The Impact of Put Warrant Listings on the Time-Varying Price Dynamics of the Underlying Stocks

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ABSTRACT

The deregulation on the constraints on the introductory of third-party put warrants in Taiwan offers an opportunity to realize whether or not the time-varying price dynamics are altered by the deregulation . We present a model which extends Engle's (2002) Multivariate Dynamic Conditional Correlation Generalize Autoregressive Conditional Heteroscedasticity (DCC-GARCH) framework to understand the impact of third-party put warrant issuances on the time-varying price dynamics of the underlying stocks on Taiwan's stock market. Empirical results show that the listing of put warrants improves market efficiency since the return volatility of the underlying stocks significantly decreases. On the other hand, growth rate of stock price, trading volume, and volatility are closely related to each other after put warrant started trading in Taiwan, both on a bivariate basis and a trivariate basis.

JEL classification: G12, G14, G18

Keywords: Third-party put warrant, multivariate DCC-GARCH model, Time-varying volatility and correlation

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I. INTRODUCTION

For the past few decades, most studies have focused mainly over the listing effect on the standard options. Opening an option market may enhance the efficiency of cash markets if a financial market is complete, and therefore the listing of an option contract is expected to have an impact on the price dynamics of the underlying stocks. In most countries, call and put warrant markets are launched at the same time. However, due to regulatory constraints in Taiwan, put warrants were launched six years after call warrants began to trade. The lagging launching practice presented in Taiwan provides a unique opportunity to study the price dynamics of underlying stocks for this specific market structure.

Taiwan's authority allowed securities houses to issue third-party warrants in 1997, but securities houses were imposed with constructing a cash portfolio against a warrant issuance. Therefore, securities houses had to engage in a long/short cash position on their issuance of a call/put warrant. At that time, Taiwanese securities houses were restricted from short-selling the underlying stocks for any reason, which means that without constructing a short cash position, there was no room for put warrant issuance. Since the short-selling restriction prevented securities houses from constructing a short position as a hedge portfolio against their own put warrant issuance, only third-party call warrants were introduced to Taiwan in 1997.

From the deregulation imposed by Taiwan's authority, the Securities Borrowing and Lending (SBL) center opened in June 2003, finally allowing securities houses to short sell stocks only for hedging purposes. In July 2003, third-party put warrants were officially introduced to Taiwan's market. If the lagged introduction of put warrants is non-redundant, then the price dynamics of underlying stocks must be affected by issuances, and the trading efficiency of the market must be enhanced by the introduction of these put warrants. Hence, an issue arises: does the introduction of third-party put warrants have a significant impact on the price dynamics of underlying stocks?

Our study addresses the relationship effect regarding the introductory of lagging put warrants. To realize the interactions of stock price, growth rate of trading volume, and volatility, we study the pair-wise relationship and also the tri-relationship between the three factors: stock price, growth rate of trading volume and volatility. By knowing the pair-wise interactions of the price dynamics, investors may initiate a profitable trading strategy and generate positive profits by longing/shorting the underlying stocks when facing positive/negative high correlations between price dynamics.

Taiwan's lagging put warrant listing practice allows us to offer an opportunity at understanding the special issuance effect on the price dynamics of the underlying stocks. We construct a model which extends Engle's (2002) multivariate dynamic conditional correlation generalize autoregressive conditional heteroscedasticity (DCC-GARCH) model to describe the time-varying conditional correlation between the price dynamics of underlying stocks on the listing of put warrants.

Regarding the volatility effect on put warrant issuance, our empirical results show that stock return is significantly negative for underlying stocks, while the return deviation drops upon the introduction of put warrants. Forecasting power increases as return deviation increases, and our empirical result also shows that the forecasting power in stock return is enhanced after put warrant issuance.

On the other hand, stock return responds negatively to growth rate of implied volatility, which is consistent with French, Schwert, and Stambaugh (1987) and Campbell and Henstschel (1992). Furthermore, stock return also responds negatively to growth rate of trading volume. In contrast, growth rate of trading volume responds positively to growth rate of implied volatility, which is consistent with Karpoff (1987) and Schwert (1989). In general, our empirical result on a bivariate conditional correlation between price dynamics is consistent with previous studies.

Regarding the put warrant listing effect on conditional correlation coefficients, our results show that the growth rate of trading volume responds more significantly negative to stock return after the issuance of put warrant. Therefore, the negative response between stock return and growth rate of trading volume is sharper after the put warrant is introduced. Furthermore, the stock return is more significantly negatively correlated to growth rate of implied volatility. In other words, growth rate of implied volatility responds more negatively to the stock return. Moreover, growth rate of trading volume and implied volatility are more related to each other after the issuance of put warrants, which means growth rate of trading volume responds more positively to growth rate of implied volatility after put warrant issuance. In general, the introduction of put warrants may induce the price dynamics to respond more positively/negatively related to each other. Because a higher relationship between price dynamics means a higher explanatory power of price dynamics to each other, the issuance of put warrants has enhanced the forecasting power of price dynamics on others. By observing the highly correlated impact on price dynamics after the listing of put warrants, investors may form a long/short strategy to gain profits from put warrant issuances.

Among all three price dynamics, the interactions are sharper after the issuance of put warrants. We conclude that the interdependence among price dynamics is more related for the post put warrant period. Investors who gather information regarding the correlation among price dynamics for the post put warrant period may see a better ability in forecasting the direction and size in the correlation, which also enhances the probability of diversification.

