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An Investigation of Warrant Introduction Effects on Stock Return Processes

發行認股權證對股價影響之探討

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Abstract

Since the Black-Scholes warrant pricing model priced warrants as an option with some modifications and dilution adjustments, this warrant pricing framework has become a common method. However, if warrant introduction already reflects the underlying stock processes, dilution adjustments will over-count the dilution effect and underestimate warrant prices. To justify whether dilution adjustments are required for warrant pricing, we extend the GARCH-M model to derive four models for testing the dilution effect on stock return processes. Our empirical results show that the volatilities of underlying stock return processes are significantly reduced. Moreover, we provide some theoretical explanations.

Classification Code: G13; G19

Key Words: Warrant; Dilution Effect; GARCH; Convertible Bond; Capital Structure

中文摘要

自Black-Scholes藉由調整選擇權評價模型並加入稀釋因子以建立認股權證評價模型，認股權證之評價以此為普遍的評價結構。然而，若認股權證發行的稀釋效果已反應於標的資產之價格動態，稀釋因子的調整將高估稀釋效果並低估權證價格。為了釐清權證價格的評價是否需要額外進行稀釋因子的調整，本研究延伸GARCH-M建立四個評價模型以檢驗股價過程是否已隱含稀釋效果。本研究之實證結果顯示標的股價的報酬變異顯著下降，此外，本研究提出相關的理論說明。

關鍵字：認股權證、稀釋效果、GARCH、可轉換公司債、資本結構

An Investigation of Warrant Introduction Effects on Stock Return Processes

1. 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 behavior of warrant holders affects warrant values and then analyzed their optimal exercise strategies for corporate warrants. As warrants are prevalently incorporated in many financial derivatives, it is important to accurately evaluate warrant prices. Numerous warrant pricing models are presented to follow the option pricing framework with some modifications, such as dilution effect adjustments and replacing stocks by equities. 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. It pointed out that the warrant listing increases both firms' equity and outstanding shares, and then the dilution effect should be taken into account.

Previous research on warrant pays much attention to reduce the underestimation problem. Several researchers concluded that this underestimation bias is improved by considering the possibility of maturity extension by the issuer, establishing the equity return volatility inversely related to the stock price, including the flexibility for early exercise, or pricing the warrant with jump-diffusion model. However, the underestimation problem is only improved, not solved, after these adjustments. From Kremer and Roenfeldt (1993), warrants are generally underpriced by the DABS model and the Dilution-Adjusted Jump-Diffusion model. Their empirical study indicated a large degree of underpricing when DABS models are applied to samples of short maturity warrants and they also found that this pricing error increases as the warrant maturity decreases. They argued that the low-priced problem is possibly resulted from negligence of maturity extension for some warrants. However, this concept is not the crucial reason of warrant underestimation. Hauser and Lauterbach (1997) provided the evidence that the underestimation problem still significantly exists in DABS models with extensible maturity adjustments. Their examination on five warrant pricing models concluded the pricing errors of the DABS model are large especially for out-of-the-money warrants, and some biases remain in the constant elasticity of variance (CEV) model despite its relatively good performance. Therefore, we suggest that some crucial factors of underestimation must still be ignored in these models.

Although several researchers suggested that the dilution adjustment is unnecessary and the underlying stock price conditionally reflects dilution at any time following the announcement of warrant listing, little attention has been drawn to determine the effect of the warrant introduction on the underlying stock return process. The literature focused on such impact was published by Alkeback and Hagelin (1998). They used the event study methodology to determine the effect on price, volatility and liquidity of the underlying stock at and around warrant introduction. Unfortunately, their conclusion did not support that the stock price already reflects the dilution of warrant listing. Their results suggested that following the warrant introduction there is no real effect on their underlying stocks, thus there is no significant impact on the price or volatility. Based on their results, since the warrant introduction has no real influence on its underlying stock, option pricing models should modify the potential equity dilution to price warrants. This

[1] The Black-Scholes warrant pricing model is presented by Black-Scholes (1973) and Galai and Schneller (1976), they showed that the Black-Sholes option pricing model can price warrants with some modifications and dilution adjustments.

conclusion seems to contradict to the studies mentioned above (Crouhy and Galai, 1991; Schulz and Trautmann, 1994; Handley, 2002). Consequently, this ambiguity justifies the need for further empirical research. This study will examine the effect of the warrant introduction on the underlying stock return process during the whole life of warrants instead of just at or around warrant introduction.

