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Warrant introduction effects on stock return processes

Jui-Jane Chang[a,*] and Szu-Lang Liao[b]

[a]*Department of Financial Engineering and Actuarial Mathematics, Soochow University, Taipei 10048, Taiwan, ROC*
[b]*Department of Money and Banking, National Chengchi University, Taipei 11605, Taiwan, ROC*

As the underpricing of warrants remains unsolved after many adjustments presented by previous researchers, we further investigate the impact of the warrant introduction on the underlying stock return processes. This research attempts to determine whether the introduction of warrants influences the return processes of underlying stocks. If the introduction creates a potential dilution effect on stock return process, full dilution adjustment pricing models would lead to underpricing. To examine whether full dilution adjustment is required for warrant pricing, the Generalized Autoregressive Conditional Heteroscedasticity in Mean (GARCH-M) model has been extended to derive four models for testing the dilution effect on stock return processes. Empirical results show that the volatilities of underlying stock return processes are significantly reduced following warrant introduction even after distinguishing dilution from asymmetric effect.

I. Introduction

Since Black and Scholes (1973) and Galai and Schneller (1978) priced warrants as an option on the stock of the underlying firm with some dilution modifications, the warrant pricing problem has become an important issue.[1] Recently, Koziol (2006) also found that the exercise behaviour of warrant holders affects warrant values and then analysed their optimal exercise strategies for corporate warrants. As warrants are incorporated in many financial derivatives, it is important to accurately evaluate warrant prices. Numerous warrant pricing models are presented, following the option pricing framework with some modifications, such as dilution adjustments. The most common and cost efficient method might be the Dilution-Adjusted Black–Scholes (DABS) model which is the Black–Scholes option pricing model with some dilution adjustments. The model assumes that warrant listing increases both firm equity and outstanding shares, thus, the dilution effect should be taken into account.

Kremer and Roenfeldt (1993) and Hauser and Lauterbach (1997) suggested that warrants are generally underpriced by the DABS model and Dilution-Adjusted Jump-Diffusion (DAJD) model. Crouhy and Galai (1991), Schulz and Trautmann (1994), Becchetti (1996) and Handley (2002) argued that stock price should already reflect the dilution effect during the life of the warrant. Handley (2002) also noted that the stock price of the underlying firm conditionally reflects dilution at any time following

*Corresponding author. E-mail: rayjanechang@gmail.com

[1] The Black–Scholes warrant pricing model is presented by Black–Scholes (1973) and Galai and Schneller (1978); they showed that the Black–Scholes option pricing model can price warrants with some modifications and dilution adjustments.

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the announcement of warrant listing. No explicit adjustment for dilution is required. If the dilution effect is already a function of time, pricing errors of dilution-adjusted warrant pricing models will be larger as the warrant approaches its expiry date. Therefore, this study investigates whether the underlying stock return process genuinely reflects the potential dilution effect during the life of the warrant.

In general, warrant pricing models need to estimate the future volatility of underlying assets. If the introduction of warrants significantly lowers the return and volatility of the underlying stocks, the warrant price drops. In this case, the valuation of warrants using post-announcement stock return processes adjusting for dilution overcompensates, forcing underpricing of warrants. Although Crouhy and Galai (1991) and Handley (2002) argued that the stock process should constantly reflect the potential dilution during the life of warrant, little attention has been paid to determine the effect of the warrant introduction on the underlying stock return process.[2] Since financial data generally exhibit time-varying variances and excess kurtoses, the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model is extended to incorporate these characteristics.

Sections II and III describe the examination methodology and the data set, respectively; Section IV presents the empirical results; Section V summarizes and discusses the results and the conclusion is presented in Section VI.

II. Methodology

Theoretical consideration for testing the effect of warrants on the underlying stock return process

When a firm issues warrants, the associated warrant premium makes the firm equity increase with cash inflow. Furthermore, if the underlying stock price is higher than the exercise price during the life of the warrants, the firm takes more equity when warrants are exercised and new stocks are offered. Hence the capital structure of the firm has changed after warrant listing. The risks of shareholders increase with higher leverage and the expected return on equity is positively related. In other words, the higher leveraged shareholders have better return in good times and worse returns in bad times than lower leveraged shareholders. This means that the higher the leverage is, the greater the risks are; therefore, shareholders would ask for more expected return as risk premium. As the warrant introduction decreases the debt–equity ratio and lowers the leverage of the firm, the company is exposed to less risk (systematic, market and default risk). Meanwhile, the shareholders of the lower leveraged firm take less risk and get less risk premium. We argue that the underlying stock return process changes and has lower volatility and expected return after warrant introduction.

Stock return processes in the GARCH-M model

Since financial data consistently exhibit different degrees of variation at different points of time, the time series models of stock prices must measure the time-varying volatilities. Following the constant elasticity of variance model by Cox and Ross (1976) and Beckers (1980), Hull and White (1987) presented an option pricing model with stochastic volatility. The GARCH process of Bollerslev (1986) and its extensions characterized asset return dynamics by different conditional volatility models. Heston (1993) and Duan (1995) also produced reasonable option pricing procedure using the GARCH model. Many extended asymmetric GARCH models adequately represent shocks and the leverage effect of different volatility response. Lauterbach and Schultz (1990) noted that the constant variance assumption of the DABS models appears to cause biases in model prices for almost all warrants over the entire sample period. Alberg *et al*. (2008) also concluded that the asymmetric GARCH model with fat-tailed densities improves overall estimation for measuring conditional variance. While the family of GARCH models has become an important empirical method for modelling financial time series data, the GARCH model is extended to verify whether the warrant introduction has any effect.

As investors require compensation for holding risky assets, the expected return of a risky asset increases with higher variance. When an asset becomes riskier, its conditional volatility increases as does the expected rate of return. The relationship between mean and variance of the excess returns

[2] The literature focused on such impact was published by Alkeback and Hagelin (1998) and Becchetti (1996). Alkeback and Hagelin (1998) used the event study methodology to determine the effect on price, volatility and liquidity of the underlying stock at and around warrant introduction. Their results suggested that there is no real effect on the underlying stocks following the warrant introduction; thus there is no significant impact on the price or volatility. Becchetti (1996) analysed the effect of bond plus equity warrant (Warrant Bond, WB) issues on underlying asset volatility, and the empirical results indicate that the underlying stock volatility decreased after the introduction of WB.

follows the framework proposed by Engle *et al.* (1987), the GARCH in Mean model (GARCH-M model), to allow for impacts of conditional variances on the conditional expected returns. The dynamics of the stock return modelled by GARCH-M process of order (p, q) are as follows:

$$\ln(S_{it}/S_{i(t-1)}) \equiv R_{it}$$

$$R_{it} = r + \lambda_i \sigma_{it} - (1/2)\sigma_{it}^2 + \sigma_{it} Z_{it}$$

$$\sigma_{it}^2 = c_i + \sum_{s=1}^{p} \alpha_{i(t-s)} \sigma_{i(t-s)}^2 + \sum_{s=1}^{q} \beta_{i(t-s)} u_{i(t-s)}^2$$

$$u_{it} \equiv \sigma_{it} Z_{it} \text{ with } Z_{it}|\Omega_{t-1} \sim N(0,1)$$

where R_{it} is the return of stock i at time t with a conditional mean $E(R_{it}|\Omega_{t-1}) = r + \lambda_i \sigma_{it} - (1/2)\sigma_{it}^2$, and conditional deviation $N(0, \sigma_{it}^2)$. r represents the risk-free rate of return, and λ_i is the price of risk of stock i, u_{it} or $\sigma_{it} Z_{it}$ is the difference between *ex ante* and *ex post* returns of stock i at time t, and Z_{it}, conditional on information Ω_{t-1} at time $t-1$, represents a sequence of independent, identically and normally distributed random variables with zero mean and unit variance. The coefficients α_i and β_i should satisfy some regularity conditions to ensure unconditional volatility σ_{it}^2 is finite. Hence, the conditional expected return of stock i at time t is given as

$$E(R_{it}|\Omega_{t-1}) = r + \lambda_i \sigma_{it} - (1/2)\sigma_{it}^2 \quad (1)$$

and its conditional volatility is

$$\text{Var}(R_{it}|\Omega_{t-1}) = \sigma_{it}^2 \quad (2)$$

where Ω_{t-1} denotes the information set at time $t-1$.

Stock return process can be represented by a conditional expected return term plus a conditional volatility term. Moreover, as Equation 1 shows, the conditional expected return is the risk-free rate with a scaled multiple of conditional volatility to compensate for risk. Thus the GARCH-M model is extended to allow the risk premium serial correlation with the volatility process σ_{it}^2.

The GARCH-M model with volatility modifications for testing the effect of warrant introduction

The general market perspective is that investors demand compensation for holding risky assets. In line with market perspective, the GARCH-M model allows the conditional expected stock return to change proportionally with serial correlations of volatilities based on the following assumption: higher volatility accompanies higher expected stock return because investors demand a risk premium. Low-risk premium is expected for lower volatility. According to this setup of the GARCH-M model, we only verify the volatility difference to evaluate the effect of warrant introduction on the stock return process.

It is reasonable that when warrant introduction decreases the firm's debt–equity ratio, leverage and risk exposure, the shareholders of the lower leveraged firm take less risk and receive a smaller premium. In order to test the impact of the underlying stock return process and to determine whether the introduction itself reflects some potential dilution effects, we introduce dummy variables into stock return process and modify the GARCH-M model with Gaussian innovation by incorporating the impact of warrant introduction. Following this framework, four extensions of the model are derived with different conditional volatility settings. The four modified models are divided into two groups: Model 1 and Model 2 in a one dummy variable framework, and Model 3 and Model 4 in a two dummy variables framework.

One dummy variable framework. A dummy variable is added into the conditional volatility of stock return processes to incorporate the effect of warrant introduction. The prime form is presented in Model 1, and the extended form clarifying the ambiguity with asymmetric effect is displayed in Model 2.

Model 1: The dilution-adjusted GARCH-M model. After adding a dummy variable, the conditional SD is changed to

$$\sigma_{it}^D = \sigma_{it}(1 - \delta_i I_{it}) \quad (3)$$

where σ_{it}^D is the SD including the introduction of stock i at time t, and σ_{it} is the fundamental SD without any volatility dilution effect from warrant introduction. I_{it} is the dummy or indicator variable of stock i at time t. I_{it} is equal to 1 if observations recorded after warrant introduction. Otherwise, I_{it} is zero. δ_i is the parameter for warrant introduction. If δ_i is *positive*, conditional volatility is *reduced* after warrant introduction. As Equation 3 shows, we assume that the SD of stock return after warrant introduction is divided into two parts. One part is the fundamental SD before listing, and the other part is a scaled multiple of the fundamental SD after warrant introduction. The conditional SD in Equation 3 can also be shown as

$$\sigma_{it}^D = \begin{cases} \sigma_{it} & \text{if } I_{it} = 0 \\ \sigma_{it}(1 - \delta_i) & \text{if } I_{it} = 1 \end{cases}$$

Fundamental conditional volatility is defined as the function of the square of the fundamental SD:

$$\sigma_{it}^2 = \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2 \tag{4}$$

If the stock return process already reflects some potential dilution effect during the life of warrants, δ_i should be positive showing the lower volatility. Where the volatility of stock returns increases during the life of warrants, δ_i should be negative. The modified GARCH (1,1)-M model incorporating a dilution-adjusted dummy can be written as

$$\ln(S_{it}/S_{i(t-1)}) \equiv R_{it}$$

$$R_{it} = r + \lambda_i\sigma_{it}^D - (1/2)(\sigma_{it}^D)^2 + u_{it}^D \tag{5}$$

where $u_{it}^D \equiv \sigma_{it}^D Z_{it} = (1-\delta_i I_{it})\sigma_{it}Z_{it}$, with $Z_{it}|\Omega_{t-1} \sim N(0,1)$. To ensure the positive value of conditional volatility, we need to set $\beta_{0i} > 0$, $\beta_{1i} \geq 0$ and $\beta_{2i} \geq 0$. The sum of β_{1i} and β_{2i} should be less than one to ensure unconditional variance of R_{it} is finite. The conditional expected return is therefore written as

$$\begin{aligned} E(R_{it}|\Omega_{t-1}) &= r + \lambda_i\sigma_{it}^D - (1/2)(\sigma_{it}^D)^2 \\ &= r + \lambda_i\sigma_{it}(1-\delta_i I_{it}) - (1/2)[\sigma_{it}(1-\delta_i I_{it})]^2 \end{aligned} \tag{6}$$

and the conditional volatility is

$$\begin{aligned} \mathrm{Var}(R_{it}|\Omega_{t-1}) &= \mathrm{Var}_{t-1}(u_{it}^D) = (\sigma_{it}^D)^2 \\ &= (1-\delta_i I_{it})^2\sigma_{it}^2 \end{aligned} \tag{7}$$

Consequently, Model 1 makes an allowance for the measurement of the warrant introduction effect. In Equations 6 and 7, if δ_i is significantly positive (negative), the conditional volatility decreases (increases) with the introduction of warrants, and therefore the expected return decreases (increases) with lower (higher) conditional volatility.