The remainder of this study is organized with the next two sections describing the empirical methodology and the sampling data used in this research. The section following that presents the empirical findings of the DCC-GARCH model, and our study ends with concluding remarks.

II. METHODOLOGY

DCC-GARCH Model

We first presents Engle's (2002) multivariate dynamic conditional correlation GARCH (DCC-GARCH) model, which estimates the conditional correlation coefficients simultaneously with the conditional variance-covariance matrix. By allowing conditional correlations to vary over time, this specification is viewed as a generalization of the Constant Conditional Correlation model (CCC model, Bollerslev (1990)). To illustrate the dynamic conditional correlation model for our purposes, let $\mathbf{x}_t$ be a 3×1 vector containing the return, volume, and growth rate of implied volatility series in a conditional mean equation as:

$$\mathbf{x_t} = \boldsymbol{\mu}_\mathbf{t} + \boldsymbol{\varepsilon}_\mathbf{t}, \quad \text{where} \ \ \boldsymbol{\varepsilon}_\mathbf{t} | \boldsymbol{\Omega}_\mathbf{t-1} \sim N(\mathbf{0}, \mathbf{H_t}), \tag{1}$$

where $\boldsymbol{\mu}_\mathbf{t} = E[\mathbf{x_t} \| \boldsymbol{\Omega}_\mathbf{t-1}]$ is the conditional expectation of $\mathbf{x_t}$ given the past information $\boldsymbol{\Omega}_\mathbf{t-1}$, and $\boldsymbol{\varepsilon}_\mathbf{t}$ is a vector of errors in the autoregression AR(1). Term $\boldsymbol{\varepsilon}_\mathbf{t}$ is assumed to be conditional multivariate normally distributed, with means of zero and variance-covariance matrix $\mathbf{H_t} \equiv \{h_{ij}\}$.

Under the assumption that the return, volume, and growth rate of implied volatility series $\mathbf{x}_t$ are determined by the information set available at time t-1, the model may be estimated using maximum likelihood methods, subject to the requirement that the conditional covariance matrix, $\mathbf{H_t}$, is positive definite for all values of $\boldsymbol{\varepsilon}_\mathbf{t}$ in the sample. We also assume that $\boldsymbol{\mu}_\mathbf{t}$ has the following formation as:

$$\mathbf{x_t} = \Phi_0 + \Phi_1 \mathbf{x_{t-1}} + \Phi_2 Market\ Index_\mathbf{t} + \boldsymbol{\varepsilon}_\mathbf{t}. \qquad (2)$$

Here, Φ_1 and Φ_2 measure the ARCH effect and market factors in the data series, respectively. In the traditional multivariate GARCH framework, the conditional variance-covariance matrix can be written as:

$$\mathbf{H_t} = \mathbf{G_t R_t G_t} \quad \text{where} \quad \mathbf{G_t} = diag\left\{\sqrt{h_{it}}\right\}, \qquad (3)$$

where h_{it} is the estimated conditional variance from the individual standard univariate GARCH(1,1) models in the following manner:

$$h_{it} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} \qquad \forall\ i. \qquad (4)$$

We see now that $\mathbf{R_t}$ is the time-varying conditional correlation coefficient matrix. According to the specification in equation (4), the variance of price dynamics is modeled as a function of the constant, the square of the last period's own residuals $\varepsilon_{i,t-1}^2$, and its previous period's conditional variance $h_{i,t-1}$. After the above basic construction, the dynamic correlation coefficient matrix of the DCC model can be denoted further as:

$$R_t = \left[diag\left(Q_t\right)\right]^{-\frac{1}{2}} Q_t \left[diag\left(Q_t\right)\right]^{-\frac{1}{2}}$$

$$Q_t = (q_{ij,t})$$

$$[diag(Q_t)]^{-\frac{1}{2}} = diag\left(\frac{1}{\sqrt{q_{11,t}}}, \frac{1}{\sqrt{q_{22,t}}}, \frac{1}{\sqrt{q_{33,t}}}\right). \quad (5)$$

In order to standardize the residual error term, Engle sets $\mathbf{z_t} = \mathbf{G_t^{-1}} \boldsymbol{\varepsilon_t}$, where $\mathbf{G_t}$ is a 3×3 diagonal matrix of conditional standard deviations. Term $\mathbf{z_t}$ is the standardized residuals vector with mean zero and variance one. Engle also suggests estimating the following time-varying correlation process as:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}},$$

where

$$\begin{aligned} q_{ij,t} &= \overline{\rho}_{ij} + a(z_{i,t-1} z_{j,t-1} - \overline{\rho}_{ij}) + b(q_{ij,t-1} - \overline{\rho}_{ij}) \\ &= (1 - a - b)\overline{\rho}_{ij} + a\, z_{i,t-1} z_{j,t-1} + b\, q_{ij,t-1} \end{aligned} \quad (6)$$

The time-varying correlation coefficients in the DCC-GARCH model can be divided into two parts. The first part indicated in the right-hand side of equation (6), $\overline{\rho}_{ij}$, represents the unconditional expectation of the cross product $z_{it} z_{jt}$, i.e. the unconditional correlation coefficient. The second part indicated on the right-hand side of equation (6), $a\, z_{i,t-1} z_{j,t-1} + b\, q_{ij,t-1}$, shows the conditional time-varying covariance. Comparing the traditional GARCH (1,1) model in equation (4) with the DCC-GARCH model in equation (6), we present that the DCC-GARCH model standardizes the residual error term into a standard normal distribution, and the constant term in the DCC-GARCH model represents the unconditional dynamic correlation between error terms, other than Bollerslev (1990)'s CCC constant correlation setting.