2. Methodology

2.1. Theoretical Consideration on Testing the Effect of Warrants on the Underlying Stock Return Process

This study suggests that when a firm issues warrants, its equity goes up with the cash inflows associated with the warrant premium. 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 is changed after the warrant listing. According to the proposition II of the capital structure theory of Modigliani and Miller (1958), the risks to shareholders increase with higher leverage and the expected return on equity is positively related to the level of leverage. In other words, the higher levered shareholders have better return in good times and worse returns in bad times than lower levered shareholders. This means that higher the leverage is, greater the risks are; therefore, the shareholders would ask for more expected return as risk premium. Thus, because the warrant introduction decreases the debt-equity ratio and lowers the leverage of the firm, the firm has less risk exposure (including systematic risk, market risk, and default risk exposure). Meanwhile, the shareholders of the lower leveraged firm take less risk and get less risk premium. Therefore, we argue that the underlying stock return process should be changed with lower volatility and expected return after warrant introduction.

2.2. Stock Return Processes in the GARCH-M Model

As investors require compensation for holding risky assets, the expected return of a risky asset increases with higher variance. Thus, when an asset becomes more risky, its conditional volatility increases and then its expected rate of return also increases. To capture the relation between mean and variance of the excess return, we will follow the framework proposed by Engle, Lilien, and Robins (1987), the so-called GARCH in the mean model (GARCH-M model), to allow the conditional variance to affect the conditional expected returns. The dynamics of the stock return modeled by GARCH -M process with order (p,q) are

$$\ln(S_{it} / S_{i(t-1)}) \equiv R_{it},$$
$$R_{it} = r + \lambda_i \sigma_{it} - (1/2)\sigma_{it}^2 + \sigma_{it} Z_{it},$$
$$\sigma_{it}^2 = c_i + \sum_{s=1}^{p} \alpha_{i(t-s)} \sigma_{i(t-s)}^2 + \sum_{s=1}^{q} \beta_{i(t-s)} u_{i(t-s)}^2,$$
$$u_{it} \equiv \sigma_{it} Z_{it}, \text{ with } Z_{it} \left| \Omega_{t-1} \right. \sim N(0,1),$$

where R_{it} is the return of stock i over a time interval at time t with conditional mean $E\left(R_{it} \left| \Omega_{t-1} \right.\right) = r + \lambda_i \sigma_{it} - (1/2)\sigma_{it}^2$, 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 return of stock i at time t, and Z_{it}, conditional on the information Ω_{t-1} at time t-1, represents a sequence of independent and identically normally distributed random variables with mean zero and volatility 1. The coefficients α_i and β_i should satisfy some regularity conditions to ensure that the unconditional volatility σ_{it}^2 is finite. Hence, the conditional expected return of stock i at time t is

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

and its conditional volatility is

$$Var\left(R_{it}\left|\Omega_{t-1}\right.\right)=\sigma_{it}^2 , \tag{2}$$

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

In the above setup, the stock return process can be represented by a conditional expected return term plus a conditional volatility term. Moreover, as Eq. (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 extended the GARCH model to let the risk premium be serially correlated with the volatility process σ_{it}^2.

2.3. The GARCH-M Model with Volatility Modifications for Testing the Effect of Warrant Introduction

It is reasonable that when the warrant introduction decreases the firm's debt-equity ratio, leverage, and risk exposure, the shareholders of such lower leveraged firm take less risk and get less risk premium. Now, in order to test the impact of the underlying stock return process after warrant introduction and to determine whether the introduction itself reflects the potential dilution effect, we take dilution 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, we will derive four extensions of the model with different conditional volatility settings to determine the impact on the stock return process after warrant introduction. The four modified models are divided into two groups: Model 1 and Model 2 in one dummy variable framework, and Model 3 and Model 4 in two dummy variables framework.

