, we first control the volatility and jump effects among the three alternative options pricing models, the B-S as a benchmark model, the SV and the SVJ models as competing models for the two effects, reviewed above. The estimated warrant pricing errors are defined as,

$$e_{i,t} = C_{i,t} - C_{i,t}^{\text{model}}, \tag{8}$$

where $C_{i,t}^{\text{model}}$ is calculated from the three models (i.e., the B-S, the SV and the SVJ) and $C_{i,t}$ is the market price.[12] By the put-call parity, the European style put warrant can be obtained. The detailed algorithms are shown in the Appendix. Then we take the pricing errors estimated from equation (8) to examine the relationship between pricing errors and (i) issuers-specifications (credit rating), (ii) characteristics of warrants (maturity, moneyness, and the three implied volatility estimators), (iii) activities of the warrants market (volume and liquidity), and (iv) the function of market making on issuers, as the following regression model,

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[11] Barone-Adesi and Whaley (1987) used the quadratic approximation method to price the American call and put options on an underlying asset with a cost-of-carry rate.

[12] If the warrant is the American type, we use the quadratic approximation method of Barone-Adesi and Whaley (1987) to adjust the early exercise premium to derive a more accurate empirical study.

$$e_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 \tau_{i,t} + \beta_3 IV_{i,t} + \beta_4 Mony_{i,t} + \beta_5 Volume_{i,t} + \beta_6 ALR_{i,t} + \beta_7 (\ln r_{C_{i,t}} / \ln r_{S_{i,t}}) + \varepsilon_{i,t} . \quad (9)$$

The subscript i and t represent the i^{th} warrant on date t. $CR_{i,t}$, is a dummy variable of the credit rating on the warrant issuer. If the credit rating is less than the A class, then the value is equal to one, and otherwise the value of the dummy is 0. The number of warrants and issuers' credit ratings is shown in Table 3. Three contract-specific variables, $Mony_{i,t}$, $\tau_{i,t}$, and $IV_{i,t}$ are measured in one hundred trading days, as the moneyness, defined as $S_{i,t}/K_i$ for the call warrant, and the remaining time to expiration for the i^{th} warrant in day t, and the implied volatility implicit in the B-S, the SV and the SVJ models, respectively. $Volume_{i,t}$ is the trading volume in terms of 10 thousand NTD. We use the variable $ALR_{i,t}$, which is on one thousand units (NTD), to investigate the functions of the liquidity provider of the issuers after the warrants are listed to be traded. The independent variable, $ALR_{i,t}$, is the daily liquidity ratio of a warrant and we plan to use other popular measures used in the market microstructure literature, the Amivest Liquidity Ratio (Groth and Dubofsky, 1984; Cooper, Groth and Avera, 1985; Amihud, Mendelson and Lauterbach, 1997; Berkman and Eleswarapu, 1998) shown in equation (10).

$$ALR_{i,t} = \frac{C_{i,t} \cdot Volume_{i,t}}{\left| \dfrac{C_{i,t} - C_{i,t-1}}{C_{i,t-1}} \right|}, \quad (10)$$

where, $C_{i,t}$ ($C_{i,t-1}$) and $Volume_{i,t}$ represent the call/put warrant i closing price and daily trade volume at day t (t -1), respectively.

< Insert Table 3 about here >

Finally, even if a premium has been charged when the warrants are issued, but the issuer still has inventory risk when the price of underlying stock rises. In advanced, the structure of a listed warrant is similar to a monopoly market between the issuer and other traders, especially to those who are individual investors. The issuer, viewed as an informed trader, has an incentive to gain abnormal profits for himself. To investigate whether or not the issuer manipulates the price of the warrants, we use a ratio, in terms of percentage, on the daily return of the warrant to the underlying stock.

$$\ln r_{C_{i,t}} \Big/ \ln r_{S_{i,t}} , \tag{11}$$

where, $\ln r_{C_{i,t}}$ and $\ln r_{S_{i,t}}$ are the nature-log daily return of the i^{th} warrants and underlying stock, respectively, on date t.

4. Empirical Results

4.1 Primarily Results

To investigate the pricing errors shown in Table 2, we present the summary in eighteen classified industries and whole sample to roughly view the pricing error patterns based on the B-S model.