The DCC-GARCH model contributes to the parameters' estimation process in two parts. The first is that the conditional correlation defined in the DCC-GARCH can be modeled individually as a univariate GARCH process. The second part is that the unconditional expectations $\overline{\rho}_{ij}$ of the residual errors can be estimated separately by historical data.

Extending the Engle's DCC-GARCH Model

GARCH models are well accepted in related fields, because they capture many stylized facts such as volatility clustering and thick-tailed returns. However, since the conditional variance is a function of the magnitudes of the last period's error terms, it involves the estimation of a set of parameters. Those parameters are assumed to be constant over the sample period. In this sense, a flexible estimation structure on the conditional volatility and correlation is incorporated into models in order to capture the change in price dynamics after the issuance of third-party warrants.

Our sampling period starts from a third-party call warrant's listing day and ends on a third-party put warrant's closing day. In order to capture the put warrant issuing effect, we use a dummy variable (I) in equation (7) to represent the periods for the after-call-before-put warrant issuance and after-put warrant issuance.

After adding the put warrant issuing effect into the DCC-GARCH model, the estimated conditional variance h_{it} from GARCH(1,1) is rewritten as:

$$h_{it} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} + \eta_i I_{t \geq t^*} \qquad \forall\, i . \tag{7}$$

Term t^* represents the put warrant's issue day, and $I_{t \geq t^*}$ denotes a dummy variable of the put issuing effect. Term $I_{t \geq t^*}$ is equal to 1 if $t \geq t^*$, which represents the trading period's after-put warrant issuance, and $I_{t \geq t^*}$ is equal to zero if $t \leq t^*$, which represents the trading period's after-call-before-put warrant issuance.

We use the same concepts to introduce a put warrant issuing effect into the conditional correlation as well as the conditional variance process. Therefore, we also specify the following time-varying correlation with the process of the put warrant issuing effects as:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}},$$

where

$$q_{ij,t} = \left(1 + \delta I_{t \geq t^*}\right)\left[\overline{\rho}_{ij} + a\left(z_{i,t-1} z_{j,t-1} - \overline{\rho}_{ij}\right) + b\left(q_{ij,t-1} - \overline{\rho}_{ij}\right)\right]. \quad (8)$$

Term t^* represents the put warrant's availability day, and indicator I denotes a dummy variable indicating the put warrant's issuing day. The coefficient δ captures the changing property on conditional covariance and conditional correlation. If the market's completeness can be improved by the introduction of third-party put warrants, then the interdependencies between growth rate of trading volume, stock price, and volatility will be more related. We thus expect to observe a tighter interrelationship between those price dynamics. Therefore, the coefficient δ is expected to be positive if third-party put warrants are introduced to the market.

III. EMPIRICAL FINDINGS

Summary Statistics

As described in the previous section, the issuance of third-party put warrants lags that of third-part call warrants by almost six years. Because the first third-party put warrants were launched on July 9th 2003 on both CSC (China Steel Corporation) and TSMC (Taiwan Semiconductor Corporation) listed shares, we will study CSC and TSMC as the underlying stocks for put warrant listings. The data series are gathered from the Taiwan Economic Journal (TEJ), and the frequency of the data series for stock price, growth rate of trading volume, and growth rate of implied volatility is on a daily basis. This study analyzes the relative change of the data series.

Table 1 summarizes the return, growth rate of trading volume, and growth rate of implied volatility statistics for the underlying stocks of third-party put warrants. As reported in Table 1, Ljung-Box Q statistics (which represent the autocorrelations of level residuals and squared residuals) are significant at the 5% level for all data series, suggesting autoregressive conditional heteroscedasticity (ARCH) residuals exist in all data series. From this finding, the heteroskedastic pattern exists for these stocks and it is reasonable to apply the GARCH model to Taiwan's stock market.

<INSERT TABLE 1 HERE>

The Jarque-Bera coefficients, as indicators for non-normality, in Table 1 are significantly positive at the 1% level, which means our data series of stock return, growth rate of trading volume, and growth rate of implied volatility series are generally not normally distributed. The data series reveal the property of autocorrelation and non-normality, and the model we adopt should account for the properties of autocorrelation and non-normality.

Volatility Effect on Put Warrant Introduction

The ARCH residuals are observed in our data series, and therefore we provide an AR(1) framework to capture the autocorrelation effect in the mean equation. The coefficient Φ_1 in Table 2 reveals the autoregressive effect in mean equation parameters for return, growth rate of trading volume, and growth rate of implied volatility, and coefficient Φ_2 accounts for the market impact on the price dynamics. The market index for stock return, growth rate of trading volume, and growth rate of implied volatility is respectively the stock market index return, market growth rate of trading volume, and market growth rate of implied volatility. The coefficient Φ_2 in the mean equation for stock is significantly positive for both CSC and TSMC, and the market index return can be thought of as a positive impact factor for stock return.