From Equations 3 and 4,

$$\begin{aligned} [\sigma_{it}^D/(1-\delta_i I_{it})]^2 &= \beta_{0i} + \beta_{1i}[\sigma_{i(t-1)}^D/(1-\delta_i I_{i(t-1)})]^2 \\ &\quad + \beta_{2i}[u_{i(t-1)}^D/(1-\delta_i I_{i(t-1)})]^2 \\ &= [1/(1-\delta_i I_{i(t-1)})^2][(1-\delta_i I_{i(t-1)})^2\beta_{0i} \\ &\quad + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(u_{i(t-1)}^D)^2 \end{aligned} \tag{8}$$

Rearranging Equation 8, the specification of the conditional volatility function obtained was as follows:

$$\begin{aligned} (\sigma_{it}^D)^2 &= [(1-\delta_i I_{it})/(1-\delta_i I_{i(t-1)})]^2[(1-\delta_i I_{i(t-1)})^2\beta_{0i} \\ &\quad + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(u_{i(t-1)}^D)^2] \end{aligned} \tag{9}$$

It can also be expressed as

$$(\sigma_{it}^D)^2 = \begin{cases} \beta_{0i} + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(u_{i(t-1)}^D)^2 \\ \quad \text{if } I_{it} = I_{i(t-1)} = 0 \\ (1-\delta_i)^2[\beta_{0i} + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(u_{i(t-1)}^D)^2] \\ \quad \text{if } I_{it} = 1, I_{i(t-1)} = 0 \\ [(1-\delta_i)^2\beta_{0i}] + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(u_{i(t-1)}^D)^2 \\ \quad \text{if } I_{it} = I_{i(t-1)} = 1 \end{cases} \tag{10}$$

Equation 10 shows that the conditional volatility after warrant listing $(\sigma_{it}^D)^2$ would be a scaled multiple of $\beta_{0i} + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(u_{i(t-1)}^D)^2$, or of the constant term β_{0i}. If δ_i is significantly positive (negative), the conditional volatility will decrease (increase) with the warrant listing. Thus Model 1 depicts the changes in conditional volatility of warrant introduction.

Model 2: The asymmetric dilution-adjusted GARCH-M model. As the stock price decreases from negative shocks, the equity value of a firm gets smaller relative to its debt, and its stocks become riskier with the higher financial leverage. This asymmetric phenomenon is referred to as the leverage effect. It is important to distinguish the volatility change due to the dilution effect from this asymmetric leverage effect in order to avoid ambiguity. Corresponding with Engle and Ng (1993), Glosten *et al.* (1993) and Christoffersen and Jacobs (2004), the conditional variance equation in Model 1 (the dilution-adjusted GARCH model) is modified to contain the asymmetric effect as follows:

$$\begin{aligned} \sigma_{it}^D &= (1-\delta_i I_{it})\sigma_{it} \\ \sigma_{it}^2 &= \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}(|u_{i(t-1)}| - l_i u_{i(t-1)})^2 \end{aligned} \tag{11}$$

The parameters β_{1i}, β_{2i} and l_i should satisfy some regularity conditions to ensure that the unconditional volatility of stock return process is finite. In Equation 11, where $l_i > 0$, negative return shocks increase volatility more than positive shocks. Therefore, the conditional volatility function for stock return process accounting for asymmetric and warrant effects is

$$\begin{aligned} (\sigma_{it}^D)^2 &= [(1-\delta_i I_{it})/(1-\delta_i I_{i(t-1)})]^2[(1-\delta_i I_{i(t-1)})^2\beta_{0i} \\ &\quad + \beta_{1i}(\sigma_{i(t-1)}^D)^2 + \beta_{2i}(|u_{i(t-1)}^D| - l_i u_{i(t-1)}^D)^2] \end{aligned} \tag{12}$$

Two dummy variable framework. In general, the dilution effect is due to the possible exercise of warrants; higher stock prices lead to a greater possibility of exercising them. When stock prices are high enough, the dilution effects may already partly or entirely be reflected in the conditional volatility representing the possibility of wealth transferring from stock holders to warrant holders. This argument is supported by Hauser and Lauterbach (1997). Hence, a threshold dummy variable is added to judge whether the stock price is higher than the exercise price, and the two dummy variable framework makes the conditional volatility unchanged after warrant introduction until stock price exceeds the exercise price.

Similar to the one dummy variable framework, the original form is presented in Model 3. Model 4 shows the extended form clarifying the ambiguity of asymmetric effect.

Model 3: The dilution-adjusted GARCH-M model with a threshold for exercise price. The threshold dummy variable helps to identify whether the relationship between stock and exercise prices affects the volatility. Since Equation 10 indicates conditional volatility scales down after warrant introduction, for simplicity, we redefine the conditional volatility function with warrant introduction as

$$\sigma_{it}^2 = \left(1 - \delta_i I_{i(t-1)}\right)^2 (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2)$$

Then, by adding a threshold dummy variable $D_{i(t-1)}$ to identify the relation between exercise price and stock price, the conditional volatility can be modified as

$$\sigma_{it}^2 = (1 - \delta_i I_{i(t-1)} D_{i(t-1)})^2 (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2) \tag{13}$$

where $D_{i(t-1)}$ is the threshold dummy variable of stock i at time $t-1$, when stock price is higher than the exercise price, $S_{i(t-1)} > k$, $D_{i(t-1)}$ is 1. Otherwise, $D_{i(t-1)}$ is 0. Regular conditions should be satisfied by δ_i, β_{0i}, β_{1i} and β_{2i} to ensure that conditional volatility is always positive and unconditional volatility is finite. Equation 13 shows that the warrant introduction leaves the conditional volatility unchanged until the firm's stock price is higher than the exercise price. We can also express it as

$$\sigma_{it}^2 = \begin{cases} \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2 \\ \quad \text{if } I_{i(t-1)} = 0 \\ \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2 \\ \quad \text{if } I_{i(t-1)} = 1, D_{i(t-1)} = 0 \\ (1-\delta_i)^2(\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2) \\ \quad \text{if } I_{i(t-1)} = 1, D_{i(t-1)} = 1 \end{cases}$$

The conditional expected return of stock i at time t is

$$E(R_{it}|\Omega_{t-1}) = r + \lambda_i\sigma_{it} - (1/2)\sigma_{it}^2$$

and its conditional volatility is

$$\begin{aligned} \mathrm{Var}_{t-1}(R_{it}|\Omega_{t-1}) = \mathrm{Var}_{t-1}(u_{it}) = \sigma_{it}^2 \\ = (1 - \delta_i I_{i(t-1)} D_{i(t-1)})^2 \\ \times (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2) \end{aligned}$$

Model 4: The asymmetric dilution-adjusted GARCH-M model with a threshold for exercise price. In order to distinguish the dilution effect of warrant introduction from the asymmetric leverage effect, as in Model 2, the conditional volatility function in Model 3 is transformed to

$$\begin{aligned} \sigma_{it}^2 = (1 - \delta_i I_{i(t-1)} D_{i(t-1)})^2 (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 \\ + \beta_{2i}(|u_{i(t-1)}| - l_i u_{i(t-1)})^2) \end{aligned} \tag{14}$$

with $l_i > 0$, negative shocks increase volatility more than positive shocks and l_i is the parameter for asymmetric effect.

III. Data

Data listed on Hong Kong Exchanges and Clearing Limited (HKEx) is used for investigation. Hong Kong is one of the world's three most actively traded warrant markets. Top six exchanges represent almost 90% of the aggregate warrant turnover around the world.[3] In general, equity warrants have a long expiration period. In the interest of observing total trading period of a warrant, unexpired warrants are excluded; empirical analysis utilizes expired warrant data issued from 1 January 2001 to 30 December 2004. Observations of each underlying stock return include its entire warrant trading life – the sample period, and an equal amount of time before warrant introduction. The time prior to warrant introduction is referred to as the control period. Observations for each stock include the sample and control periods.

All official daily closing prices of stocks after capital action adjustments are obtained from the datastream. The data for exercise provisions and other descriptions of the warrants are collected from the annual Fact Book published by HKEx. There

[3] In 2005, HKEx published a brief comparison of the Hong Kong warrant market with oversea counterparts in terms of the number issued and turnover. It showed that Hong Kong was ranked number two in terms of annual turnover of listed warrants among world stock exchanges in 2003, just behind Deutsche Börse (DB) of Germany. Clarification of the double counts problem in Germany, Hong Kong became the world's most actively traded warrant market by turnover value in 2003.

were 82 new equity warrants listed on HKEx during 2001 to 2004. An equal amount of time as warrant lifetime is required for the control group prior to its introduction. A considerable number of stocks are excluded, which include those with another warrant listing during the observation period or those with warrants shortly after an Initial Public Offering (IPO) making the control period too short for comparison.[4] To avoid the complication of different exchange rates, the warrants traded in currencies other than Hong Kong dollars are also excluded. Finally, the study also excludes a few coding error warrants or stocks that are no longer in the public equity market. After elimination, the final sample includes 36 warrants issued from 2001 to 2004 with 37 748 observations.

Table 1 summarizes the 36 warrants sorted by listing date. Since almost all subscription periods, except a warrant issued by Regal Hotels International Holdings in 2004, start prior to the listing day of warrants, the starting date of subscription periods is considered the same as the date warrants are introduced. The warrants in Table 1 cover different lengths of time and range from deep-in-the-money to deep-out-of-the-money. Exercise prices of warrants are drawn and plotted with daily returns of the underlying stocks in the Appendix to show the basic patterns of stock returns and to see the relationship between stock and exercise prices.[5] As indicated in Appendix, stock returns display smaller volatilities after warrant introduction.

IV. Empirical Results

Model 1: The dilution-adjusted GARCH-M model

Table 2 shows the empirical results of Model 1 by maximizing its log-likelihood function. All parameters are estimated simultaneously on the daily returns of total observations for each sample. The full sample period is from 1 January 2001 to 30 December 2004, assuming the risk-free rate of return, r, is a constant 5% annual rate as shown by Christoffersen and Jacobs (2004) and the daily return rate is 0.000137. The second to the sixth column of Table 2 provide the parameter estimates for r, λ, β_0, β_1 and β_2 as in standard GARCH-M models. Note that the t-statistics of the parameters β_1 and β_2 are strongly significant in most samples, indicating the volatility clustering in stock returns and justifying the suitability of GARCH models.

The second to the last column in Table 2 provides the estimates for parameter δ, the introduction effect dummy variable. This table shows that out of the 36 stocks, δ of 30 stocks is estimated to be significant. Thus the dummy variable identifies some of the introduction effect.