< Insert Table 3 about here >

Table 3 summarizes the statistics of the variables used in the paper. The first and most important variable, the credit rating of warrant issuers, is defined as a binary variable, which is equal to 1, if the credit rating is less than the A class, and otherwise the value of the dummy is 0. There are 918 warrants, including 403,448 trading records, issued by the A (and the above A) classes from 14 security companies. There are 204 warrants, which include 90,165 trading records, issued by B (and below B) classes from five security companies, respectively.[13] Table 4 shows descriptive statistics for the other variables. The mean of the implied volatility estimated from the B-S model is 42.35% with a standard deviation of 10.17%, a slightly right skewed, 0.1308, and a platykurtic but near a normal kurtosis of 2.6323. Comparing these statistics with the pricing errors of the total market values shown in the last row of Table 2 tells an interesting phenomenon. The pricing errors have a skewing to the right, an estimated value of 6.735, and lepto-kurtosis, an estimated value of 122.973. If the sources of the warrant pricing errors mainly come from the implied volatility

[13] For the sake of academic neutrality, we do not plan to release the names of the security companies. But if necessary, we will provide the detailed credit ratings data.

implicit in the different models, we would have similar patterns for both pricing errors and implied volatility. However, the distribution patterns between the three implied volatility figures shown in the first row and the pricing errors shown in the middle bottom row of Figure 1 demonstrate many differences. The implied volatility almost shows a normal distribution, but the B-S pricing errors have a uniform distribution. Apparently, it could exist in other factors that could not have been reviewed, which affect the pricing of warrant. Thus, we could preliminarily infer that the source of warrant pricing errors does not only come from theoretical models, but also be originated from other factors, such as trading activities and characteristics if the warrant issuers are discussed in the paper.

< Insert Figure 1 about here >

The trading volume in NTD, used as an activity measure in the last study of our paper, shows an average value of about 9.8 million with a value of standard deviation, 12.90 million. The daily log-return on underlying stocks and warrants both appear in a reverting pattern with a near zero mean. The underlying stock seems to violate about seven times more than the warrants in terms of standard deviations. It also can be proved from both the range of the Max-min values and the estimates of the fourth moment. From the viewpoint of leverage effects, the return process of derivatives would be more in violation than that of the underlying, if it shows one of the clues for discovering the pricing errors on warrant pricing in Taiwan.[14]

Finally, we use the Amivest Liquidity Ratio (ALR) in one thousand NTD to measure the effect of liquidity on the pricing errors of the warrants. The average daily liquidity is about 23.49 thousand with a standard deviation of 113.18 thousand. The ALR liquidity ranges from zero to 16,720.47 thousand and has a skewness of 43.47 and a kurtosis of 4,308.33. Both reveals a fact that most warrants are liquid, but in some cases, especially in the deeply out-of-money and near maturity date cases, they are not liquid. In other cases, especially on the first listed day, they have extreme liquidity in terms of the ALR function with trading values. The trading motivation is

[14] It sounds like an interesting idea to compare the price dynamics of options listed in the TAIFX with those with warrants on the same underlying securities and related compounded securities, such as ETF 50. But for the sake of focusing on investigating how the effects of the issuers' credit ratings disturb the pricing dynamics, these topics are covered in our proceeding working paper.

inspired by issuers who hope to manage the inventory risk they will face in the future.[15]

4.2 Regression Analysis on Decomposing Warrants Pricing Errors

We use equation (10) to investigate how both the credit rating of warrants issuers and trading activities $Volume_{i,t}$, $ALR_{i,t}$, and $(\ln r_{C_{i,t}} / \ln r_{S_{i,t}})$, measure the market making activities of warrant issuers, under the characteristics of a warrant contract, $\tau_{i,t}$ and $Mony_{i,t}$. $IV_{i,t}$ is used to discriminate the pricing errors among the three theoretical models. The empirical results are shown in Tables 5 and 6. The reason why we are using two regressions to analyze the pricing errors is because we firstly use standard measurements, such as time to maturity, implied volatility, trading volumes and moneyness, revealed in options pricing literature and then use the credit rating of the issuers as an interested independent variables to see how the rating of issuers' credit affects the pricing after controlling the explainers argued in the smile and smirk effects.

In Table 5, first, we find consistent results of cross section analysis from the following eight industries, Food (the first two SIC codes, 12), Plastic (SIC: 13), Electric Machinery (SIC: 15), Iron & Steel (SIC: 20), Rubber (SIC: 21), Electronic Parts and Semiconductors (SIC: 23 & 24), Shipping & Transportation (SIC: 26), and Financial & Insurance (SIC: 28). The coefficients are statistically significant all at the 1% level and the positive coefficient on the estimates of credit rating, β_1, shows the hypothesis we discussed in sections 2 and 3. If the credit rating of a warrant issuers is evaluated from the B to A class, the pricing errors will be reduced from 1.9% (in the Rubber Industry, 21) to 8.3% (in the Food Industry, 12), since the *CR* variable is set to 1 if the credit rating belongs to class B.