After adjusting the market impact and autocorrelation effect for the return process, the Ljung-Box Q statistics are no longer significant at the 5% level. However, after adjusting the market impact, the growth rate of trading volume is significantly negative correlated to last period's growth rate of trading volume, while growth rate of implied volatility is significantly positive correlated to last period's growth rate of implied volatility. After considering the market impact and autocorrelation effect in our framework, the Ljung-Box Q statistics ($Q^2(8)$ and $Q^2(24)$) in Table 2 are no longer significant at the 5% level for all series, suggesting that ARCH residuals are eliminated by considering the AR(1) process.

<INSERT TABLE 2 HERE>

We adopt the multivariate GARCH model to incorporate non-normality properties into data series, in order to investigate the changes in time-varying conditional volatility on put warrant issuances. Coefficient ω in Table 3 represents the unconditional variance in the multivariate GARCH (1,1) volatility equation, and α and β represent the unconditional and conditional volatility, respectively. Parameter η represents the proxy of the put issuance effect. A positive η indicates that the volatility of trading behavior decreases after put warrant issuance, while a negative η indicates the opposite case.

<INSERT TABLE 3 HERE>

Coefficient β in Table 3 shows that the conditional volatility of stock return is significantly positive for both CSC and TSMC, which means the conditional volatility of stock return is positively determined by prior period's volatility. This empirical result is consistent with Aitken and Segara (2005)'s study in Australia's warrant market. However, coefficient η for stock return is significantly negative for both CSC and TSMC, and the return deviation drops upon the introduction of put warrants. Forecasting power increases as return deviation increases, and our empirical result shows that the forecasting power in stock return is enhanced after put warrant issuance.

Time-Varying Bivariate Conditional Correlations

The corresponding interrelationships between return, growth rate of trading volume, and growth rate of implied volatility are investigated by the bivariate DCC-GARCH, which checks whether the corresponding correlations between return, growth rate of trading volume, and growth rate of implied volatility significantly increase after put warrant issuance. Through this type of study, the formation of a profitable trading strategy regarding a put warrant issuance event can be realized.

The conditional correlations between price dynamics of underlying stocks are indicated as coefficient b in Table 4. From Table 4, stock return responds negatively to growth rate of implied volatility for both CSC and TSMC at the 1% level, which is consistent with French, Schwert, and Stambaugh (1987) and Campbell and Henstschel (1992). Furthermore, stock return also responds negatively to growth rate of trading volume for both CSC and TSMC at the 1% level. In contrast, growth rate of trading volume responds positively to growth rate of implied volatility for both CSC and TSMC at the 1% level, which is consistent with Karpoff (1987) and Schwert (1989). In general, our empirical result on a bivariate conditional correlation between price dynamics is consistent with previous studies.

<INSERT TABLE 4 HERE>

Put Warrant Listing Effect on Correlation

Coefficient δ in Table 4 indicates the put warrant listing effect on conditional correlation coefficients. The growth rate of trading volume responds more significantly negative to stock return for both CSC and TSMC after the issuance of put warrant. Therefore, the negative response between stock return and growth rate of trading volume is sharper after the put warrant is introduced. Furthermore, the stock return is more significantly negatively correlated to growth rate of implied volatility for both CSC and TSMC at the 1% level. In other words, growth rate of implied volatility responds more negatively to the stock return. Moreover, growth rate of trading volume and growth rate of implied volatility are more related to each other for both CSC and TSMC after the issuance of put warrants at the 1% level, which means growth rate of trading volume responds more positively to growth rate of implied volatility after put warrant issuance. In general, the introduction of put warrants may induce the price dynamics to respond more positively/negatively related to each other. Because a higher relationship between price dynamics means a higher explanatory power of price dynamics to each other, the issuance of put warrants has enhanced the forecasting power of price dynamics on others. By observing the highly correlated impact on price dynamics after the listing of put warrants, investors may form a long/short strategy to gain profits from put warrant issuances.

Time Patterns of Bivariate Conditional Correlations

Figures 1, 2, and 3 plot the time-varying relationship between each trading behavior in order to realize the timing patterns in te conditional correlations between price dynamics. The listing day of put warrants for CSC and TSMC is 7/9/2003, and from Panels A and B in Figure 1 we see that the time-varying conditional correlations for both CSC and TSMC are positive. Panel A shows that the volatility of time-varying correlations for CSC increased in the beginning of the post put warrant period, but the volatility ceases to be stable in the latter part of the post put warrant period. Panel B shows that the time-varying correlations are more volatile for TSMC after put warrants' listing. The moving path of the time-varying correlations between return and growth rate of trading volume for both CSC and TSMC indicates an upward trend after put warrant issuance.

<INSERT FIGURE 1 HERE>

Figure 2 shows the brivariate time-varying conditional correlation coefficient between return and growth rate of implied volatility. The listing day of the put warrants for CSC and TSMC is 7/9/2003. From Panel A in Figure 2, the volatility of conditional correlation coefficients for CSC increased after put warrant issuance. In Panel B, the conditional correlation for TSMC is much more volatile after put warrant issuance. From both CSC and TSMC stock shares, the moving path of time-varying correlation between return and growth rate of implied volatility indicates a downward trend for the post put warrant period.

<INSERT FIGURE 2 HERE>

Figure 3 indicates the brivariate time-varying conditional correlation coefficient between growth rate of trading volume and growth rate of implied volatility. From both Panels A and B, the time-varying relationship between growth rate of trading volume and growth rate of implied volatility is positive. From Panel A for CSC, the conditional correlation coefficient is much more volatile after put warrant issuance. By Panel B, the conditional correlation for TSMC is much more volatile after put warrant issuance. The moving path of the time-varying correlation between growth rate of trading volume and growth rate of implied volatility reveals an upward trend after put warrant issuance.