The positive (negative) estimate of parameter δ indicates that stock return volatility decreases (increases) with warrant introduction. Empirical results of Model 1 are summarized in Table 3. In the full sample, δ is significantly different from zero of 30 samples at the 5% level with a high rejection rate of 0.8333. Considering the dilution effect of volatility, only significant rejection with positive δ was selected. There is still a high rejection rate of 0.75. This shows that stock returns changed significantly in the volatility following warrant introduction, and in most cases the volatility decreases. It is worth noting that two of the three significantly negative δ are from the warrants issued with deep-in-the-money.[6] This is reasonable, considering the dilution effect or wealth transferring from stock holders to warrant holders already reflected in stock prices after the announcement of deep-in-the-money warrant listing. Two distinctive samples are excluded when evaluating the rejection rate (0.7941) in the last column of Table 3.

Model 2: The asymmetric dilution-adjusted GARCH-M model

In Model 2, the asymmetric effect was incorporated by estimating the parameter l to allow different positive and negative shocks to act on the conditional volatility. If the parameter l is not significantly different from zero, the asymmetric effect is necessarily zero and Model 2 is reduced to Model 1.

Table 4 shows that δ is still significantly different from zero for most samples, although the asymmetric effect is included as an explanatory variable in conditional volatility. Therefore, the statistically significant changes of following warrant introduction are not referred to as an omission of asymmetric

[4] Riche Multi-Media HDG went public on 15 February 2000. The control period is briefly unavailable from 19990617 to 2000214.

[5] Each stock is plotted and it is found that most stocks appear to have smaller volatilities after warrant introduction. Because of page limitation, it is only possible to show the stock return process for some sample companies in the Appendix.

[6] The two deep-in-the-money issued warrants are Harmony Asset and Heritage Intl. HDG. When the warrants were introduced, the stock price was 102 times of the exercise price for the former and 45 times for the latter.

Table 1. Summary of the 36 warrants issued from 1 January 2001 to 31 December 2004

Sample sequence number and company	Listing date	Introduction date	Subscription period	Date in control group	Total date in sample	Number of valid observations	Exercise price per unit (HK$)
(1) SUN HUNG KAI & CO.	15/01/2001	12/01/2001	12/01/2001–11/01/2003	12/01/1999–11/01/2001	12/01/1999–11/01/2003	1043	3
(2) GOLD PEAK INDS.	14/02/2001	09/02/2001	09/02/2001–08/02/2002	09/02/2000–08/02/2001	09/02/2000–08/02/2002	522	2.2
(3) COSMOS MACHINERY ENTS.	15/06/2001	11/06/2001	11/06/2001–10/06/2003	11/06/1999–10/06/2001	11/06/1999–10/06/2003	1042	0.4
(4) LUKS GROUP	18/06/2001	14/06/2001	14/06/2001–17/06/2004	14/06/1998–13/06/2001	14/06/1998–17/06/2004	1568	0.9
(5) LEI SHING HONG	22/06/2001	19/06/2001	19/06/2001–19/06/2006	19/06/1996–18/06/2001	19/06/1996–19/06/2006	2608	3
(6) CHINA TRAVEL INTL.INVS.	03/07/2001	03/07/2001	03/07/2001–30/06/2003	01/07/1999–02/07/2001	01/07/1999–30/06/2003	1042	1.22
(7) KITH HOLDINGS	11/07/2001	11/07/2001	11/07/2001–30/06/2004	13/07/1998–10/07/2001	13/07/1998–30/06/2004	1557	2.2
(8) KINGBOARD CHEMICALS HDG.	03/09/2001	03/09/2001	03/09/2001–31/12/2003	01/05/1999–02/09/2001	01/05/1999–31/12/2003	1217	5.8
(9) CITY TELECOM	02/11/2001	02/11/2001	02/11/2001–01/11/2004	02/11/1998–01/11/2001	02/11/1998–01/11/2004	1565	0.11
(10) HAIER ELECTRONICS GP.	26/02/2002	26/02/2002	26/02/2002–26/02/2004	26/02/2000–25/02/2002	26/02/2000–26/02/2004	1043	0.52
(11) PAUL Y ENGR.GP.	05/03/2002	01/03/2002	01/03/2002–29/08/2003	01/09/2000–28/02/2002	01/09/2000–29/08/2003	780	0.4
(12) ASIA ALUMINUM HOLDINGS	12/04/2002	10/04/2002	10/04/2002–09/04/2004	10/04/2000–09/04/2002	10/04/2000–09/04/2004	1044	0.77
(13) FAR EAST PHARM.TECH.	07/05/2002	07/05/2002	07/05/2002–06/05/2003	07/05/2001–06/05/2002	07/05/2001–06/05/2003	521	2.62
(14) HOP HING HOLDINGS	03/06/2002	29/05/2002	29/05/2002–30/04/2005	27/06/1999–28/05/2002	27/06/1999–30/04/2005	1524	0.27
(15) SINOLINK WORLDWIDE HDG.	05/06/2002	31/05/2002	31/05/2002–29/11/2003	29/11/2000–30/05/2002	29/11/2000–29/11/2003	782	1
(16) RICHE MULTI-MEDIA HDG.	20/06/2002	17/06/2002	17/06/2002–16/06/2005	14/02/2000–16/06/2002	14/02/2000–16/06/2005	1392	3.6
(17) HARMONY ASSET	25/06/2002	21/06/2002	21/06/2002–30/06/2004	21/06/2000–20/06/2002	21/06/2000–30/06/2004	1050	0.08
(18) PREMIUM LAND	09/07/2002	09/07/2002	09/07/2002–08/07/2003	09/07/2001–08/07/2002	09/07/2001–08/07/2003	521	0.22
(19) SOUTH CHINA HDG.	25/07/2002	23/07/2002	23/07/2002–23/07/2003	23/07/2001–22/07/2002	23/07/2001–23/07/2003	522	0.42
(20) CHINA STRATEGIC HDG.	29/08/2002	29/08/2002	29/08/2002–31/12/2003	01/04/2001–28/08/2002	01/04/2001–31/12/2003	717	0.16
(21) ALCO HOLDINGS	02/09/2002	02/09/2002	02/09/2002–01/09/2005	02/09/1999–01/09/2002	02/09/1999–01/09/2005	1565	0.98
(22) PACIFIC ANDES INTL.HDG.	26/09/2002	26/09/2002	26/09/2002–25/03/2004	26/09/2000–25/09/2002	26/09/2000–25/03/2004	912	0.85
(23) PEACE MARK HDG.	07/08/2003	05/08/2003	05/08/2003–04/08/2005	05/08/2001–04/08/2003	05/08/2001–04/08/2005	1043	0.65
(24) SOUNDWILL HOLDINGS	05/09/2003	03/09/2003	03/09/2003–02/03/2006	02/03/2001–02/09/2003	02/03/2001–02/03/2006	1304	2
(25) HERITAGE INTL.HDG.	16/10/2003	13/10/2003	13/10/2003–12/04/2005	13/04/2002–12/10/2003	13/04/2002–12/04/2005	781	0.17
(26) EFORCE HOLDINGS	10/12/2003	08/12/2003	08/12/2003–07/12/2004	08/12/2002–07/12/2003	08/12/2002–07/12/2004	521	0.28
(27) ALLIED PROPERTIES	05/12/2003	05/12/2003	05/12/2003–06/12/2004	05/12/2002–04/12/2003	05/12/2002–06/12/2004	522	2.5
(28) KENFAIR INTL.HDG.	05/12/2003	02/12/2003	02/12/2003–02/12/2005	02/12/2001–01/12/2003	02/12/2001–02/12/2005	952	0.69
(29) QUALITY HLTHCR.ASIA	14/01/2004	14/01/2004	14/01/2004–13/01/2007	14/01/2001–13/01/2007	14/01/2001–13/01/2007	1564	2.5
(30) PLAYMATES HOLDINGS	24/05/2004	24/05/2004	24/05/2004–23/05/2005	24/05/2003–23/05/2004	24/05/2003–23/05/2005	520	1.42
(31) CHINA TRAVEL INTL.INVS.	02/06/2004	02/06/2004	02/06/2004–31/05/2006	03/06/2002–01/06/2004	03/06/2002–31/05/2006	1042	1.508
(32) GLOBAL BIO-CHEM TECH.GP.	01/06/2004	28/05/2004	28/05/2004–31/05/2007	28/05/2001–27/05/2004	28/05/2001–31/05/2007	1568	9.8
(33) U-RIGHT INTL.HDG.	24/06/2004	18/06/2004	18/06/2004–23/06/2005	18/06/2003–17/06/2004	18/06/2003–23/06/2005	526	0.2
(34) RONTEX INTL.HDG.	30/06/2004	28/06/2004	28/06/2004–27/06/2005	28/06/2003–27/06/2004	28/06/2003–27/06/2005	520	0.102
(35) REGAL HOTELS INTL.HDG.	04/08/2004	02/02/2005	02/02/2005–26/07/2007	26/07/2002–01/02/2005	26/07/2002–26/07/2007	1304	0.25
(36) MAN YUE INTL.HDG.	04/11/2004	04/11/2004	04/11/2004–03/11/2006	04/11/2002–03/11/2004	04/11/2002–03/11/2006	1044	0.48