A. One Dummy Variable Framework

We add a dummy variable into the conditional volatility of stock return processes to incorporate the effect of the 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

We incorporate a dilution dummy variable in the conditional volatility of stock return process to test the effect of the warrant introduction on stock return volatility, and therefore, the conditional standard deviation function with warrant introduction is changed to

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

where σ_{it}^D is the standard deviation including the dilution effect of stock i at time t, and σ_{it} is the fundamental standard deviation without any volatility dilution effect of warrant introduction.

I_{it} is the dummy or indicator variable of stock i at time t. I_{it} equals unity for observations recorded after warrant introduction or zero if otherwise. δ_i is the parameter capturing the warrant introduction effect. If δ_i is *positive*, the conditional volatility is *diluted* after warrant introduction. As Eq. (3) shows, we assume that the standard deviation of stock return after warrant introduction is divided into two parts. One part is the fundamental standard deviation, the standard deviation before warrant listing; and the other part is a scaled multiple of the fundamental standard deviation, the standard deviation after warrant introduction. Therefore, the conditional standard deviation in Eq. (3) can also be shown as

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

We set the fundamental conditional volatility, the function of the square of the fundamental standard deviation, to be equal to the conditional volatility under the GARCH (1,1)-M model:

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

If stock return process already reflects the dilution effect during the life of warrants, δ_i should be positive to show the lower volatility of stock returns during the life of warrants. Whereas the volatility of stock returns increases during the life of warrants, δ_i should be negative. Hence, the modified GARCH(1,1)-M model with dilution-adjusted dummy can be written as

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

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

$\sigma_{it}^D = (1-\delta_i I_{it})\sigma_{it}$, after warrant introduction $I_{it} = 1$, and otherwise $I_{it} = 0$,

where $\sigma_{it}^2 = \beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2$, and

$u_{it}^D \equiv \sigma_{it}^D Z_{it} = \left(1-\delta_i I_{it}\right)\sigma_{it} Z_{it}$, with $Z_{it}\left|\Omega_{t-1} \sim N(0,1)\right.$. 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 that the unconditional variance of R_{it} is finite.

The conditional expected return therefore is

$$E\left(R_{it}\left|\Omega_{t-1}\right.\right) = r + \lambda_i\sigma_{it}^D - (1/2)\left(\sigma_{it}^D\right)^2 = r + \lambda_i\sigma_{it}(1-\delta_i I_{it}) - (1/2)\left[\sigma_{it}(1-\delta_i I_{it})\right]^2, \quad (6)$$

and the conditional volatility is

$$Var\left(R_{it}\left|\Omega_{t-1}\right.\right) = Var_{t-1}\left(u_{it}^D\right) = (\sigma_{it}^D)^2 = (1-\delta_i I_{it})^2\sigma_{it}^2. \quad (7)$$

Since Model 1 makes an allowance for the measurement of the warrant introduction effect, Eqs. (6) and (7) are different from Eqs. (1) and (2) in GARCH-M model. In Eqs. (6) and (7), if δ_i is significantly positive (negative), the conditional volatility decreases (increases) with warrant introduction, and therefore the expected return decreases (increases) with lower (higher) conditional volatility.

By Eq. (4), the fundamental conditional volatility process, and Eq. (3), we see that

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

Rearranging (8), we can obtain the following specification of the conditional volatility function for stock return process with warrant introduction as

$$\left(\sigma_{it}^{D}\right)^{2}=\left[(1-\delta_{i}I_{it})/(1-\delta_{i}I_{i(t-1)})\right]^{2}\left[(1-\delta_{i}I_{i(t-1)})^{2}\beta_{0i}+\beta_{1i}\left(\sigma_{i(t-1)}^{D}\right)^{2}+\beta_{2i}\left(u_{i(t-1)}^{D}\right)^{2}\right]. \qquad (9)$$