<INSERT FIGURE 3 HERE>

Trivariate Conditional Correlations

We realize herein of the interdependencies between stock return, growth rate of trading volume, and growth rate of implied volatility from the bivariate DCC-GARCH framework. However, a unique indicator representing the interrelationships among the three price dynamics is not available by the current framework. Therefore, a trivariate GARCH framework is addressed in order to understand whether or not the overall correlation among the three price dynamics increases in the event of a put warrant issuance.

The coefficient b in Table 5 shows the conditional correlations among stock return, growth rate of trading volume, and growth rate of implied volatility. At the same time, the introductory effect on put warrant issuance is revealed by the coefficient δ, and a positive δ says that the changes in correlation among three price dynamics significantly increase after put warrant introduction. The coefficient b for both CSC and TSMC is significantly positive at the 1% level, or in other words, the tri-relationship among stock return, growth rate of trading volume and growth rate of implied volatility is positive. Moreover, the coefficient δ for both CSC and TSMC is significantly positive at the 1% level. We conclude that the interdependence among price dynamics is more related for the post put warrant period. Investors who gather information regarding the correlation among price dynamics for the post put warrant period may see a better ability in forecasting the direction and size in the correlation, which also enhances the probability of diversification.

<INSERT TABLE 5 HERE>

IV. CONCLUDING REMARKS

In most countries, opening a warrant market up provides investors an opportunity to choose between both a call and put. In Taiwan, due to regulatory constraint, put warrants were launched six years after call warrants. This special launching practice induced a question as to whether the market behaviors of call and put warrants launched at the same time are different from the practice of when only call warrants, but not put warrants, are introduced. Hence, the lagging listing of put warrants in the Taiwan stock market offers a unique opportunity to realize the special structure on a derivative's introduction and to see the impacts on the underlying stock under the special structure.

In order to understand the introductory effect on a warrant's underlying assets in Taiwan's market, we extend Engle's (2002) Multivariate Dynamic Conditional Correlation Generalize Autoregressive Conditional Heteroscedasticity (DCC-GARCH) model to examine the time-varying volatilities and correlations on the price dynamics of the underlying stocks. The empirical results show that the introduction of put warrants reduces the return volatility, but on the other hand, the pair-wise correlations between price dynamics are more related to each other at the post put warrant period. Furthermore, the tri-correlation among price dynamics is sharper after the issuing day of a put warrant.

Observing a lower return volatility and a higher correlation of market behaviors for the event of put warrant issuance will induce investors to buy the underlying stock once the put warrant is issued. As we now know, the issuance of put warrants reduces return volatility, and return volatility is more negatively correlated with stock return. Buying the underlying stock of a warrant after put warrant issuance will result in an profit gaining experience for investors. Knowing the price dynamics of underlying stocks after the issuing day of put warrants will lead to a higher probability in forming a diversifiable portfolio.

References

Alkeback, P., and N. Hagelin, 1998, The impact of warrant introductions on the underlying stocks, with a comparison to stock options, *Journal of Futures Markets*, Vol. 18, issue 3, 307

Bollerslev, T., 1990, Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized Arch Model, *The Review of Economics and Statistics*, Vol. 72, issue 3, 498

Campbell, J.Y., and L. Hentschel, 1992, No news is good news: An asymmetric model of changing volatility in stock returns, *Journal of Financial Economics*, Vol. 31, 281

Chaudhury, M., and S. Elfakhani, 1997, Listing of put options: Is there any volatility effect? *Review of Financial Economics*, Vol.6, issue 1, 57

Corrado, C.J., and T.W. Miller Jr., 2005, The forecast quality of CBOE growth rate of implied volatility indexes, *Journal of Futures Market*, Vol. 25, issue 4, 339

Draper, P., B. Mak and G. Tang, 2001, The derivative warrant market in Hong Kong: Relationships with underlying assets, *Journal of Derivatives*, Vol.8, issue 4, 72

Engle, R.F., 2002, Dynamic conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity models, *Journal of Business and Economic Statistics,* Vol. 20, 339

French, K.R., G.W. Schwert and R. Stambaugh, 1987, Expected stock returns and volatility, *Journal of Financial Economics*, Vol. 19, 3

Karpoff, J.M., 1987, A theory of growth rate of trading volume, *The Journal of Finance*, Vol. 41, 1069

Schwert, G.W., 1989, Why does stock market volatility change over time?, *The Journal of Finance*, Vol. 44, 1115

Table 1: Summary statistics

	CSC			TSMC		
	Return	Volume	Growth rate of implied volatility	Return	Volume	Growth rate of implied volatility
Mean	0.0015	0.1475	0.6406	0.0014	0.1271	0.6782
Standard deviation	0.0202	0.7049	0.2863	0.0228	0.5864	0.7450
Skewness	0.5099***	2.3329**	10.2278***	0.1302***	2.0068**	8.4884***
Kurtosis	1.4294***	6.7532***	133.5353***	0.4227**	6.1758***	90.4302***
Jarque-Bera	31.0912***	679.3956***	1840.1887***	2.5066***	551.5493***	860.3920***
Q(8)	26.9187***	26.2782***	30.2802***	21.0008***	24.1944***	20.7499***
Q(24)	61.5633***	39.6086**	58.2848***	41.7931***	62.3579***	49.2622***
$Q^2(8)$	72.0418***	58.3861***	60.1528***	44.5238***	63.7672***	60.6656***
$Q^2(24)$	142.1304***	117.0152***	70.8185***	46.0790***	77.9719***	71.2280***

1. Data series for CSC are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 242 datapoints.
2. Data series for Acer are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 244 datapoints.
3. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.
4. Q(8), Q(24), $Q^2(8)$, and $Q^2(24)$ are the Ljung-Box tests for the 8^{th} and 24^{th} order serial correlation of standardized residuals and standardized squared residuals, respectively.