< Insert Table 5 about here >

Secondly, time to maturity, $\tau_{i,t}$ is ambiguous to pricing errors: Food, Shipping &

[15] In the paper, we wish to use the term, "inventory risk" but not "trading strategy" to convey an idea that we believe all participants, including the issuers and other investors, are well-behaved. However, in practice, if the issuers have a motivation to own the most "chips" in this game with their counterparts, they usually are the individual investors. It is doubtful that the warrant markets are fair.

Transportation, and Financial & Insurance all have a negative coefficient (i.e., the nearer to the maturity date, the greater the pricing errors). Generally, the pricing errors will fall as close to maturity day, since the premium of the warrant, including intrinsic and time value, almost covers its intrinsic value. Thus, in the above situation, the negative coefficients are tricky. We will leave this phenomenon for our further studies.[16]

Thirdly, estimated parameters, β_3 of implied volatility, $IV_{i,t}$, has a consistently negative effect of pricing errors from the highlighted industries of the third column in Table 5. It shows a smile effect in terms of the B-S model, since most of our samples are not at-the-money warrants. One unit of volatility implicit in the market price of a warrant increase will reduce the pricing errors. For example, 28.6% in the Electronic parts and Semiconductor industry, implies a difference between the market price and the theoretical price which falls in the B-S model. In our sample, the Financial & Insurance industry is the most sensitive, with a value of 50%, on the implied volatility to warrant pricing errors. Moreover, the variable, $Volume_{i,t}$, has a positive relationship with pricing errors, which indicate greater trading volumes tends to result in greater pricing errors. This phenomenon is consistent with the argument proposed by Black (1986) and Easley, O'Hara and Srinivas (1998).

Finally, we find statistically significant coefficients between the independent variable, moneyness, $Mony_{i,t}$, and the dependent variable, pricing error, $e_{i,t}$. According to the smile effect of the empirical study in options pricing, the closer the at-the-money warrants are from the out-of-money side, the warrant pricing will reduce according to the smirk effect. But, if the moneyness of a warrant comes from the in-the-money category to the at-the-money or even to the out-of-the-money category as the underlying stock price rises/falls (call warrant/put warrant), the volatility smirk effect will slow the pricing errors. The conflicts discussed above is caused and we don't classify the changing patterns of either the moneyness or the warrant to go near the 1 (at-the-money, i.e., $S_{i,t} = K_i$) or leave from the 1 moneyness.

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[16] We propose that a possible reason could explain the following: negative correlations of the underlying stock prices of these three industries with another five industries. Also, it could be caused by the same inference as stated in footnote 15.

For robustness, we use equation (10) to test whether the B-S, the SV, and the SVJ implied volatility disturbs the results on the issuers' credit ratings, trading activities and warrants characteristics in Table 5 by using total samples. Consistently, the estimated coefficients of explained regressors on dependent variables earn similar results in Table 5, but these parameters are more statistically significant than those in Table 5. The parameters, except for the variable, implied volatility, are indifferent among the three alternative models, the B-S, the SV and the SVJ models.

< Insert Table 6 about here >

The empirical results show both statistically and economically significant-estimated parameters. When the issuer's rating was evaluated from the B class to A class, the pricing errors of the warrant are reduced by approximately 0.0632 NTD. The estimated parameters in the B-S, the SV, and the SVJ models indifferently show both credit ratings, characteristics of warrant contracts, $\tau_{i,t}$ and $Mony_{i,t}$ and trading activities, $Volume_{i,t}$, $ALR_{i,t}$, and $(\ln r_{C_{i,t}} / \ln r_{S_{i,t}})$. The Amivest Liquidity ratio owns a negative correlation that shows the greater liquidity the warrant, the lower the pricing errors. This phenomenon contributes similar evidence to the microstructure literature. The coefficients of daily return of the warrant to the underlying stock are negative and imply the asynchronous and asymmetric patterns on the returns process between the warrants and the underlying stock. A 1% increase (decrease) in the stock price reduces the pricing errors, less than 1% increase (decrease) in a call warrant price. Moreover, we should consider the leverage effect, defined as the asymmetric return changes between the warrant and the related underlying stock in the paper, but we have to include the effect into another available paper.

Different models, in addition to the implied volatility estimated parameters, and other variables parameters remain similar. The main source of warrant pricing errors is the credit rating and market transaction variable. Even the literature, such as the SV, the SVJ and the SV with stochastic interest rate processes, indeed shows an improvement in the options pricing error. However, our results show that the issuers' credit rating and market transaction variables identically affect the pricing errors as improved theoretical models. The SV and the SVJ model can indeed elevate the options pricing performance, but in practice, such as the CBOE's VIX index is not calculated from theoretical models, or even none of the B-S.[17] Our studies do not ignore the contributions from the improvement of pricing models, which consider more precise conditions into the process on model setting, nevertheless, the paper provides other viewpoints which could contribute to the theoretical option pricing model for future reference.