It can also be expressed as

$$\left(\sigma_{it}^{D}\right)^{2}=\begin{cases}\beta_{0i}+\beta_{1i}\left(\sigma_{i(t-1)}^{D}\right)^{2}+\beta_{2i}\left(u_{i(t-1)}^{D}\right)^{2}, & if\ I_{it}=I_{i(t-1)}=0,\\ (1-\delta_{i})^{2}\left[\beta_{0i}+\beta_{1i}\left(\sigma_{i(t-1)}^{D}\right)^{2}+\beta_{2i}\left(u_{i(t-1)}^{D}\right)^{2}\right], & if\ I_{it}=1, I_{i(t-1)}=0,\\ (1-\delta_{i})^{2}\beta_{0i}+\beta_{1i}\left(\sigma_{i(t-1)}^{D}\right)^{2}+\beta_{2i}\left(u_{i(t-1)}^{D}\right)^{2}, & if\ I_{it}=I_{i(t-1)}=1.\end{cases} \qquad (10)$$

Eq. (10) shows that the conditional volatility after warrant listing, $\left(\sigma_{it}^{D}\right)^{2}$, would be a scale multiple of $\beta_{0i}+\beta_{1i}\left(\sigma_{i(t-1)}^{D}\right)^{2}+\beta_{2i}\left(u_{i(t-1)}^{D}\right)^{2}$, 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 captures the changes in conditional volatility of warrant introduction.

Model 2: The Asymmetric Dilution-Adjusted GARCH-M Model

There are many asymmetric GARCH model characterized by the difference in the conditional volatility function to fit the asymmetric phenomenon that negative shocks of stock prices generally have larger effects on their volatility than positive shocks. This asymmetric phenomenon is referred to as the leverage effect. As the stock price decreases from negative shocks, the equity value of the firm gets smaller relative to its debt, and its stocks become more risky with the higher financial leverage. Because we argue that warrant introduction may affect underlying stock return process and dilute the volatility, it is important to distinguish the volatility change of the dilution effect from the asymmetric leverage effect. By doing this, we can avoid this kind of ambiguities. Corresponding to Engle and Ng (1993), Glosten et al. (1993), and Christoffersen and Jacobs (2004), we modified Model 1 (the Dilution-Adjusted GARCH Model) with the asymmetric effect in the conditional variance equation and created Model 2 as following:

$$R_{it}=r+\lambda_{i}\sigma_{it}^{D}-(1/2)\left(\sigma_{it}^{D}\right)^{2}+u_{it}^{D},$$
$$u_{it}^{D}\equiv\sigma_{it}^{D}Z_{it}=\left(1-\delta_{i}I_{it}\right)\sigma_{it}Z_{it}, \text{ with } Z_{it}\left|\Omega_{t-1}\sim N(0,1)\right.,$$
$$\sigma_{it}^{D}=(1-\delta_{i}I_{it})\sigma_{it},$$
$$\sigma_{it}^{2}=\beta_{0i}+\beta_{1i}\sigma_{i(t-1)}^{2}+\beta_{2i}\left(\left|u_{i(t-1)}\right|-l_{i}u_{i(t-1)}\right)^{2}. \qquad (11)$$

The parameters β_{1i}, β_{2i}, and l_i must satisfy some regularity conditions to ensure that the unconditional volatility of stock return process is finite. In Eq. (11), with l_i<0, negative return shocks increase volatility more than positive shocks; thus the equation includes asymmetric effects. The conditional volatility function for stock return process with the asymmetric effect and the warrant introduction effect is

$$\left(\sigma_{it}^{D}\right)^{2}=\left[(1-\delta_{i}I_{it})/(1-\delta_{i}I_{i(t-1)})\right]^{2}\left[(1-\delta_{i}I_{i(t-1)})^{2}\beta_{0i}+\beta_{1i}\left(\sigma_{i(t-1)}^{D}\right)^{2}+\beta_{2i}\left(\left|u_{i(t-1)}^{D}\right|-l_{i}u_{i(t-1)}^{D}\right)^{2}\right]. \qquad (12)$$

B. Two Dummy Variables Framework

Hauser and Lauterbach (1997) stated that the ratio of stock price to exercise price is one of the major determinates of pricing error. Hence, we would include another dummy variable in the conditional volatility to verify whether the relation between stock price and exercise price also influences the underlying stock process. Similar to one dummy variable framework, the prime form is presented in Model 3, and the extended form clarifying the ambiguity with asymmetric effect is displayed in Model 4.