Table 2: The conditional mean equation in AR(1) process

The conditional mean equation is an autoregression (AR1) process:

$\mathbf{x_t} = \Phi_0 + \Phi_1 \mathbf{x_{t-1}} + \Phi_2 \textit{Market Index}_\mathbf{t} + \boldsymbol{\varepsilon}_\mathbf{t}$, where $\boldsymbol{\varepsilon}_\mathbf{t} \big| \boldsymbol{\Omega}_\mathbf{t-1} \sim N(\mathbf{0}, \mathbf{H_t})$ and $\boldsymbol{\varepsilon}_\mathbf{t}$ is a vector of errors in the AR(1) process with a conditional variance-covariance matrix $\mathbf{H_t} \equiv \{h_{ij}\}$

	CSC			TSMC		
	Return	Volume	Growth rate of implied volatility	Return	Volume	Growth rate of implied volatility
Φ_0	0.0008 (3.9337)***	0.1272 (3.3529)***	0.1388 (5.0230)***	0.0004 (3.3734)***	0.1312 (4.0461)***	0.4081 (8.5278)***
Φ_1	-0.0599 (-4.07036)***	-0.1795 (-3.4656)***	0.7891 (18.0224)***	0.0568 (7.6516)***	-0.1328 (-1.7866)*	0.6590 (15.7520)***
Φ_2	0.00750 (10.6387)***	1.1384 (7.9901)***	0.0029 (5.3685)***	0.0118 (24.2767)***	-0.3311 (-2.3762)**	-0.1341 (-8.5905)***
Q(8)	11.1125	19.1013**	7.9293	5.0702	9.8203	8.2623
Q(24)	39.4263**	34.3069*	31.4574	25.3132	29.8200	26.3946
$Q^2(8)$	9.4068	4.8763	5.7156	8.2925	6.4840	7.4910
$Q^2(24)$	22.3851	12.1254	11.0024	14.3146	22.0484	20.0114

1. Data series for CSC are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 242 datapoints.
2. Data series for Acer are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 244 datapoints.
3. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.
4. Parentheses represent the t statistics.

Table 3: Time-varying conditional volatility on the DCC-GARCH model with a put warrant issuance concern

Adding the put warrant issuing effect into the DCC-GARCH model, the estimated conditional variance h_{it} from GARCH (1,1) is $h_{it} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} + \eta_i I_{t \geq t^*} \; \forall \; i$, where t^* represents the issue day of put warrants, and $I_{t \geq t^*}$ denotes a dummy variable of put issuing effect. $I_{t \geq t^*}$ is equal to 1 if $t \geq t^*$, which represents the trading period after put warrant issuance, and $I_{t \geq t^*}$ is equal to zero if $t \leq t^*$, which represents the trading period after-call-before-put warrant issuance.

	CSC			TSMC		
	Return	Volume	Growth rate of implied volatility	Return	Volume	Growth rate of implied volatility
ω	0.0117 (2.1890)**	0.0548 (2.5607)**	0.0314 (2.1882)**	0.0210 (5.8300)***	0.0837 (3.7672)***	0.0298 (5.9948)***
α	0.0466 (1.9760)**	-0.0490 (-5.5277)***	0.7871 (3.6703)***	-0.0746 (-5.1893)***	0.0051 (10.0178)***	1.4315 (5.6695)***
β	0.9163 (3.1709)***	0.9097 (17.4424)***	0.3118 (4.6451)***	1.0045 (7.5950)***	1.0189 (14.0178)***	0.2489 (8.6427)***
η	-0.8875 (-2.0215)**	-0.8078 (-3.0893)***	0.9696 (5.3329)***	-0.9976 (-11.0422)***	-0.6395 (-10.1408)***	0.3187 (4.9522)***

1. Data series for CSC are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 242 datapoints.
2. Data series for Acer are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 244 datapoints.
3. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.
4. Parentheses represent the t statistics.

Table 4: Bivariate time-varying conditional correlations on the DCC-GARCH model with a put warrant issuance concern

The time-varying correlation with put warrant issuing effects are processed as $\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}}$, where $q_{ij,t} = \left(1 + \delta I_{t \geq t^*}\right)\left[\bar{\rho}_{ij} + a\left(z_{i,t-1} z_{j,t-1} - \bar{\rho}_{ij}\right) + b\left(q_{ij,t-1} - \bar{\rho}_{ij}\right)\right]$. Here, $\bar{\rho}_{ij}$ represents the unconditional expectation of the cross product of residual error terms $z_{it} z_{jt}$, or in other words, $\bar{\rho}_{ij}$ is the unconditional correlation coefficient among growth rate of trading volume, stock return, and growth rate of implied volatility. Indicator I denotes the dummy of put warrant issuance day, and δ is used to capture the changing property on conditional variance and conditional correlation.