5. Conclusions

In this paper, our major investigation is on the credit rating of warrant issuers and to study the quality of liquidity in terms of the Amivest Liquidity Ratio and other measureable proxies, such as trading volumes and rationing on returns of warrants to stocks, affect warrant pricing errors in the TWSE by decomposing the pricing errors from the contract-specific characteristics, functions of liquidity providers performed by issuers and issuers-specific identities.

We find the credit ratings of warrant issuers are evaluated from the B to A class. The pricing errors will reduce from 1.9% (in the Rubber Industry, 21) to 8.3% (in the Food Industry, 12), and on average 6.32% falling of the errors in terms of the total markets. The parameters, except for the variables, implied volatility, are indifferent among three alternative models, B-S, SV and SVJ models. The variable, time to maturity, is ambiguous to pricing errors. Generally, the pricing errors will fall as it gets closer to the maturity date, since the premium of warrants, including intrinsic and time value, almost includes its intrinsic value. Implied volatility has a consistently negative effect of pricing errors and shows smile effects in terms of the B-S model. Since most of our sample are not the at-the-money warrants, the variable has a positive relationship with pricing errors. This result is consistent with the argument proposed by the Black (1986) and Easley, O'Hara and Srinivas (1998). We find that conflicts occur for the smile effect of empirical studies in options pricing still exist and the volatility smirk effect will slow the pricing errors to be caused by that which we don't classify the changing patterns in terms of raising or falling of the price change on the underlying stock. Moreover, the Amivest Liquidity Ratio shows that the greater liquidity is the warrants, the lower pricing errors they will have. The

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[17] See the VIX White Paper from the CBOE, http://www.cboe.com/micro/vix/vixwhite.pdf.

coefficients of the ratio on daily return of the warrant to the underlying stock are negative and imply that there are asynchronously asymmetric patterns on the returns process between warrants and the underlying stock.

How the credit rating, the quality of liquidity of warrant issuers and the ratio on the daily return of the warrant to underlying stocks disturb the formation of warrant prices, are our core topics in this paper. In this study, we believe that all participants, including the issuers and other investors, are well-behaved. This is especially valid for the issuers who are viewed as an informed audience and are those who own the largest position of the warrants that they themselves have issued. But, if the issuers have a motivation to own the most "chips" in this game with their counterparts, they usually are individual investors. It is doubtful that the warrant markets are fair. This proposition is proven by this paper.

Finally, we investigate how the degree of warrant pricing errors are disturbed by the issuers' credit evaluations by using three option pricing models, the B-S, the SV and the SVJ models under both smile effects across moneyness and the smirk pattern across time to maturity are controlled. We contribute to the academic literature by focusing on the issues of options pricing errors from the asymmetric information problem perspective for the counterparties of warrant traders. The paper provides academic practices to learn about the quality of liquidity providers of warrant issuers through a conscientious and careful empirical methodology and carries the achievements beyond the typical options pricing models.

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Appendix

Presently, the values of volatility in the B-S model and the other parameters of the mean and volatility process implicit in the SV and SVJ models need to be estimated before the theoretical premiums of the warrants are obtained. We first show the algorithm to obtain the volatility estimates and then illustrate the parameters in the SV and SVJ models as follows.

Step1. The history volatility is estimated from three methods. The standard deviation of the return on underlying stocks and the GARCH-families volatility models are proposed by Engle (1982) and extended by Bollerslev (1986).

Step2. To obtain the parameters implicit in the SV and SVJ options pricing models, we sample trades from 2004 to 2008 and use an equally-weighted sum of square errors in day t for the same underlying security for all warrants traded in the market to back out the implicated parameters in the return and volatility processes. Then we use the estimated values as input parameters to the SV and SVJ models to obtain the theoretical price of a warrant.

Step3. Since the estimated values of volatility and parameters in the dynamic return and volatility process of the SV and SVJ models could have small sample biases as the warrant nears its maturity date, we will use a non-parametric bootstrapping approach to overcome the low frequency data problem by drawing samples at random with replacement by performing calculations 100,000 times to obtain a smooth time-matching volatility distribution.