Model 3: The Dilution-Adjusted GARCH-M Model with a Threshold of Exercise Price

Since Eq. (10) indicates that the conditional volatility would scale down after warrant introduction, we simplify the conditional volatility function with warrant introduction in the Dilution-Adjusted GARCH-M Model in model 1 as

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

Using a threshold dummy variable, $D_{i(t-1)}$, to identify the relation between exercise price and stock price, the model can be modified as following:

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

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

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

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

where $D_{i(t-1)}$ is the threshold dummy variable of stock i at time t-1, when the stock price is higher than the exercise price, $S_{i(t-1)} > k$, $D_{i(t-1)}$ is 1. Otherwise, when the stock price is lower than the exercise price, $S_{i(t-1)} < k$, $D_{i(t-1)}$ is 0. As mentioned before, δ_i , β_{0i} , β_{1i} , and β_{2i} should satisfy some regularity conditions to ensure that the conditional volatility is always positive and the unconditional volatility is finite. Eq. (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

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

The conditional expected return of stock i at time t is

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

and its conditional volatility is

$Var_{t-1}\left(R_{it} \left| \Omega_{t-1} \right.\right) = Var_{t-1}\left(u_{it}\right) = \sigma_{it}^2 = (1-\delta_i I_{i(t-1)} D_{i(t-1)})^2 (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}u_{i(t-1)}^2)$.

Model 4: The Asymmetric Dilution-Adjusted GARCH-M Model with a Threshold of Exercise Price

In order to distinguish the dilution effect of warrant introduction from the asymmetric leverage effect, as we considered in Model 2, the conditional volatility function in Model 3 would be transformed to

$$\sigma_{it}^2 = (1-\delta_i I_{i(t-1)} D_{i(t-1)})^2 (\beta_{0i} + \beta_{1i}\sigma_{i(t-1)}^2 + \beta_{2i}(\left|u_{i(t-1)}\right| - l_i u_{i(t-1)})^2). \quad (14)$$

With $l_i < 0$, negative shocks increase volatility more than positive shocks and l_i is the parameter capturing the asymmetric effect.

3. Data

We will use data listed on Hong Kong Exchanges and Clearing Limited (HKEx) for demonstration. Hong Kong is one of the world's top three most actively traded warrant markets while the top six exchanges represent almost 90% of the aggregate warrant turnover around the world.[2] In general, equity warrants have longer expiration period than 2 years; therefore most equity warrants issued after 2005 are unexpired. In order to cover the complete trading period of the warrant life, we need to exclude unexpired warrants; thus we will conduct our empirical analysis using the expired warrant data issued from Jan. 1, 2001, to Dec. 30, 2004. The total observations of each underlying stock return includes its entire warrant trading life and exactly the same time length of its trading life before warrant introduction. The time period before warrant introduction is referred to as a control period in which there should be no warrant trading. Thus, the total observations for each stock include the entire warrant trading life, referenced as the sample period, and the control period in this study.

The official daily closing prices of stocks after subsequent capital action adjustments are obtained from Datastream, and the data on the exercise provisions and other descriptions of the warrants are gathered from the annual Fact Book published by HKEx. The total number of new equity warrants listed on HKEx during 2001-2004 is 82. Since the same length of time as the warrant's lifetime prior to warrant introduction is required for the control group, we exclude a considerable number of stocks including the stocks with another warrant listing during the observation time period, or the ones introduced warrants shortly after an Initial Public Offering (IPO) which makes the control period too short for comparison.[3] In addition, to avoid the disarrangement of complex variations in different exchange rates, the warrants traded in currencies other than Hong Kong dollars, are also excluded. Lastly, the study also excludes a few coding error warrants or the stocks underlying have gone private from the public equity market of Hong Kong. After elimination, the final sample of the study includes 36 warrants issued from 2001 to 2004.