	CSC			TSMC		
	Return-Volume	Return-Growth rate of implied volatility	Volume-Growth rate of implied volatility	Return-Volume	Return-Growth rate of implied volatility	Volume-Growth rate of implied volatility
a	0.0311 (8.6058)***	0.0056 (2.8909)***	-0.0169 (-3.4754)***	-0.0270 (-7.1722)***	-0.0126 (-4.4627)***	0.0129 (3.1934)***
b	-0.8641 (-14.7247)***	-0.9416 (-7.5018)***	0.7304 (2.9060)***	-0.8575 (-8.5017)***	-0.3116 (-11.2648)***	0.9270 (14.4719)***
δ	0.1375 (3.1866)***	0.6977 (4.4702)***	0.6989 (9.1765)***	0.1593 (3.2101)***	2.0670 (7.8165)***	1.3451 (12.4142)***

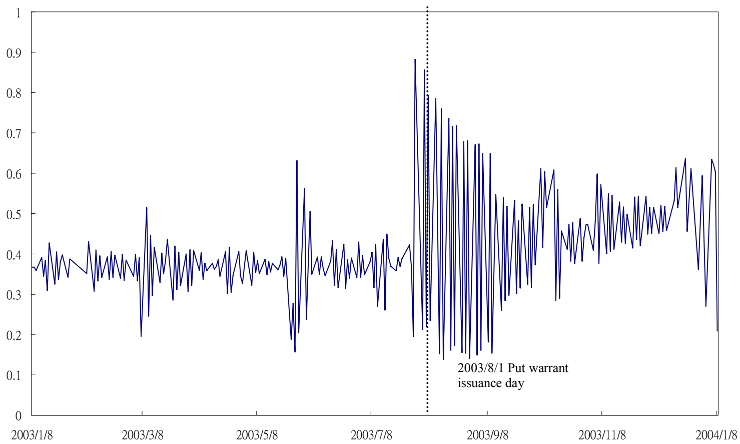
1. Data series for CSC are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 242 datapoints.
2. Data series for Acer are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 244 datapoints.
3. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.
4. Parentheses represent the t statistics.

Table5: Trivariate time-varying conditional correlations on the DCC-GARCH model with a put warrant issuance concern

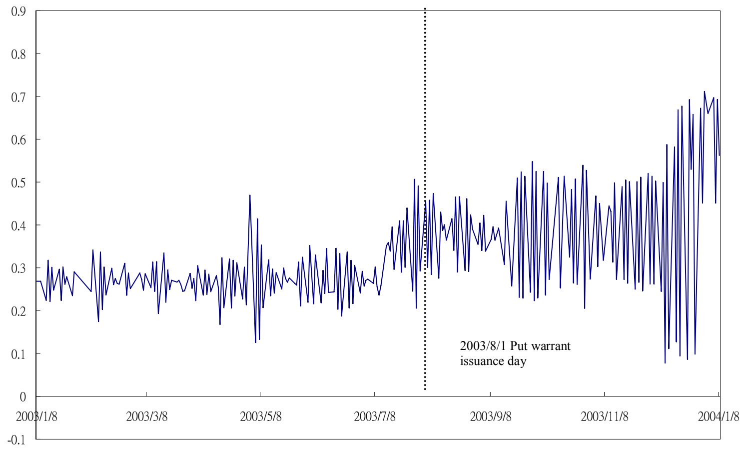
We specify the following time-varying correlation with put warrant issuing effects process as $\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}}$, where $q_{ij,t} = (1 + \delta I_{t \geq t^*})[\bar{\rho}_{ij} + a(z_{i,t-1} z_{j,t-1} - \bar{\rho}_{ij}) + b(q_{ij,t-1} - \bar{\rho}_{ij})]$. Here, $\bar{\rho}_{ij}$ represents the unconditional expectation of the cross product of residual error terms $z_{it} z_{jt}$, or in other words, $\bar{\rho}_{ij}$ is the unconditional correlation coefficient among growth rate of trading volume, stock return, and growth rate of implied volatility. Indicator I denotes the dummy of put warrant issuance day, and δ is used to capture the changing property on conditional variance and conditional correlation.

	CSC			TSMC		
	Return	Volume	Growth rate of implied volatility	Return	Volume	Growth rate of implied volatility
a		0.0505 (19.3627)***			-0.0103 (-2.8780)***	
b		0.8916 (2.7061)***			1.0048 (15.9239)***	
δ		3.9416 (3.6781)***			3.2944 (10.3050)***	

1. Data series for CSC are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 242 datapoints.
2. Data series for Acer are from 1/8/2003 to 1/8/2004, and growth rate of daily data are used, which represent 244 datapoints.
3. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.
4. Parentheses represent the t statistics.