Step4. We match the time to maturity for the estimates of volatility and those of parameters implicit in the SV and SVJ models from *Step1* to *Step3*. For example, one warrant i has a remaining time to expiration, τ, on the underlying stock j in day t. We use the estimated values of historical volatility on the duration t-τ as the input values to calculate the theoretical warrant price. A similar approach is applied to back out the parameters in the SV and SVJ as inputs in the models. According to the time series pricing errors estimated from three alternative models for each warrant, we arrange sample into subgroups based on suitable and reasonable criteria.

Table 1
Issued Numbers and Traded Volumes of Warrants in Taiwan

Year	Numbers of warrants issued		Volume (Trading value in 10 thousands of NTD)		Number of shares traded (in ten thousands)		Ratio of warrant volume divided by stock volume (%)
		Annual growth rate (%)		Annual growth rate (%)		Annual growth rate (%)	
1999	66		64.78		3.81		0.22
2000	103	56.06	162.26	150.48	11.59	204.20	0.53
2001	110	6.80	28.44	-82.47	7.78	-32.87	0.15
2002	158	43.64	74.47	161.85	1.91	-75.45	0.34
2003	408	158.23	118.34	58.91	48.84	2457.07	0.58
2004	480	17.65	207.75	75.55	108.55	122.26	0.87
2005	984	105.00	142.36	-31.48	12.26	-88.71	0.76
2006	1,445	46.85	175.07	22.98	149.12	1116.31	0.73
2007	3,335	130.80	253.18	44.62	259.79	74.22	0.77
2008	5,732	71.87	275.82	8.94	300.08	15.51	2.36

Source: Taiwan Stock Exchange Corporation.

Table 2.

Pricing Errors on Warrants Calculated from Black and Scholes (1973) Model

This table reveals pricing errors, the difference between daily closed price and theoretical warrant prices estimated from B-S model, in eighteen industries.

First two SIC Code	Industry Identity	Numbers of Samples (%)	Mean	Standard deviation	Skewness	Kurtosis
11XX	Cement	7,464 (1.51)	0.281	0.453	2.377	12.891
12XX	Food	10,161 (1.04)	0.238	0.449	2.753	13.712
13XX	Plastic	15,843 (1.63)	0.310	0.494	3.466	18.733
14XX	Textile	8,500 (0.89)	0.283	0.441	3.381	19.306
15XX	Electric Machinery	7,731 (0.82)	0.274	0.344	2.562	12.035
16XX	Electrical & Cable	4,944 (0.53)	0.263	0.372	2.157	7.771
17XX	Chemical Industry	13,035 (1.40)	0.308	0.473	2.728	12.805
18XX	Glass & Ceramic	110 (0.01)	0.426	0.309	0.735	3.211
19XX	Paper & Pulp	1,743 (0.19)	0.238	0.319	3.016	16.156
20XX	Iron & Steel	22,568 (2.46)	0.276	0.403	2.752	13.834
21XX	Rubber	10,418 (1.16)	0.306	0.464	2.804	13.435
22XX	Automobile	5,242 (0.59)	0.266	0.414	3.296	16.006
23XX 24XX	Electronic Parts/ Semiconductor	266,408 (30.29)	0.311	0.626	7.530	134.578
25XX	Building Material & Construction	15,241 (2.49)	0.273	0.455	4.865	50.974
26XX	Shipping & Transportation	29,753 (4.98)	0.261	0.445	5.383	63.401
27XX	Tourism	3,698 (0.65)	0.217	0.275	2.138	12.444
28XX	Financial & Insurance	64,630 (11.45)	0.322	0.490	2.858	14.447
29XX	Trading & Consumers Goods	6,124 (1.23)	0.266	0.573	4.433	32.720
	Market	493,613 (100)	0.301	0.555	6.735	122.937

Table 3.
Numbers of Warrants and Samples Classified by Credit Ratings

Credit Ratings	Numbers of Warrants	Numbers of Observations	Numbers of Issuers
Above (including) A class of issuers on warrant	918	403,448	14
Below A Class rating of issuers on warrant	204	90,165	5
Total	1,122	493,613	493,613

Table 4

Descriptive Statistics

The table reports implied volatilities derived from the Black-Scholes model. Trading volume (in NTD) is used to measure the trading activity of warrants. Daily returns on the underlying stock and respective warrant are reported The Amivest Liquidity Ratio (ALR) in one thousand NTD measures the effect of liquidity on the pricing errors for warrants.

	Mean	Max.	Min.	Standard Deviation	Skewness	Kurtosis
Implied Volatility	0.4235	0.72	0.12	0.10	0.13	2.63
Trading Volume (NTD)	979.82	128,970.00	0.00	1,894.25	9.41	204.62
Return of Stock	-0.00	6.87	-4.88	0.46	6.4007	72.30
Return of Warrant	-0.00	3.16	-3.34	0.07	8.23	293.10
ALR	23.49	16720.47	0.00	113.19	43.47	4308.33

Table 5.