Since almost all subscription periods, except a warrant issued by Regal Hotels Intl. HDG. in 2004, start prior to the listing day of warrants, we recognize the start date of subscription periods as the warrant introduction date. Table 1 displays a summary of some basic descriptions of the 36 warrants sorted by listing date. Because the warrants in Table 1 cover different lengths of lifetime and range from deep-in-the-money to deep-out-of-the-money, we draw the exercise prices of warrants and plot the prices and daily returns of the underlying stocks in Appendix A to show the

[2] In 2005, Hong Kong Exchanges and Clearing Limited (HKEx) published a brief comparison of Hong Kong's warrant market with oversea counterparts in terms of number of warrant issues and turnover in a study of the Hong Kong warrant market. It showed that Hong Kong is ranked number two in terms of annual turnover of listed warrants among world stock exchanges in 2003, just behind Deutsche Börse (DB) of Germany. But after clarification of the double counts problem in Germany, Hong Kong has become the world's most actively traded warrant market by turnover value in 2003.

[3] The only exception is Riche Multi-Media HDG.. Because it went public on Feb. 15, 2000, its unavailable control period is only during 19990617-2000214 which is much shorter than its total observation period.

basic patterns of stock returns and to see the relation between stock prices and exercise prices.[4] As indicated in Appendix A, stock returns display smaller volatilities after warrant introduction.

4. Empirical Results

For maximum likelihood estimation procedure, we run the regression respectively for each stock in each model. In this section, we report the empirical results for the four dilution-adjusted GARCH-M models. First, we present the estimates of Model 1, an extended GARCH-M model incorporating a dummy variable for warrant introduction, to determine the estimated relation between volatility and warrant introduction. Second, in order to distinguish the volatility fluctuation of the dilution effect from the asymmetric leverage effect, we add an asymmetric effect variable into Model 2. Third, different from previous models, we consider the level of stock price by including a threshold dummy variable. Then the conditional volatility is influenced by warrant introduction in Model 3 only when stock prices are higher than exercise prices. Finally, like Model 2, Model 4 adds an asymmetric effect variable to Model 3.

4.1.Model 1: The Dilution-Adjusted GARCH-M Model

Table 2 shows the empirical results of Model 1 by maximizing its log-likelihood function. We estimate all parameters simultaneously on the daily returns of total observations for each sample. Full sample of this study includes the stocks underlying of the 36 warrants issued from Jan. 1, 2001, to Dec. 30, 2004. We assume that the risk-free rate of return, r, is a constant 5% annual rate as shown in Christoffersen and Jacobs (2004) and then the daily return rate is 0.000137. The second to sixth columns 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 highly significant in most samples, indicating the volatility clustering in stock returns and justifying the fitness for GARCH models.

4.2.Model 2: The Asymmetric Dilution-Adjusted GARCH-M Model

In Model 2, we incorporate the asymmetric effect by estimating the parameter l to allow different positive and negative shocks on the conditional volatility. Since we argue that warrant introduction may affect the conditional volatility, we would add the parameter l for asymmetric effect to draw such asymmetric effect from the parameter δ. If the parameter l is not significantly different from zero, the asymmetric effect is forced to be zero and Model 2 is reduced to Model 1; therefore, Model 2 is less restrictive than 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 on conditional volatility of warrant introduction is no more confused with asymmetric effect nor referred to as the omission of asymmetric phenomenon.

Model 3: The Dilution-Adjusted GARCH-M Model with a Threshold of Exercise Price

To verify whether the relation between stock price and exercise price will affect the changes of conditional volatility, we include a threshold of the excise price in stock prices. As mentioned in Section 2, we simplify the warrant introduction variable of Model 1 and multiply it by a threshold dummy, D, for judging whether the stock price is higher than the exercise price for each observation in each sample. Following that, the conditional volatility is affected by the compound

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[4] We plotted for each stock and found that most stocks seems to have smaller volatilities after warrant introduction. Because of the maximum page limitation we only show the stock return process for some sample companies in Appendix A.

dummy variable which synthesizes the warrant introduction dummy and the threshold dummy in stock price. The conditional volatility is not changed after warrant introduction until stock price exceeds the exercise price.