Table 2. Maximum likelihood estimates of Model 1

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	Log-likelihood
(1) SUN HUNG KAI & CO.	0.000137	0.0168	0.0001	0.8342	0.1333	0.1458	2100.00
		(0.6339)	(3.6755)	(36.63169)	(6.4567)	(1.9713)	
(2) GOLD PEAK INDS.	0.000137	−0.0211	0.0003	0.4503	0.2117	0.5127	1316.51
		(−0.5003)	(2.7038)	(3.1437)	(3.8583)	(12.2628)	
(3) COSMOS MACHINERY ENTS.	0.000137	0.0093	0.0018	0.0824	0.1216	−0.0173	1709.69
		(0.2949)	(4.8435)	(0.5070)	(3.2339)	(−0.3606)	
(4) LUKS GROUP	0.000137	0.0046	0.0002	0.7732	0.1396	0.5257	3393.68
		(0.1747)	(5.3455)	(24.9845)	(6.4198)	(17.3588)	
(5) LEI SHING HONG	0.000137	−0.0223	0.0000	0.8606	0.0442	−0.0080	6794.03
		(−1.1790)	(10.0033)	(72.1045)	(6.1469)	(−0.2710)	
(6) CHINA TRAVEL INTL.INVS.	0.000137	0.0269	0.0001	0.8861	0.0757	0.4193	2195.42
		(0.9123)	(4.3261)	(55.4358)	(5.8586)	(8.1958)	
(7) KITH HOLDINGS	0.000137	0.0270	0.0000	0.7837	0.1178	0.0871	4012.59
		(1.0873)	(7.4119)	(58.4544)	(7.7641)	(6.5784)	
(8) KINGBOARD CHEMICALS HDG.	0.000137	0.0698	0.0002	0.6953	0.1487	0.0774	2591.97
		(2.3294)	(6.8508)	(18.9458)	(4.0174)	(2.4755)	
(9) CITY TELECOM	0.000137	0.0039	0.0009	0.4628	0.3221	0.4585	2795.17
		(0.1623)	(5.9158)	(7.7147)	(7.8890)	(16.1411)	
(10) HAIER ELECTRONICS GP.	0.000137	−0.0045	0.0003	0.7813	0.2187	0.4750	1628.98
		(−0.1572)	(6.5184)	(43.9579)	(8.6624)	(8.1851)	
(11) PAUL Y ENGR.GP.	0.000137	−0.0239	0.0004	0.6809	0.3191	0.4597	1354.26
		(−0.6848)	(2.2438)	(16.1904)	(2.8533)	(3.8207)	
(12) ASIA ALUMINUM HOLDINGS	0.000137	0.0299	0.0002	0.6137	0.2447	0.1555	2225.89
		(1.0127)	(5.2357)	(13.7912)	(6.5021)	(2.4854)	
(13) FAR EAST PHARM.TECH.	0.000137	0.0816	0.0001	0.8128	0.1129	0.3096	1079.74
		(1.8943)	(2.8863)	(16.5678)	(3.3450)	(4.1645)	
(14) HOP HING HOLDINGS	0.000137	−0.0024	0.0007	0.4697	0.1993	−0.0166	2757.61
		(−0.0990)	(8.6732)	(8.4908)	(4.7449)	(−0.4132)	
(15) SINOLINK WORLDWIDE HDG.	0.000137	0.0748	0.0012	0.0477	0.2148	0.2496	1518.49
		(2.4722)	(7.4394)	(0.5470)	(4.1506)	(4.9954)	
(16) RICHE MULTI-MEDIA HDG.	0.000137	0.0039	0.0009	0.4013	0.4375	0.5930	2893.33
		(0.1520)	(7.1140)	(7.8823)	(7.2431)	(26.7244)	
(17) HARMONY ASSET	0.000137	−0.0186	0.0010	0.0841	0.1686	−0.9801	1648.27
		(−0.6176)	(6.3178)	(0.7505)	(4.0526)	(−10.3083)	
(18) PREMIUM LAND	0.000137	−0.0074	0.0001	0.9273	0.0621	0.3158	909.28
		(−0.1680)	(3.2188)	(57.0207)	(4.0048)	(3.5635)	
(19) SOUTH CHINA HDG.	0.000137	−0.0507	0.0014	0.1294	0.0883	0.0113	928.72
		(−1.1136)	(4.0017)	(0.7338)	(2.0028)	(0.1778)	
(20) CHINA STRATEGIC HDG.	0.000137	−0.0062	0.0013	0.5281	0.0811	0.2703	1145.77
		(−0.1591)	(3.5240)	(4.4298)	(3.1474)	(6.2371)	
(21) ALCO HOLDINGS	0.000137	0.0364	0.0006	0.1552	0.2219	0.2890	3561.59
		(1.5663)	(5.7972)	(1.3493)	(6.7015)	(9.3450)	
(22) PACIFIC ANDES INTL.HDG.	0.000137	0.0926	0.0003	0.6889	0.1186	0.3576	1914.96
		(2.8343)	(2.1831)	(5.9560)	(3.2141)	(8.4637)	
(23) PEACE MARK HDG.	0.000137	0.0693	0.0002	0.8196	0.1013	0.4441	2161.25
		(2.2703)	(2.5029)	(17.1138)	(4.1854)	(10.3882)	
(24) SOUNDWILL HOLDINGS	0.000137	0.0015	0.0001	0.8272	0.1458	0.2208	2324.41
		(0.0542)	(2.7824)	(35.3832)	(7.7712)	(2.9173)	
(25) HERITAGE INTL.HDG.	0.000137	−0.0427	0.0013	0.4093	0.1732	−0.3116	1086.87
		(−1.2863)	(6.3435)	(4.7453)	(4.6709)	(−4.2578)	
(26) EFORCE HOLDINGS	0.000137	0.0151	0.0000	0.9342	0.0400	−0.7632	975.72
		(0.3640)	(5.4483)	(306.3754)	(5.2904)	(−3.9230)	
(27) ALLIED PROPERTIES	0.000137	0.0098	0.0000	0.8253	0.1385	−0.0175	1301.84
		(0.2252)	(3.2980)	(26.6715)	(4.7910)	(−0.1351)	
(28) KENFAIR INTL.HDG.	0.000137	0.1619	0.0003	0.5375	0.1679	0.4181	2256.12
		(4.4383)	(4.3350)	(6.4191)	(4.1766)	(11.5656)	
(29) QUALITY HLTHCR.ASIA	0.000137	−0.0071	0.0005	0.5702	0.1056	0.4574	3304.88
		(−0.2790)	(3.8410)	(5.5810)	(4.0888)	(17.5870)	
(30) PLAYMATES HOLDINGS	0.000137	0.0733	0.0002	0.7472	0.1364	0.1199	1032.70

(*continued*)

Table 2. Continued

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	Log-likelihood
		(1.6716)	(2.3254)	(8.5180)	(2.8212)	(1.3420)	
(31) CHINA TRAVEL INTL.INVS.	0.000137	0.0171	0.0002	0.4820	0.1565	0.1142	2560.85
		(0.5627)	(3.4921)	(3.9419)	(3.7418)	(2.3113)	
(32) GLOBAL BIO-CHEM TECH.GP.	0.000137	0.0337	0.0003	0.6346	0.1576	0.1052	3142.89
		(1.3606)	(4.5613)	(10.4745)	(5.3635)	(2.4446)	
(33) U-RIGHT INTL. HDG.	0.000137	0.0085	0.0002	0.7337	0.0001	0.1992	1146.09
		(0.2223)	(1.7952)	(5.6383)	(0.0044)	(2.2694)	
(34) RONTEX INTL.HDG.	0.000137	0.1187	0.0004	0.7429	0.1317	0.3412	935.89
		(2.6326)	(3.3083)	(12.3208)	(3.6998)	(5.9941)	
(35) REGAL HOTELS INTL.HDG	0.000137	0.0271	0.0000	0.8685	0.1006	0.1514	2776.86
		(0.9246)	(2.2226)	(31.6399)	(5.7975)	(2.1506)	
(36) MAN YUE INTL.HDG.	0.000137	0.0842	0.0013	0.1285	0.2603	0.1716	1897.10
		(3.0419)	(8.6249)	(1.6670)	(4.8883)	(4.1396)	

Notes: Model 1: the dilution-adjusted GARCH-M model is

$$\ln(S_{it}/S_{i(t-1)}) \equiv R_{it} = r + \lambda_i \sigma_{it}^D - (1/2)\left(\sigma_{it}^D\right)^2 + u_{it}^D$$
$$\sigma_{it}^D = (1 - \delta_i I_{it})\sigma_{it}$$

after warrant introduction $I_{it} = 1$, and otherwise $I_{it} = 0$

$$u_{it}^D \equiv \sigma_{it}^D Z_{it} = (1 - \delta_i I_{it})\sigma_{it} Z_{it} \quad \text{and} \quad Z_{it}|\Omega_{t-1} \sim N(0,1)$$
$$\sigma_{it}^2 = \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2$$

Parameter estimates on daily return of the 36 samples are obtained by maximizing the log-likelihood function of Model 1. The t-statistics are reported above with each estimate in parentheses. For the risk-free rate, r, we assume a constant 5% annual rate as Christoffersen and Jacobs (2004) and a daily return rate of 0.000137.

Table 3. Summary statistics for the parameters of introduction dummy on Model 1

Sample	Full sample	Samples without deep-in-the-money issued warrants
Number of samples	36	34
H_0: $\delta = 0$		
Summary A		
Number of rejections	30	28
Rate of rejection	0.8333	0.8235
Summary B		
Number of rejections with positive parameters	27	27
Rate of rejection with positive parameters	0.75	0.7941

Notes: This table shows the number and percentage of stocks with significant changes in volatility after warrant introduction on Model 1. Rejections of the null hypotheses are reported at the 5% level. Summary A reports the number and percentage of stocks with significant changes in volatility after warrant introduction. Then we only select the rejections with positive parameter, i.e. their volatility is significantly diluted, in summary B. The second column shows the results of the total samples, while the sub-samples without deep-in-the-money issued warrants are reported in the last column.

phenomenon. Table 5 is a summary of Table 6. The rejection rate of the parameter for asymmetric effect l, in the full sample is 0.5556, for approximately half of the samples. If we test whether the negative shocks have a larger effect on the volatility than positive shocks, $l > 0$, then the rejection rate is only 0.3611. The result suggests that the impact of parameter l on asymmetric effect is unstable.

Model 3: The dilution-adjusted GARCH-M model with a threshold for exercise price

To distinguish dilution from other introduction effects, a threshold for excise price in stock is chosen. As discussed in Section II, the conditional volatility is affected by the compound dummy variable which synthesizes the warrant introduction dummy and the threshold dummy in stock prices. The conditional volatility is not changed after warrant introduction until stock price exceeds exercise price.

Never (or almost never) in-the-money samples make the threshold dummy variable equal to zero, thus those samples are excluded.[7] After the elimination, the total number of samples in Model 3 is 28. Table 6 documents the results for Model 3. It shows

[7] Omitted samples: 1, 2, 3, 13, 15, 19, 27 and 32 are in Table 1. Six of these eight samples (1, 2, 13, 15, 27 and 32) are never in the money, and the other two samples (3 and 19) are almost never in the money.