Regression Analysis on Decomposing Warrants Pricing Errors from B-S by Industry

The table report the estimation results for the following regression model:

$$e_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 \tau_{i,t} + \beta_3 IV_{i,t} + \beta_4 Mony_{i,t} + \beta_5 Volume_{i,t} + \beta_6 ALR_{i,t} + \beta_7 (\ln r_{C_{i,t}} \big/ \ln r_{S_{i,t}}) + \varepsilon_{i,t}$$

where $e_{i,t}$ denotes the pricing error for warrant i at date t. $CR_{i,t}$ is a dummy variable for the credit rating of the third-party issuer, and is with value of 1 if the credit rating is less than the A class, 0 otherwise. $IV_{i,t}$ refers to the implied volatility estimated from different option pricing models: Black-Scholes, SV and SVJ; $Volume_{i,t}$ denotes the trading volume. Two contract-specific variables, $Mony_{i,t}$ and $\tau_{i,t}$, represent the moneyness (defined by $S_{i,t}/K_i$ for the call warrant) and the remaining time to expiration, respectively.

Industry	% of Sample	Const.	β_1	β_2	β_3	β_4	β_5	β_6	β_7
11 Cement	1.51%	-0.019	0.012	0.007	-0.041	0.461***	0.224***	-1.039***	-0.716
		(-1.105)	(1.345)	(1.031)	(-1.107)	(92.654)	(10.349)	(-17.457)	(-1.155)
12 Food	1.04%	0.025	0.083***	-0.018***	-0.234***	0.510***	0.173***	-0.967***	-0.785
		(1.341)	(14.003)	(-3.773)	(-6.000)	(133.462)	(11.241)	(-16.574)	(-1.374)
13 Plastic	1.63%	0.103***	0.067***	0.044***	-0.492***	0.541***	0.082***	-0.838***	-0.829***
		(13.920)	(13.084)	(12.496)	(-29.715)	(206.506)	(7.075)	(-13.264)	(-6.971)
14 Textile	0.89%	0.062***	0.012*	-0.048***	-0.169***	0.501***	0.231***	-1.049***	-0.772***
		(3.701)	(1.654)	(-9.601)	(-4.702)	(131.867)	(13.685)	(-22.745)	(-5.214)
15 Electric Machinery	0.82%	0.062***	0.032***	0.052***	-0.255***	0.465***	0.236***	-1.056***	-0.722***
		(5.617)	(5.293)	(13.825)	(-9.646)	(128.038)	(19.375)	(-23.981)	(-6.746)
16 Electrical & Cable	0.53%	-0.015	-0.022***	-0.003	0.033	0.620***	0.031***	-0.766***	-0.941
		(-1.139)	(-4.353)	(-0.831)	(1.035)	(154.068)	(3.060)	(-24.581)	(-0.861)
17 Chemical Industry	1.40%	0.106***	0.000	0.021***	-0.312***	0.468***	0.171***	-0.964***	-0.726
		(10.946)	(-0.057)	(4.772)	(-16.713)	(171.073)	(13.098)	(-20.010)	(-0.880)
18 Glass & Ceramic	0.01%	1.296***	-0.011	0.027***	-0.099***	0.571***	0.124***	-1.644***	-0.762
		(13.965)	(-0.074)	(4.001)	(-14.912)	(52.073)	(10.911)	(-22.614)	(-0.841)
19 Paper & Pulp	0.19%	-0.062***	-0.070***	0.040***	-0.004	0.503***	0.261***	-1.091***	-0.775***
		(-2.693)	(-4.849)	(5.888)	(-0.073)	(60.754)	(11.669)	(-16.087)	(-2.941)
20 Iron & Steel	2.46%	0.008	0.065***	0.036***	-0.220***	0.489***	0.118***	-0.889***	-0.755
		(1.277)	(19.897)	(15.254)	(-14.757)	(249.725)	(18.197)	(-24.225)	(-1.032)
21 Rubber	1.16%	0.081***	0.019***	0.018***	-0.294***	0.484***	0.214***	-1.025***	-0.748***
		(4.980)	(2.864)	(3.684)	(-8.475)	(146.640)	(15.260)	(-25.699)	(-3.175)
22 Automobile	0.59%	0.172***	0.098***	0.002	-0.544***	0.568***	0.105***	-0.870***	-0.867
		(16.201)	(15.022)	(0.385)	(-21.264)	(156.837)	(8.037)	(-19.146)	(-0.203)
23, 24 Electronic Parts/ Semiconductor	30.29%	0.077***	0.057***	0.038***	-0.286***	0.403***	0.200***	-1.005***	-0.634***
		(17.608)	(24.736)	(23.271)	(-31.551)	(443.111)	(42.407)	(-26.761)	(-9.754)
25 Building Material & Construction	2.49%	0.130***	0.090***	0.002	-0.358***	0.528***	0.109***	-0.876***	-0.811***
		(8.397)	(15.363)	(0.441)	(-12.408)	(118.241)	(7.546)	(-17.357)	(-6.380)