Comparing Model 3 to Model 1, we also find that the maximum log-likelihood is improved in 13 samples. Since the main criterion used to judge model performance is maximum likelihood, Model 3 performs better than Model 1 in 13 samples as shown in Table 6. It indicates that although Model 3 simplifies the introduction effect of model 1, the additional information of the relation between stock price and exercise price makes Model 3 perform better in almost half of the samples.

4.3. Model 4: The Asymmetric Dilution-Adjusted GARCH-M Model with a Threshold of Exercise Price

As mentioned in Model 2, the use of parameter l enables the model to respond asymmetrically to positive and negative shocks on conditional volatility. We add parameter l to the conditional volatility in Model 3 and thus make Model 4 the most richly parameterized model in this study. As Table 8 shows, even though the rejection rate of the parameter δ is a little lower than all the previous models, 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 negative l are only 0.25 and 0.2692 respectively. From the results of Model 4, it is noteworthy that the compound dummy of warrant introduction is still able to capture the potential dilution effect on stock return process even after the introduction effect was simplified and both introduction effect and asymmetric effect were clarified.

5. Conclusions

Because the underestimation problem of warrant remains unsolved with many adjustments presented by previous researchers, we go back to investigate the underlying stock return processes with warrant introduction. We seek to determine whether the introduction of warrant influences the return processes of underlying stocks. If the introduction has released the potential dilution effect in stock return processes, full dilution adjustment pricing models consequently lead to underestimation. We establish four models to examine the introduction effect on underlying stock return processes by modifying the GARCH-M model. All the models investigated in this paper show that stock return processes are significantly changed to lower volatility after warrant introduction. The results also indicate that the reduction in volatility is correlated to the relation between stock prices and exercise prices. The results are robust after clarifying the ambiguity between the introduction effect and the asymmetric effect.

Contrary to the prior empirical results, this paper provides the evidence that some potential dilution effect is already reflected in the underlying stock return processes. In short, the results reveal that traditional warrant pricing models over count the dilution effect and cause underestimation biases. In addition, we provide several theoretical explanations to support this over counted possibility. Therefore, the reduction in volatility of the underlying stock return processes accompanied by warrant introduction should be considered when valuing warrants and other derivatives packaged with warrants, such as convertible bonds and employee stock options. Thus, our study would be extremely helpful to accurately value warrants and other related financial derivatives. Future analysis can be expanded to include samples that cover more markets for verifying whether our results can be generalized to all markets.

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附表

Table 1

Summary of basic data of the 36 warrants issued from Jan. 1, 2001, to Dec. 31, 2004