Table 4. Maximum likelihood estimates of Model 2

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	l	Log-likelihood
(1) SUN HUNG KAI & CO.	0.000137	−0.0118	0.0001	0.8978	0.0901	0.4145	0.3669	2110.40
		(−0.3638)	(3.1632)	(44.1669)	(5.3298)	(4.0584)	(3.7944)	
(2) GOLD PEAK INDS.	0.000137	−0.0310	0.0003	0.5253	0.1659	0.5227	0.1645	1317.17
		(−0.7463)	(2.2942)	(3.1098)	(2.6411)	(12.3852)	(1.1653)	
(3) COSMOS MACHINERY ENTS.	0.000137	0.0100	0.0018	0.0890	0.1205	−0.0174	−0.0220	1709.71
		(0.3235)	(4.1179)	(0.4586)	(3.2851)	(−0.3452)	(−0.1769)	
(4) LUKS GROUP	0.000137	0.0237	0.0002	0.7663	0.1355	0.5226	−0.2282	3399.97
		(0.9866)	(5.0937)	(21.8356)	(6.3657)	(17.1389)	(−3.4573)	
(5) LEI SHING HONG	0.000137	−0.0380	0.0000	0.8576	0.0204	−0.0423	1.0000	6839.72
		(−1.9581)	(8.8693)	(57.6971)	(3.7004)	(−1.3469)	(5.4447)	
(6) CHINA TRAVEL INTL.INVS.	0.000137	0.0075	0.0001	0.8947	0.0739	0.4594	0.2367	2199.80
		(0.2231)	(4.1834)	(58.4510)	(5.3719)	(8.0349)	(2.8562)	
(7) KITH HOLDINGS	0.000137	0.0235	0.0000	0.7845	0.1182	0.0898	0.0371	4012.69
		(1.0136)	(5.4910)	(29.6822)	(6.7298)	(5.0346)	(0.7067)	
(8) KINGBOARD CHEMICALS HDG.	0.000137	0.0629	0.0002	0.6496	0.1592	0.0898	0.0710	2592.46
		(2.5414)	(10.9709)	(79.3989)	(6.6040)	(2.6884)	(11.8745)	
(9) CITY TELECOM	0.000137	0.0240	0.0010	0.4325	0.3064	0.4655	−0.1628	2799.63
		(0.9376)	(5.2717)	(6.1907)	(7.0230)	(15.6944)	(−2.6376)	
(10) HAIER ELECTRONICS GP.	0.000137	0.0038	0.0003	0.7905	0.1889	0.4494	−0.0532	1629.33
		(0.1332)	(6.4329)	(48.4760)	(8.7920)	(7.7943)	(−1.4159)	
(11) PAUL Y ENGR.GP.	0.000137	−0.0232	0.0004	0.6816	0.3147	0.4641	−0.0058	1354.27
		(−0.3131)	(1.8018)	(18.2798)	(3.4939)	(3.2069)	(−0.0294)	
(12) ASIA ALUMINUM HOLDINGS	0.000137	0.0078	0.0002	0.5990	0.2153	0.1552	0.1899	2229.31
		(0.2509)	(5.1629)	(11.9818)	(5.3175)	(2.7753)	(2.3548)	
(13) FAR EAST PHARM.TECH.	0.000137	0.0589	0.0002	0.8182	0.0658	0.3421	0.5271	1084.42
		(1.3782)	(3.0398)	(14.0649)	(1.6985)	(5.7964)	(1.5718)	
(14) HOP HING HOLDINGS	0.000137	−0.0073	0.0007	0.4292	0.2335	−0.0283	0.1350	2758.79
		(−0.2868)	(9.4466)	(8.4153)	(4.5820)	(−0.6733)	(1.5663)	
(15) SINOLINK WORLDWIDE HDG.	0.000137	0.0713	0.0013	0.0379	0.2192	0.2534	0.0519	1518.60
		(1.9183)	(7.7146)	(0.4608)	(4.8432)	(5.5678)	(0.5071)	
(16) RICHE MULTI-MEDIA HDG.	0.000137	0.0341	0.0006	0.4411	0.4127	0.5326	−0.1664	2857.97
		(1.2950)	(6.2602)	(8.1004)	(6.6998)	(21.2252)	(−2.7267)	
(17) HARMONY ASSET	0.000137	−0.0194	0.0000	0.9501	0.0308	−0.5308	−0.0785	1676.67
		(−0.6361)	(3.9277)	(99.5937)	(4.7926)	(−3.9046)	(−0.7970)	
(18) PREMIUM LAND	0.000137	−0.0386	0.0001	0.9330	0.0547	0.3799	0.4172	914.49
		(−0.9197)	(3.1520)	(60.3619)	(3.8231)	(4.6202)	(2.8390)	
(19) SOUTH CHINA HDG.	0.000137	−0.0571	0.0016	0.0001	0.0381	0.0413	1.0000	931.92
		(−1.3364)	(2.2646)	(0.0003)	(1.5491)	(0.4351)	(2.2223)	
(20) CHINA STRATEGIC HDG.	0.000137	−0.0260	0.0013	0.5378	0.0884	0.2769	0.3854	1150.30
		(−0.7058)	(4.4358)	(5.6523)	(2.9163)	(6.5869)	(3.3652)	
(21) ALCO HOLDINGS	0.000137	0.0582	0.0004	0.4340	0.1512	0.2877	−0.3482	3569.01
		(2.2938)	(3.6289)	(3.5086)	(4.3946)	(8.9913)	(−3.3369)	
(22) PACIFIC ANDES INTL.HDG.	0.000137	0.0945	0.0003	0.6872	0.1188	0.3592	−0.0275	1914.99
		(2.8348)	(2.2505)	(6.1373)	(3.1139)	(8.5117)	(−0.2903)	
(23) PEACE MARK HDG.	0.000137	0.0628	0.0001	0.8241	0.1005	0.4401	0.1314	2162.40
		(2.0667)	(2.4913)	(18.3335)	(4.1880)	(9.8544)	(1.4606)	
(24) SOUNDWILL HOLDINGS	0.000137	0.0193	0.0001	0.8347	0.1279	0.2564	−0.1370	2327.75
		(0.5968)	(2.0275)	(22.0565)	(6.5801)	(4.0790)	(−1.7506)	
(25) HERITAGE INTL.HDG.	0.000137	−0.0318	0.0013	0.4308	0.1493	−0.3077	−0.1614	1087.92
		(−0.8691)	(5.1751)	(4.2785)	(3.7128)	(−4.0884)	(−1.2582)	
(26) EFORCE HOLDINGS	0.000137	0.0063	0.0000	0.9702	0.0132	−0.1100	0.9990	984.58
		(0.1542)	(3.8857)	(125.0793)	(2.1960)	(−0.7129)	(3.2973)	
(27) ALLIED PROPERTIES	0.000137	0.0391	0.0000	0.8284	0.1207	−0.0619	−0.2385	1304.48
		(0.8268)	(3.3749)	(25.8350)	(3.7979)	(−0.4356)	(−2.2419)	
(28) KENFAIR INTL.HDG.	0.000137	0.0164	0.0003	0.5852	0.1714	0.4232	−0.2125	2259.01
		(0.5322)	(4.2018)	(8.1479)	(4.6682)	(11.8455)	(−2.6747)	
(29) QUALITY HLTHCR.ASIA	0.000137	−0.0180	0.0012	0.0774	0.1214	0.4136	0.2993	3305.60
		(−0.7160)	(7.1804)	(0.6838)	(4.1889)	(17.7927)	(2.3865)	

(*continued*)

Table 4. Continued

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	l	Log-likelihood
(30) PLAYMATES HOLDINGS	0.000137	0.0581 (1.2869)	0.0002 (2.1381)	0.6666 (4.9581)	0.1900 (2.4071)	0.1179 (1.2768)	0.2562 (2.3765)	1035.06
(31) CHINA TRAVEL INTL.INVS.	0.000137	0.0080 (0.2557)	0.0002 (3.4554)	0.5482 (5.1288)	0.1441 (3.3473)	0.1124 (2.3429)	0.1825 (2.0690)	2562.85
(32) GLOBAL BIO-CHEM TECH.GP.	0.000137	0.0167 (0.6528)	0.0003 (4.6165)	0.6527 (11.1047)	0.1466 (5.2264)	0.1105 (2.3587)	0.2141 (3.0722)	3148.25
(33) U-RIGHT INTL.HDG.	0.000137	0.0152 (0.3369)	0.0001 (6.0693)	0.8387 (36.3930)	0.0176 (2.0188)	0.0981 (1.4738)	−1.0006 (−3.0989)	1149.45
(34) RONTEX INTL.HDG.	0.000137	0.1267 (3.0281)	0.0004 (3.0733)	0.7456 (11.2735)	0.1213 (3.3128)	0.3447 (5.8723)	−0.1183 (−1.0452)	936.48
(35) REGAL HOTELS INTL.HDG.	0.000137	0.0315 (0.9830)	0.0000 (19.5568)	0.8746 (90.3966)	0.0964 (93.2648)	0.1338 (2.1134)	−0.0484 (−1.3260)	2777.19
(36) MAN YUE INTL.HDG.	0.000137	0.0854 (2.8312)	0.0013 (9.7844)	0.1297 (1.8274)	0.2588 (4.7991)	0.1716 (4.2036)	−0.0178 (−0.2136)	1897.12

Notes: Model 2: the asymmetric dilution-adjusted GARCH-M model is

$$\ln(S_{it}/S_{i(t-1)}) \equiv R_{it} = r + \lambda_i \sigma_{it}^D - (1/2)\left(\sigma_{it}^D\right)^2 + u_{it}^D$$
$$\sigma_{it}^D = (1 - \delta_i I_{it})\sigma_{it}$$

after warrant introduction $I_{it} = 1$, and otherwise $I_{it} = 0$

$$u_{it}^D \equiv \sigma_{it}^D Z_{it} = (1 - \delta_i I_{it})\sigma_{it} Z_{it} \quad \text{and} \quad Z_{it}|\Omega_{t-1} \sim N(0,1)$$
$$\sigma_{it}^2 = \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}\left(\left|u_{i(t-1)}^D\right| - l_i u_{i(t-1)}^D\right)^2$$

with $l_i > 0$, negative return shocks increase volatility more than positive shocks, thus including asymmetric effects. Parameter estimates of daily return of the 36 samples are obtained by maximizing the log-likelihood function of Model 2. The t-statistics are reported above with each estimate in parentheses. For the risk-free rate, r, we assume a constant 5% annual rate as in Christoffersen and Jacobs (2004) and a daily return rate of 0.000137.

that the parameter δ of the compound dummy variable is still statistically significant in most samples. The results are briefly summarized in Table 7. Of the samples, 23 out of 28 are rejected at a rate of 0.8214. By excluding the two deep-in-the-money issued warrants, as in Model 1, the rejection rate goes up to 0.8462. It is interesting that all significant parameters of the compound dummy variable are positive except a deep-in-the-money warrant, Harmony Asset, whose issued price is 102 times of the exercise price. If we exclude the deep-in-the-money warrants, all significant parameters of the compound dummy variable are positive. The interpretation of dilution effect after warrant introduction becomes much clearer.

Comparing Model 3 to Model 1, we also find maximum log-likelihood estimation is improved in 13 samples. As shown in Table 6, Model 3 performs better than Model 1 in 13 samples. Although Model 3 simplifies the introduction effect of Model 1, the additional information of the relationship between stock and exercise price makes Model 3 perform better in almost half of the samples.

Model 4: The asymmetric dilution-adjusted GARCH-M model with a threshold for exercise price

By adding the asymmetric leverage parameter l to the conditional volatility in Model 3, Model 4 becomes the most heavily parameterized. Table 8 shows the parameters remain significant and are positive in most samples. Conversely, the parameter of asymmetric effect is still unstable and insignificantly positive in most samples. As summarized in Table 9, the rejection rates of δ and positive δ are 0.75 and 0.6786, respectively. Meanwhile, the rejection rates of l and positive l are only 0.5714 and 0.3214, respectively. From the results of Model 4, it is noteworthy the compound dummy for warrant introduction shows the potential dilution effect on stock return process is significant even after clarification and distinguishing asymmetric effect.

V. Discussion

There has long been a debate on the influences of derivative listing on the underlying stocks.

Table 5. Summary statistics for the parameters of introduction dummy and asymmetric dummy on Model 2

Sample	Full sample	Samples without deep-in-the-money issued warrants
Number of samples	36	34
H_0: $\delta = 0$		
Summary A		
Number of rejections	28	26
Rate of rejection	0.7778	0.7647
Summary B		
Number of rejections with positive parameters	26	26
Rate of rejection with positive parameters	0.7222	0.7647
H_0: $l = 0$		
Summary C		
Number of rejections	20	20
Rate of rejection	0.5556	0.5882
Summary D		
Number of rejections with positive parameters	13	13
Rate of rejection with positive parameters	0.3611	0.3824

Notes: The table shows the number and percentage of stocks with significant changes in volatility after warrant introduction of Model 2. Rejections of the null hypothesis, H_0, are reported at the 5% level. Summary A reports the number and percentage of stocks with significant changes in volatility after warrant introduction. Then, we only select the rejections with positive parameter, i.e. their volatility is significantly diluted, in summary B. The second column shows the results of the total samples, while the subsamples without deep-in-the-money issued warrants are reported in the last column. Summaries C and D show the results of parameter l for determining the asymmetric effect on conditional volatility.

Many researchers have concluded that influences come from a number of different directions. Stein (1987) and Ma and Rao (1988) proposed that the price of an underlying asset may become more volatile after derivative introduction because increased speculators and uninformed traders bring imperfect information into the derivative market. Another perspective concluded that if the derivative market generates a migration of noisy traders from the underlying asset market or enhances the information efficiency by allowing hedging, the volatility of underlying assets will decline. This argument is supported by Ma and Rao (1988), Skinner (1989), Damodaran and Lim (1991) and Fedenia and Grammatikos (1992). There are also studies which suggest that there are no significant changes in the stock return volatility after derivative introduction (Edwards, 1988a, b; Baldauf and Santoni, 1991; Kamara *et al.*, 1992; Bollen, 1998).

In this study, instead of using simple SD measurement in volatility changes, the GARCH-M model is modified to include time-varying volatility. The results in all models display significant changes of underlying stock processes following warrant introduction. We obtain some empirical evidence and justify a crucial point in the warrant underpricing problem. We find that the stock return process will lead to lower volatility and expected returns after warrant introduction. This variation is also highly correlated with stock price compared to exercise price. As firms receive warrant premia while issuing and possibly gaining more equity when exercised, the firms' capital structure will be changed to a lower debt–equity ratio after warrant listing. In general, shareholders expect a higher possibility of warrants being exercised with either a higher stock price or deeper in-the-money warrant, and *vice versa*.