26 Shipping & Transportation	4.98%	0.108*** (14.665)	0.065*** (13.519)	-0.013*** (-3.906)	-0.307*** (-21.196)	0.481*** (162.938)	0.207*** (21.470)	-1.015*** (-19.264)	-0.744*** (-4.755)
27 Tourism	0.65%	-0.032*** (-2.761)	0.053*** (8.535)	0.026*** (5.340)	0.032 (1.433)	0.383*** (93.869)	0.165*** (12.999)	-0.955*** (-16.030)	-0.606 (-1.054)
28 Financial & Insurance	11.45%	0.188*** (45.240)	0.019*** (7.948)	-0.014*** (-7.772)	-0.584*** (-60.985)	0.593*** (387.643)	0.163*** (34.478)	-0.952*** (-22.431)	-0.903*** (-6.192)
29 Trading & Consumers Goods	1.23%	-0.235*** (-6.810)	0.129*** (9.115)	-0.015 (-1.288)	0.270*** (4.361)	0.537*** (57.032)	0.154*** (4.376)	-0.940*** (-20.801)	-0.823 (-1.033)

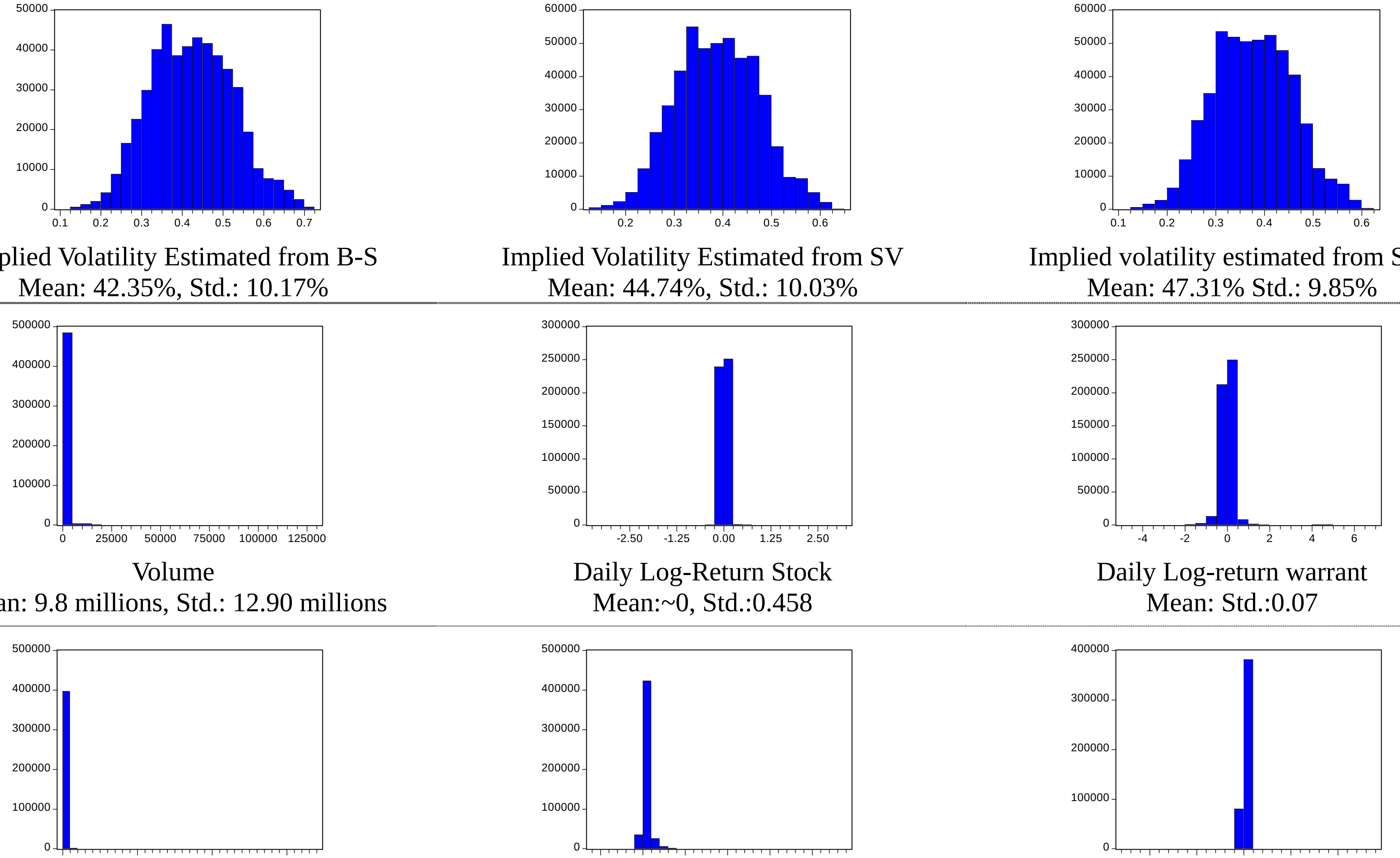
Table 6

Results of the Regression Model Considering Types of Pricing Models, Contract-Specific Features, and Credit Ratings of Issuers

Regression model is, $e_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 \tau_{i,t} + \beta_3 IV_{i,t} + \beta_4 Mony_{i,t} + \beta_5 Volume_{i,t} + \beta_6 ALR_{i,t} + \beta_7 (\ln r_{C_{i,t}} / \ln r_{S_{i,t}}) + \varepsilon_{i,t}$. The subscript i and t represent the i^{th} warrant on date t. $CR_{i,t}$, is a dummy variable of the credit rating of the issuer. If the credit rating is less than the A class, then the value is equal 1, otherwise the value of the dummy is 0. . $IV_{i,}$ is the implied volatility estimated from the three option pricing models, B-S, SV and SVJ; $Volume_{i,t}$ is the trading volume in terms of 10 thousand NTD. Two contract-specific variables, $Mony_{i,t}$ and $\tau_{i,t}$, measured in one hundred trading days, are the moneyness, defined as $S_{i,t}/K_i$ for the call warrant, and the remaining time to expiration for the i^{th} warrant in day t, respectively. The variable $ALR_{i,t}$, which is on one thousand units (NTD), to investigate functions of liquidity