Sample Sequence Number & 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.	20010115	20010112	20010112-20030111	19990112-20010111	19990112-20030111	1043	3
(2) GOLD PEAK INDS.	20010214	20010209	20010209-20020208	20000209-20010208	20000209-20020208	522	2.2
(3) COSMOS MACHINERY ENTS.	20010615	20010611	20010611-20030610	19990611-20010610	19990611-20030610	1042	0.4
(4) LUKS GROUP	20010618	20010614	20010614-20040617	19980614-20010613	19980614-20040617	1568	0.9
(5) LEI SHING HONG	20010622	20010619	20010619-20060619	19960619-20010618	19960619-20060619	2608	3
(6) CHINA TRAVEL INTL.INVS.	20010703	20010703	20010703-20030630	19990701-20010702	19990701-20030630	1042	1.22
(7) KITH HOLDINGS	20010711	20010711	20010711-20040630	19980713-20010710	19980713-20040630	1557	2.2
(8) KINGBOARD CHEMICALS HDG.	20010903	20010903	20010903-20031231	19990501-20010902	19990501-20031231	1217	5.8
(9) CITY TELECOM	20011102	20011102	20011102-20041101	19981102-20011101	19981102-20041101	1565	0.11
(10) HAIER ELECTRONICS GP.	20020226	20020226	20020226-20040226	20000226-20020225	20000226-20040226	1043	0.52
(11) PAUL Y ENGR.GP.	20020305	20020301	20020301-20030829	20000901-20020228	20000901-20030829	780	0.4
(12) ASIA ALUMINUM HOLDINGS	20020412	20020410	20020410-20040409	20000410-20020409	20000410-20040409	1044	0.77
(13) FAR EAST PHARM.TECH.	20020507	20020507	20020507-20030506	20010507-20020506	20010507-20030506	521	2.62
(14) HOP HING HOLDINGS	20020603	20020529	20020529-20050430	19990627-20020528	19990627-20050430	1524	0.27
(15) SINOLINK WORLDWIDE HDG.	20020605	20020531	20020531-20031129	20001129-20020530	20001129-20031129	782	1
(16) RICHE MULTI-MEDIA HDG.	20020620	20020617	20020617-20050616	20000214-20020616	20000214-20050616	1392	3.6
(17) HARMONY ASSET	20020625	20020621	20020621-20040630	20000621-20020620	20000621-20040630	1050	0.08
(18) PREMIUM LAND	20020709	20020709	20020709-20030708	20010709-20020708	20010709-20030708	521	0.22
(19) SOUTH CHINA HDG.	20020725	20020723	20020723-20030723	20010723-20020722	20010723-20030723	522	0.42
(20) CHINA STRATEGIC HDG.	20020829	20020829	20020829-20031231	20010401-20020828	20010401-20031231	717	0.16
(21) ALCO HOLDINGS	20020902	20020902	20020902-20050901	19990902-20020901	19990902-20050901	1565	0.98
(22) PACIFIC ANDES INTL.HDG.	20020926	20020926	20020926-20040325	20000926-20020925	20000926-20040325	912	0.85
(23) PEACE MARK HDG.	20030807	20030805	20030805-20050804	20010805-20030804	20010805-20050804	1043	0.65
(24) SOUNDWILL HOLDINGS	20030905	20030903	20030903-20060302	20010302-20030902	20010302-20060302	1304	2
(25) HERITAGE INTL.HDG.	20031016	20031013	20031013-20050412	20020413-20031012	20020413-20050412	781	0.17
(26) EFORCE HOLDINGS	20031210	20031208	20031208-20041207	20021208-20031207	20021208-20041207	521	0.28
(27) ALLIED PROPERTIES	20031205	20031205	20031205-20041206	20021205-20031204	20021205-20041206	522	2.5
(28) KENFAIR INTL.HDG.	20031205	20031202	20031202-20051202	20011202-20031201	20011202-20051202	952	0.69
(29) QUALITY HLTHCR.ASIA	20040114	20040114	20040114-20070113	20010114-20070113	20010114-20070113	1564	2.5
(30) PLAYMATES HOLDINGS	20040524	20040524	20040524-20050523	20030524-20040523	20030524-20050523	520	1.42
(31) CHINA TRAVEL INTL.INVS.	20040602	20040602	20040602-20060531	20020603-2040601	20020603-20060531	1042	1.508
(32) GLOBAL BIO-CHEM TECH.GP.	20040601	20040528	20040528-20070531	20010528-20040527	20010528-20070531	1568	9.8
(33) U-RIGHT INTL.HDG.	20040624	20040618	20040618-20050623	20030618-20040617	20030618-20050623	526	0.2
(34) RONTEX INTL.HDG.	20040630	20040628	20040628-20050627	20030628-20040627	20030628-20050627	520	0.102
(35) REGAL HOTELS INTL.HDG.	20040804	20050202	20050202-20070726	20020726-20050201	20020726-20070726	1304	0.25
(36) MAN YUE INTL.HDG.	20041104	20041104	20041104-20061103	20021104-20041103	20021104-20061103	1044	0.48

Table 9

Summary Statistics for the Parameters of Introduction Dummy and Asymmetric Dummy on Model 4

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. Summary C and Summary D show the results of parameter *l* for determining the asymmetric effect on conditional volatility.

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 negative parameters	7	7
Rate of rejection with negative parameters	0.25	0.2692