Table 6. Maximum likelihood estimates on Model 3

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	Log-likelihood
(4) LUKS GROUP	0.000137	0.0086	0.0000	0.8861	0.1047	0.0387	3405.79
		(0.3918)	(3.1441)	(52.3392)	(6.3179)	(3.2219)	
(5) LEI SHING HONG	0.000137	−0.0223	0.0000	0.8642	0.0454	0.0159	6801.18
		(−1.0939)	(9.8800)	(70.1245)	(5.8496)	(3.4818)	
(6) CHINA TRAVEL INTL.INVS.	0.000137	0.0188	0.0000	0.9212	0.0669	0.0238	2200.39
		(0.5820)	(2.7803)	(57.5371)	(4.4813)	(2.8814)	
(7) KITH HOLDINGS	0.000137	0.0263	0.0000	0.7714	0.1186	−0.0027	4012.34
		(1.6880)	(37.3025)	(67.7593)	(9.1087)	(−0.4228)	
(8) KINGBOARD CHEMICALS HDG.	0.000137	0.0762	0.0001	0.8645	0.0872	0.0113	2597.29
		(6.2165)	(3.2887)	(70.9211)	(9.2804)	(2.2596)	
(9) CITY TELECOM	0.000137	0.0091	0.0007	0.5029	0.3586	0.1967	2783.77
		(0.3822)	(4.9997)	(7.2806)	(6.3968)	(6.4308)	
(10) HAIER ELECTRONICS GP.	0.000137	0.0021	0.0001	0.8259	0.1740	0.0138	1622.10
		(0.0305)	(4.0449)	(40.3910)	(8.5750)	(2.1640)	

(*continued*)

Table 6. Continued

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	Log-likelihood
(11) PAUL Y ENGR.GP.	0.000137	−0.0167	0.0001	0.6787	0.3136	0.0462	1350.67
		(−0.5283)	(5.0045)	(18.4627)	(5.6150)	(2.3302)	
(12) ASIA ALUMINUM HOLDINGS	0.000137	0.0285	0.0002	0.6216	0.2297	−0.0038	2223.27
		(0.9409)	(4.9713)	(12.9609)	(5.8895)	(−0.2286)	
(14) HOP HING HOLDINGS	0.000137	−0.0035	0.0007	0.4589	0.2092	0.5402	2758.01
		(−0.1465)	(9.6859)	(9.1672)	(5.4729)	(2.7019)	
(16) RICHE MULTI-MEDIA HDG.	0.000137	0.0059	0.0000	0.9005	0.0899	0.0533	2893.41
		(0.2176)	(4.2005)	(250.7212)	(11.3608)	(5.2890)	
(17) HARMONY ASSET	0.000137	−0.0239	0.0003	0.7242	0.0769	−0.0898	1678.05
		(−0.7446)	(6.8691)	(19.4284)	(5.2711)	(−4.6742)	
(18) PREMIUM LAND	0.000137	−0.0057	0.0001	0.9025	0.0890	0.0203	899.03
		(−0.1285)	(2.1421)	(24.8821)	(2.5494)	(2.0036)	
(20) CHINA STRATEGIC HDG.	0.000137	−0.0088	0.0011	0.5974	0.0793	0.1165	1143.43
		(−0.2515)	(2.4701)	(3.9870)	(2.4580)	(2.6930)	
(21) ALCO HOLDINGS	0.000137	0.0379	0.0002	0.5762	0.1962	0.1030	3556.49
		(1.5961)	(3.8903)	(7.1888)	(5.9105)	(3.6511)	
(22) PACIFIC ANDES INTL.HDG.	0.000137	0.0927	0.0002	0.7721	0.1046	0.0920	1909.80
		(2.8743)	(2.4882)	(10.6788)	(3.3879)	(2.6727)	
(23) PEACE MARK HDG.	0.000137	0.0742	0.0001	0.8560	0.1132	0.0569	2164.65
		(2.4239)	(2.5909)	(25.9192)	(3.9705)	(2.6147)	
(24) SOUNDWILL HDGHHOLDINGS	0.000137	0.0030	0.0001	0.8424	0.1466	0.0357	2327.21
		(0.1104)	(4.0671)	(45.6641)	(7.6717)	(3.1678)	
(25) HERITAGE INTL.HDG.	0.000137	−0.0410	0.0015	0.4676	0.1738	−0.1114	1076.19
		(−1.1730)	(3.9611)	(4.2797)	(4.1538)	(−0.5227)	
(26) EFORCE HOLDINGS	0.000137	0.0202	0.0000	0.9693	0.0307	0.0000	956.73
		(0.4590)	(0.4512)	(47.9792)	(2.4818)	(−0.0001)	
(28) KENFAIR INTL.HDG.	0.000137	0.0019	0.0002	0.6669	0.1646	0.1619	2257.19
		(0.0570)	(3.9147)	(9.0785)	(3.5154)	(4.5753)	
(29) QUALITY HLTHCR.ASIA	0.000137	0.0121	0.0000	0.9802	0.0191	0.0040	3301.26
		(1.5748)	(2.0668)	(319.8741)	(5.4834)	(2.6592)	
(30) PLAYMATES HOLDINGS	0.000137	0.0688	0.0005	0.5151	0.2043	0.0040	1047.53
		(1.6255)	(2.1747)	(2.7146)	(2.4451)	(2.9923)	
(31) CHINA TRAVEL INTL.INVS.	0.000137	0.0167	0.0002	0.4939	0.1611	0.0299	2558.77
		(0.5250)	(3.4940)	(4.2097)	(3.8450)	(1.2381)	
(33) U-RIGHT INTL.HDG.	0.000137	0.0000	0.0001	0.9151	0.0182	0.0154	1146.70
		(0.0015)	(7.5043)	(81.6733)	(2.5049)	(4.8386)	
(34) RONTEX INTL.HDG.	0.000137	0.1208	0.0004	0.7154	0.1626	0.0998	935.67
		(2.8547)	(1.9973)	(5.9892)	(2.3241)	(2.2309)	
(35) REGAL HOTELS INTL.HDG.	0.000137	0.0310	0.0000	0.8677	0.1016	0.0211	2783.32
		(1.1517)	(2.8432)	(34.6871)	(5.8213)	(2.1752)	
(36) MAN YUE INTL.HDG.	0.000137	0.0858	0.0012	0.1225	0.2877	0.1165	1895.17
		(2.8557)	(9.6050)	(1.8079)	(4.8340)	(3.4427)	

Notes: Model 3: the dilution-adjusted GARCH-M model with a threshold of exercise price is

$$\ln(S_{it}/S_{i(t-1)}) \equiv R_{it} = r + \lambda_i \sigma_{it} - (1/2)\sigma_{it}^2 + u_{it}$$
$$u_{it} \equiv \sigma_{it} Z_{it} \quad \text{and} \quad Z_{it}|\Omega_{t-1} \sim N(0,1)$$
$$\sigma_{it}^2 = (1 - \delta_i I_{i(t-1)} D_{i(t-1)})^2 (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i} u_{i(t-1)}^2)$$

where D_{it} is the dummy variable of stock i at time t, when the stock price is higher than the exercise price, $S_{it} > k$, D_{it} is 1; otherwise when the stock price is lower than the exercise price, $S_{it} < k$, D_{it} is 0. The samples which are never or almost never in-the-money are excluded to avoid the parameter δ from being zero all the time. Then parameter estimates on daily return of the 28 samples are obtained by maximizing the log-likelihood function of Model 3. The t-statistics are reported above with each estimate in parentheses. For the risk-free rate, r, we assume a constant 5% annual rate and a daily return rate of 0.000137.

Table 7. Summary statistics for the parameters of introduction dummy on Model 3

Sample	Full sample	Samples without deep-in-the-money issued warrants
Number of samples	28	26
***H*₀: δ = 0**		
Summary A		
Number of rejections	23	22
Rate of rejection	0.8214	0.8462
Summary B		
Number of rejections with positive parameters	22	22
Rate of rejection with positive parameters	0.7857	0.8462

Notes: The table shows the number and percentage of stocks with significant changes in volatility after warrant introduction on Model 3. Rejections of the null hypothesis are reported at the 5% level. Summary A reports the number and percentage of stocks with significant changes in volatility after warrant introduction. Then, we only select the rejections with positive parameter, i.e. their volatility is significantly diluted, in summary B. The second column shows the results of the total samples, while the sub-samples without deep-in-the-money issued warrants are reported in the last column.

This expectation of equity offering will be efficiently embedded in the market. The underlying stock process should reflect the potential dilution effect. The higher the possibility to exercise a warrant, the more dilution effect is embedded in the underlying stock process. Thus, the dilution effect will 'not only' affect the stock price at the exercised moment. The stocks following warrant introduction, compared to the time before introduction, have a lower debt–equity ratio and less risk exposure, making shareholders expect less return because of lower return variance. If stock processes already reflect the potential dilution effect, any dilution-adjusted warrant pricing model leads to underpricing in valuating post-announcement warrants.

VI. Conclusions

Since the DABS model was introduced, the framework has become a common approach for warrant pricing. However, if warrant introduction already reflects some dilution in the underlying stock processes, dilution adjustments may overcompensate the

Table 8. Maximum likelihood estimates on Model 4

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	l	Log-likelihood
(4) LUKS GROUP	0.000137	0.0141	0.0000	0.8823	0.1004	0.0418	−0.0823	3407.82
		(0.5568)	(2.5296)	(41.6004)	(6.4396)	(2.8855)	(−1.1369)	
(5) LEI SHING HONG	0.000137	−0.0364	0.0000	0.8597	0.0206	0.0112	0.9999	6841.88
		(−1.6771)	(8.4046)	(58.9350)	(3.1435)	(2.0400)	(4.7375)	
(6) CHINA TRAVEL INTL.INVS.	0.000137	0.0041	0.0000	0.9208	0.0708	0.0243	0.1598	2202.55
		(0.1306)	(2.7111)	(62.1638)	(4.9111)	(3.0439)	(2.0576)	
(7) KITH HOLDINGS	0.000137	0.0243	0.0000	0.7722	0.1188	−0.0023	0.0211	4012.39
		(0.9203)	(3.7379)	(16.4656)	(5.4418)	(−0.2357)	(0.3143)	
(8) KINGBOARD CHEMICALS HDG.	0.000137	0.0719	0.0001	0.8639	0.0877	0.0111	0.0523	2597.60
		(2.3559)	(2.2254)	(21.9620)	(3.7765)	(1.2521)	(0.7427)	
(9) CITY TELECOM	0.000137	0.0258	0.0008	0.4783	0.3546	0.2137	−0.1429	2787.08
		(0.9928)	(5.3281)	(6.7445)	(6.2822)	(7.1155)	(−2.5180)	
(10) HAIER ELECTRONICS GP	0.000137	0.0269	0.0001	0.8181	0.1771	0.0186	−0.1236	1626.53
		(0.8176)	(4.5893)	(46.1457)	(7.3435)	(2.5284)	(−2.3665)	
(11) PAUL Y ENGR.GP.	0.000137	−0.0137	0.0001	0.6857	0.3139	0.0467	−0.0147	1350.71
		(−0.3861)	(5.0519)	(21.4585)	(6.2857)	(2.3380)	(−0.2556)	
(12) ASIA ALUMINUM HOLDINGS	0.000137	0.0085	0.0002	0.6065	0.2065	−0.0013	0.1716	2225.99
		(0.2729)	(4.4697)	(10.6164)	(4.6375)	(−0.0713)	(2.0857)	
(14) HOP HING HOLDINGS	0.000137	−0.0074	0.0007	0.4208	0.2355	−0.0067	0.1321	2758.04
		(−0.3025)	(10.6976)	(8.5962)	(4.4212)	(−0.3384)	(1.5882)	
(16) RICHE MULTI-MEDIA HDG.	0.000137	0.0354	0.0000	0.9070	0.0917	0.0534	−0.1667	2913.27
		(1.2985)	(2.6629)	(177.8461)	(7.3175)	(5.7271)	(−4.0205)	
(17) HARMONY ASSET	0.000137	−0.0199	0.0003	0.7223	0.0766	−0.0902	−0.0815	1678.46
		(−0.6471)	(6.9429)	(19.4637)	(5.7116)	(−4.8322)	(−0.9126)	
(18) PREMIUM LAND	0.000137	−0.0361	0.0003	0.7740	0.1716	0.0761	0.5631	908.15
		(−0.8198)	(1.8618)	(8.6610)	(2.5875)	(2.8208)	(4.1322)	

(*continued*)