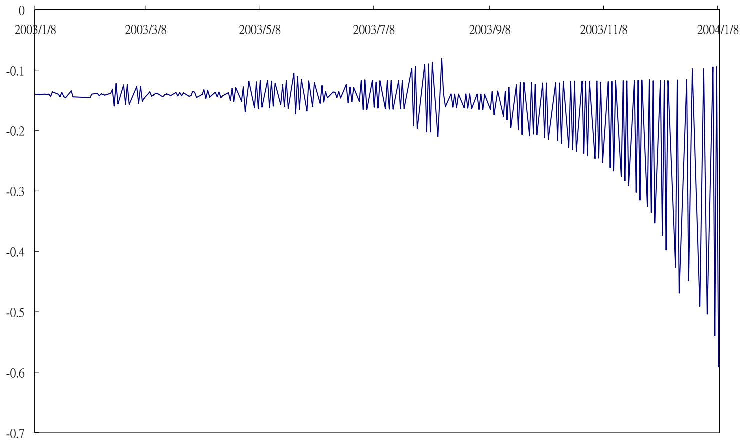
Panel A: CSC



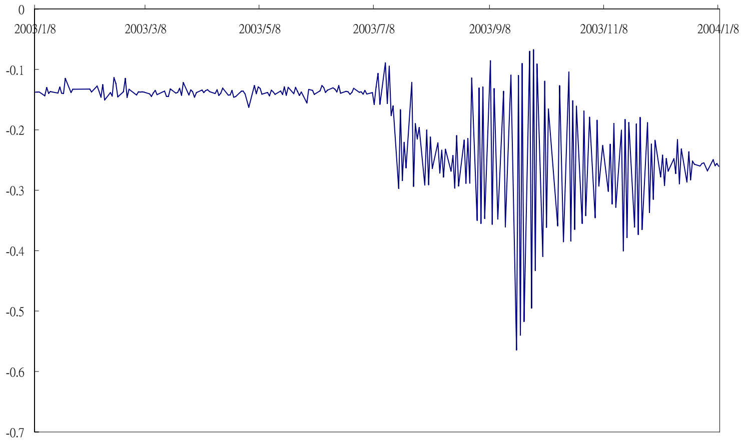
Panel B: TSMC

Figure 1: Bivariate time-varying conditional correlation coefficient between return and growth rate of trading volume

The listing day of put warrants for CSC and TSMC is 7/9/2003. From Panels A and B, we can see that the time-varying conditional correlation for both CSC and TSMC is positive. The volatility of time-varying correlations increases after the put warrant listing day, and the path of time-varying correlation moves for both CSC and TSMC on an upward trend.



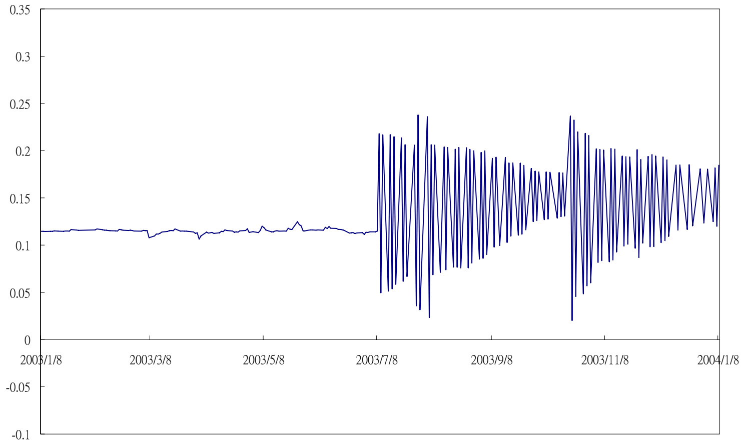
Panel A: CSC



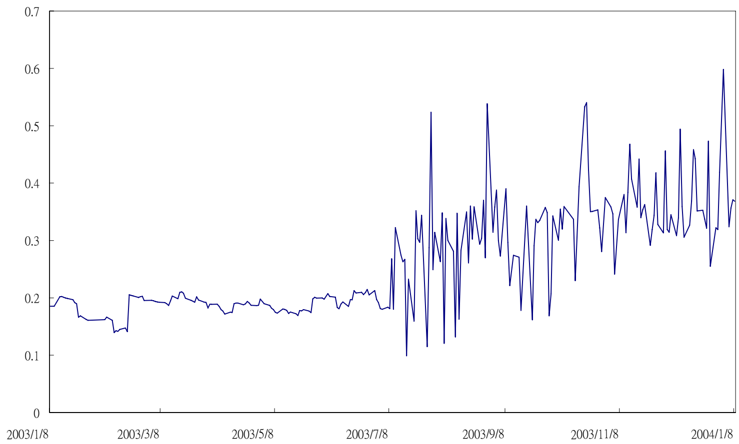
Panel B: TSMC

Figure 2: Bivariate time-varying conditional correlation coefficient between return and growth rate of implied volatility

The listing day of put warrants for CSC and TSMC is 7/9/2003. From both Panels A and B, we know that the relationship between return and growth rate of implied volatility is negative. From Panel A, the conditional correlation coefficient for CSC stock is much more volatile after put warrant issuance, while the volatility increases as issuance times goes by. From Panel B, the conditional correlation for TSMC is much more volatile after put warrant issuance, and the time-varying correlation path for TSMC has a downward trend.



Panel A: CSC



Panel B: TSMC

Figure 3: Bivariate time-varying conditional correlation coefficient between growth rate of trading volume and growth rate of implied volatility

The listing day of put warrants for CSC and TSMC is 7/9/2003. From both Panels A and B, the relationship between growth rate of trading volume and implied volatility is positive. From Panel A for CSC, the conditional correlation coefficient is much more volatile after put warrant issuance. From Panel B, the conditional correlation for TSMC is much more volatile after put warrant issuance and reveals an upward trend on the moving path of time-varying correlations.