provider of the issuers after the warrants are listed to trade. The independent variable, $ALR_{i,t}$, is the daily liquidity ratio of a warrant and we plan to use well-popular measure used in market microstructure literatures, Amivest Liquidity Ratio, in terms of percentage, on daily return of the warrant to underlying stock. And ln $r_{Ci,t}$/ ln$r_{Si,t}$ which is used to investigate whether issuer manipulates the price of the warrants or not, is the ration of the nature-log daily return of i^{th} the warrants and underlying stock, respectively, on date t.

Pricing Errors / Alternative Models	Constant Term	Dummy for Credit Rating of Issuers β_1	Time to Maturity of Warrants β_2	Implied Volatility β_3	Moneyness β_4	Trading Volume β_5	Amivest Liquidity Ratio β_6	Ratio on Returns of Warrant to Stock β_7	Adjusted R Square Values $\bar{R}^2$
Black & Scholes (1973)	0.0905***	0.0632***	0.0446***	-0.3643***	0.4224***	0.1962***	-0.1514***	-0.0450***	42.04%
	(27.80)	(36.60)	(34.56)	(-55.03)	(529.66)	(58.99)	(-22.88)	(-2.53)	
SV, Heston (1993)	0.1084***	0.0632***	0.0445***	-0.4427***	0.4224***	0.1962***	-0.1514***	-0.0452***	47.19%
	(30.81)	(36.61)	(34.56)	(-55.46)	(529.74)	(58.98)	(-22.88)	(-2.54)	
SVJ, Bates (1996)	0.1084***	0.0632***	0.0445***	-0.4563***	0.4224***	0.1962***	-0.1514***	-0.0452***	51.77%
	(30.81)	(36.61)	(34.94)	(-57.96)	(529.74)	(58.98)	(-22.88)	(-2.54)	

Figure 1. Distribution of Dependent Variables



Implied Volatility Estimated from B-S
Mean: 42.35%, Std.: 10.17%

Implied Volatility Estimated from SV
Mean: 44.74%, Std.: 10.03%

Implied volatility estimated from SVJ
Mean: 47.31% Std.: 9.85%

Volume
Mean: 9.8 millions, Std.: 12.90 millions

Daily Log-Return Stock
Mean:~0, Std.:0.458

Daily Log-return warrant
Mean: Std.:0.07

ALR
Mean: 23.49 thousand, Std.: 113.18 thousand

Pricing Errors
Mean:30.10%, Std.:55.50%

Return ratio
Mean:0.157 Std.:0.374