Table 8. Continued

Sample sequence number and company	r	λ	β_0	β_1	β_2	δ	l	Log-likelihood
(20) CHINA STRATEGIC HDG.	0.000137	−0.0254 (−0.6327)	0.0009 (3.1549)	0.6318 (5.8818)	0.0815 (2.6808)	0.1049 (3.3531)	0.3535 (2.5685)	1146.82
(21) ALCO HOLDINGS	0.000137	0.0596 (2.3577)	0.0002 (4.4930)	0.6093 (9.3577)	0.1512 (4.7935)	0.0995 (4.1384)	−0.3498 (−4.1731)	3565.48
(22) PACIFIC ANDES INTL.HDG.	0.000137	0.0824 (2.4942)	0.0007 (3.1663)	0.1951 (0.8803)	0.1882 (3.5845)	0.2672 (4.3297)	0.2396 (2.1049)	1907.72
(23) PEACE MARK HDG.	0.000137	0.0671 (2.1459)	0.0001 (2.7660)	0.8556 (27.4602)	0.1133 (4.0608)	0.0560 (2.6156)	0.1276 (1.5488)	2165.76
(24) SOUNDWILL HOLDINGS	0.000137	0.0243 (0.8693)	0.0001 (4.1311)	0.8585 (48.3355)	0.1235 (6.7306)	0.0388 (3.3851)	−0.1745 (−2.4867)	2331.69
(25) HERITAGE INTL.HDG.	0.000137	−0.0312 (−0.8722)	0.0014 (5.8481)	0.3805 (3.8999)	0.1185 (3.6448)	−0.1481 (−3.1256)	−0.2343 (−1.7109)	1088.91
(26) EFORCE HOLDINGS	0.000137	0.0090 (0.0465)	0.0000 (0.2140)	0.9764 (28.8887)	0.0118 (3.4189)	−0.0066 (−1.2613)	1.0000 (22.8844)	972.78
(28) KENFAIR INTL.HDG.	0.000137	0.0114 (0.3399)	0.0002 (4.4216)	0.6716 (10.9250)	0.1744 (3.9364)	0.1536 (4.7477)	−0.1737 (−2.0983)	2259.13
(29) QUALITY HLTHCR.ASIA	0.000137	−0.0243 (−0.9634)	0.0008 (11.2414)	0.0920 (1.3102)	0.1339 (4.1813)	0.2509 (6.4389)	0.2621 (2.2706)	3227.30
(30) PLAYMATES HOLDINGS	0.000137	0.0550 (1.2685)	0.0005 (2.7671)	0.4813 (3.2103)	0.2550 (2.8426)	0.2372 (3.4411)	0.2561 (2.1164)	1049.50
(31) CHINA TRAVEL INTL.INVS.	0.000137	0.0077 (0.2441)	0.0001 (2.9373)	0.5565 (4.7321)	0.1501 (3.5516)	0.0269 (1.1295)	0.1841 (1.8028)	2560.78
(33) U-RIGHT INTL.HDG.	0.000137	0.0196 (0.4393)	0.0001 (2.6561)	0.8970 (28.6372)	0.0145 (1.5925)	0.0050 (0.5589)	−0.9994 (−2.5062)	1151.26
(34) RONTEX INTL.HDG.	0.000137	0.1276 (3.0544)	0.0004 (1.9440)	0.6998 (5.7024)	0.1618 (2.5269)	0.1063 (1.9839)	−0.0890 (−0.7714)	936.00
(35) REGAL HOTELS INTL.HDG.	0.000137	0.0325 (0.9126)	0.0000 (78.5431)	0.8687 (87.5931)	0.1004 (6.6900)	0.0204 (3.1070)	−0.0173 (−0.3054)	2783.36
(36) MAN YUE INTL.HDG.	0.000137	0.0864 (2.8244)	0.0012 (9.3643)	0.1233 (1.8032)	0.2866 (4.7175)	0.1163 (3.4094)	−0.0088) (−0.0984)	1895.17

Notes: Model 4: the asymmetric dilution-adjusted GARCH-M model with a threshold of exercise price is

$$\ln(S_{it}/S_{i(t-1)}) \equiv R_{it} = r + \lambda_i\sigma_{it} - (1/2)\sigma_{it}^2 + u_{it}$$
$$u_{it} \equiv \sigma_{it}Z_{it} \quad \text{and} \quad Z_{it}|\Omega_{t-1} \sim N(0,1)$$
$$\sigma_{it}^2 = (1 - \delta_i I_{i(t-1)} D_{i(t-1)})^2(\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}(|u_{i(t-1)}| - l_i u_{i(t-1)})^2)$$

with $l_i > 0$, negative return shocks increase volatility more than positive shocks, thus including asymmetric effects. Where D_{it} is the dummy variable of stock i at time t, when the stock price is higher than the exercise price, $S_{it} > k$, D_{it} is 1; otherwise, when the stock price is lower than the exercise price, $S_{it} < k$, D_{it} is 0. The samples which are never or almost never in-the-money are excluded to avoid the parameter δ from being zero all the time. Then parameter estimates on daily return of the 28 samples are obtained by maximizing the log-likelihood function of Model 4. The t-statistics are reported above with each estimate in parentheses. For the risk-free rate, r, we assume a constant 5% annual rate and a daily return rate of 0.000137.

effect and underestimate warrant prices. We establish four models to examine the introduction effect on underlying stock return processes by modifying the GARCH-M model. All models show that stock return processes have significantly lower volatilities after warrant introduction. Moreover, the results also indicate that the reduction in volatility is correlated to the relation between stock and exercise prices.

After separating dilution from asymmetric effect, our empirical results still indicate that stock return processes are significantly diluted after warrant listing. Therefore, contrary to the prior empirical results, this article provides evidence to support some dilution effect reflected in the underlying stock return processes. The results also reveal that traditional warrant pricing models would overcompensate for the dilution effect and cause underestimation. The reduction in volatility of the underlying stock return processes accompanied by warrant introduction should be considered when valuing warrants and other derivatives packages, such as convertible bonds and employee stock options. This should be helpful to accurately value warrants and other related financial derivatives.

Table 9. Summary statistics for the parameters of introduction dummy and asymmetric dummy on Model 4

Sample	Full sample	Samples without deep-in-the-money issued warrants
Number of samples	28	26
H_0: $\delta = 0$		
Summary A		
Number of rejections	21	19
Rate of rejection	0.7500	0.7308
Summary B		
Number of rejections with positive parameters	19	19
Rate of rejection with positive parameters	0.6786	0.7308
H_0: $l = 0$		
Summary C		
Number of rejections	16	16
Rate of rejection	0.5714	0.6154
Summary D		
Number of rejections with positive parameters	9	9
Rate of rejection with positive parameters	0.3214	0.3462

Notes: The table shows the number and percentage of stocks with significant changes in volatility after warrant introduction on Model 4. Rejections of the null hypothesis, H_0, are reported at the 5% level. Summary A reports the number and percentage of stocks with significant changes in volatility after warrant introduction. Then, we only select the rejections with positive parameter, i.e. their volatility is significantly diluted, in summary B. The second column shows the results of the total samples, while the sub-samples without deep-in-the-money issued warrants are reported in the last column. Summaries C and D show the results of parameter l for determining the asymmetric effect on conditional volatility.

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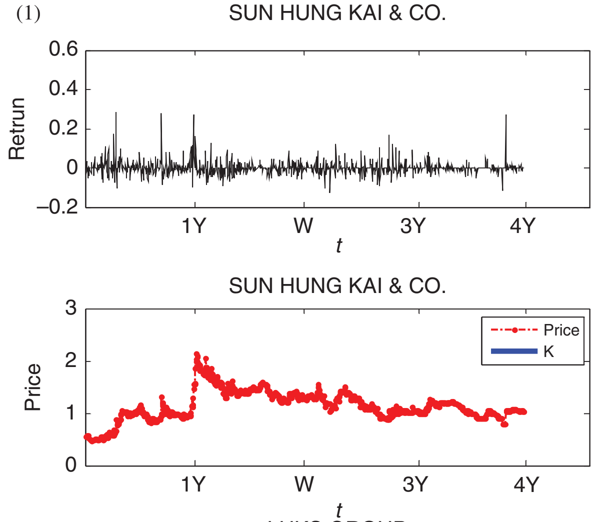
Appendix

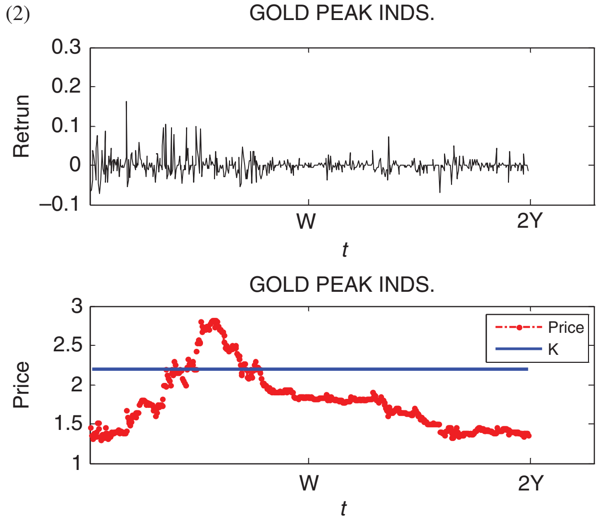
The stock return process of some companies in Table 1

Time plots of daily returns and daily prices for some underlying stocks from the start of control periods to the end of the lifetime of warrants. The solid vertical line denotes the exercise price (K) of each warrant. The sample period of each warrant includes total lifetime and the period of time before warrant introduction. The introduction time W (midpoint of observations) separates the time before warrant introduction, referred to as the control period, from the observation time period after warrant introduction. In the abscissa, Y denotes years of sample periods. All samples are the expired warrants issued from 1 January 2001 to 30 December 2004 in the HKEx.

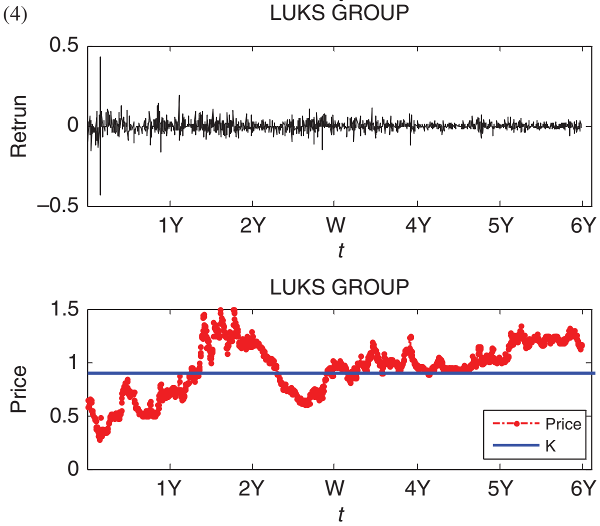
(1) SUN HUNG KAI & CO.



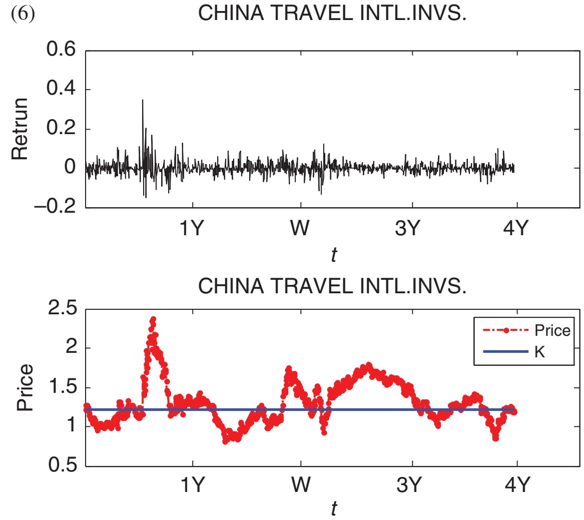
(2) GOLD PEAK INDS.



(4) LUKS GROUP



(6) CHINA TRAVEL INTL.INVS.



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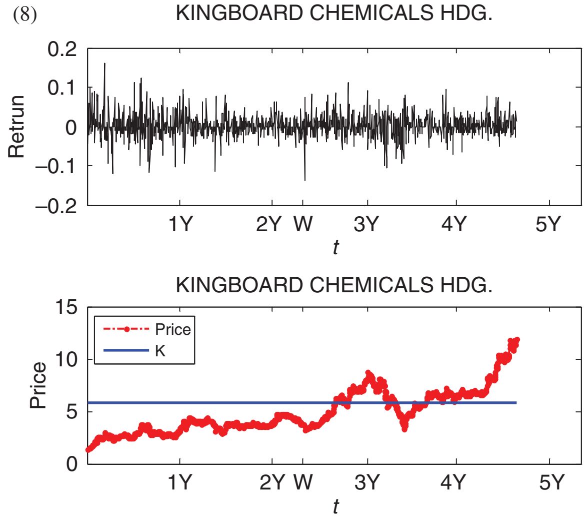
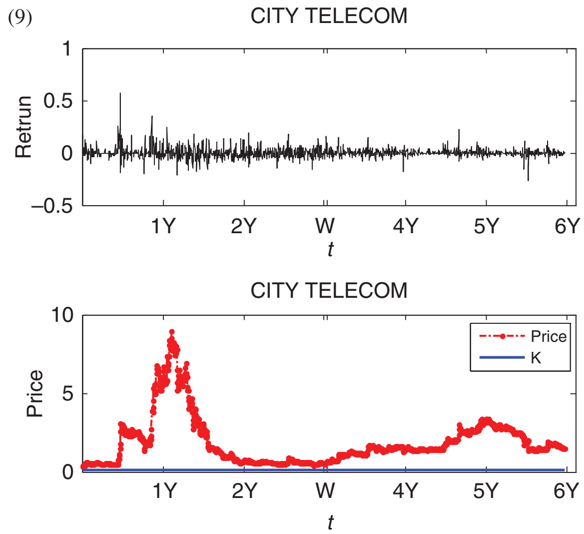
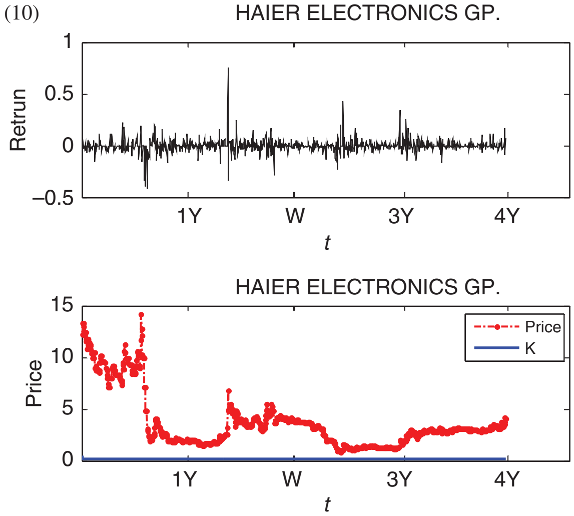

KINGBOARD CHEMICALS HDG.
Retrun
0.2
0.1
0
−0.1
−0.2
1Y
2Y W
3Y
4Y
5Y
t
KINGBOARD CHEMICALS HDG.
Price
15
10
5
0
Price
K
1Y
2Y W
3Y
4Y
5Y
t

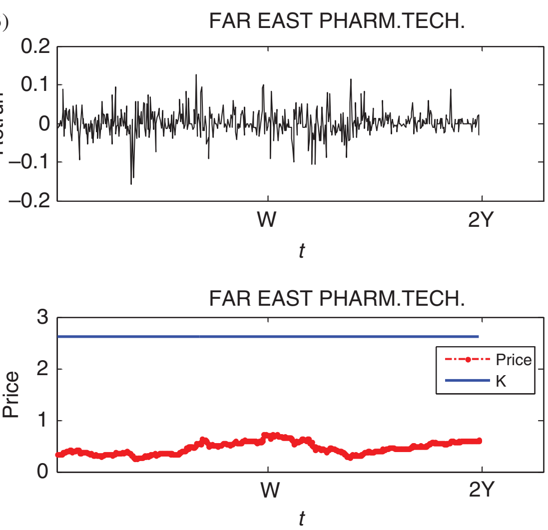
(9)


CITY TELECOM
Retrun
1
0.5
0
−0.5
1Y
2Y
W
4Y
5Y
6Y
t
CITY TELECOM
Price
10
5
0
Price
K
1Y
2Y
W
4Y
5Y
6Y
t

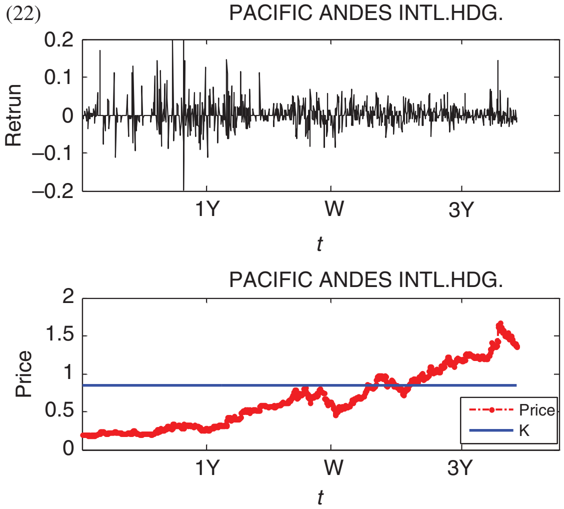
(10)


HAIER ELECTRONICS GP.
Retrun
1
0.5
0
−0.5
1Y
W
3Y
4Y
t
HAIER ELECTRONICS GP.
Price
15
10
5
0
Price
K
1Y
W
3Y
4Y
t

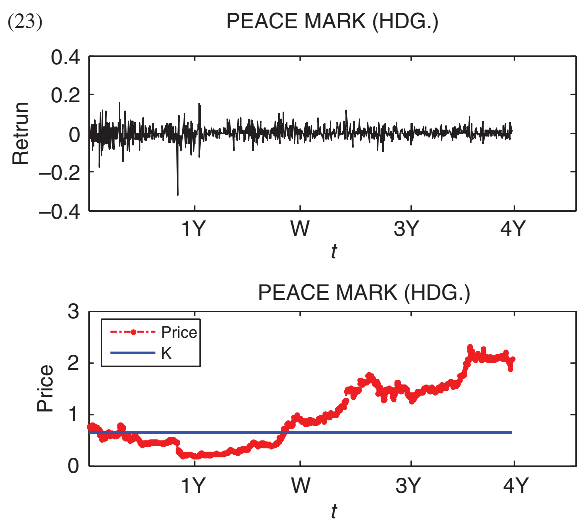
(13)

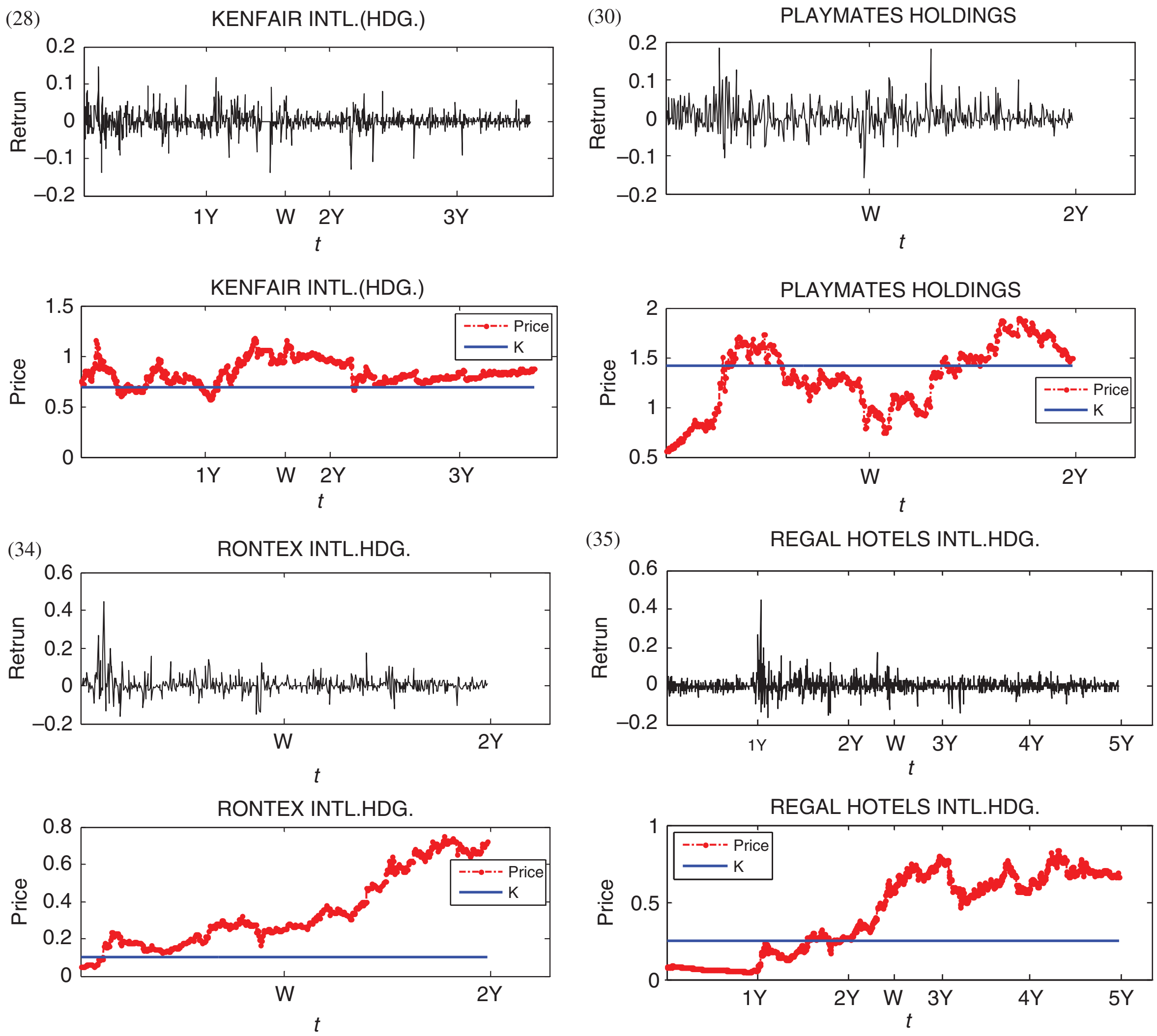

FAR EAST PHARM.TECH.
Retrun
0.2
0.1
0
−0.1
−0.2
W
2Y
t
FAR EAST PHARM.TECH.
Price
3
2
1
0
Price
K
W
2Y
t

(22)


PACIFIC ANDES INTL.HDG.
Retrun
0.2
0.1
0
−0.1
−0.2
1Y
W
3Y
t
PACIFIC ANDES INTL.HDG.
Price
2
1.5
1
0.5
0
Price
K
1Y
W
3Y
t

(23)


PEACE MARK (HDG.)
Retrun
0.4
0.2
0
−0.2
−0.4
1Y
W
3Y
4Y
t
PEACE MARK (HDG.)
Price
3
2
1
0
Price
K
1Y
W
3Y
4Y
t


(28)
KENFAIR INTL.(HDG.)
Retrun
0.2
0.1
0
−0.1
−0.2
1Y
W
2Y
3Y
t
KENFAIR INTL.(HDG.)
Price
1.5
1
0.5
0
Price
K
(30)
PLAYMATES HOLDINGS
Retrun
W
2Y
t
PLAYMATES HOLDINGS
Price
2
1.5
1
0.5
(34)
RONTEX INTL.HDG.
Retrun
0.6
0.4
0.2
0
−0.2
W
2Y
t
RONTEX INTL.HDG.
Price
0.8
0.6
0.4
0.2
0
(35)
REGAL HOTELS INTL.HDG.
Retrun
1Y
2Y
W
3Y
4Y
5Y
t
REGAL HOTELS INTL.HDG.
Price
1
0.5
0