On the Relationship between Time-Varying Price dynamics of the Underlying Stocks: Deregulation Effect on the Issuance of Third-Party Put Warrant

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ABSTRACT

Due to regulation constraints, third-party put warrant in Taiwan was launched at the day after six year of third-party call warrant's issuance. We present a model which extends Engle's (2002) DCC-GARCH approach to study the impact of the deregulation on Taiwan's third-party put warrants listing practice in order to realize the time-varying price dynamics of the underlying stocks. Our empirical results show that even though third-party put warrant launched six year after the listing day of third-party call warrant, the introductory of third-party put warrants tighten the time-varying interdependences between price dynamics of underlying stocks. The growth rate of trading volume responses more positively to stock return after the day of put warrant issuance, moreover, stock return responses sharply to the expected change of implied volatility. The resulted closely responses from one price dynamic to another provide a higher explanatory power in engaging profitable portfolios.

JEL classification: G12, G14, G18

Keywords: Third-party put warrant, multivariate DCC-GARCH model, Time-varying conditional correlations

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I. INTRODUCTION

The underlying assets on a newly opening market may behave differently from others, since hedgers, arbitrager and speculators may enter into the market in an incomplete market. The bidding process of informed trading releases useful information for uninformed traders. Realizing the information release from the price dynamics[1] of the underlying assets on a newly opened market may enhance the potential profitability of noise trading from trading cash markets.

In most countries, opening a warrant market will provide investor an opportunity to choose between call and put, which means, warrant market for both call and put are launched in the same time. In Taiwan, due to regulatory constraint[2], third-party put warrant was launched six years lags after third-party call warrant's launching. This special launching practice induced us to ask that whether the market behaviors with call and put warrant launched at the same time is different from the market behaviors that provide only call warrant but not the put warrant in their launching. The lagged put warrant listing on Taiwan offers a unique opportunity to realize the price dynamics of the underlying stock under the special structure on derivative's introduction.

Due to the deregulation by Taiwan's authorities in 2003, our study mainly focus on the interrelationship between price dynamics of the underlying stocks, and address the issue that whether we observe a stronger/weaker correlation between price dynamics

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[1] Price dynamics is defined as the stock return, the growth rate of trading volume and the expected change of implied volatility of the underlying stocks.

[2] Taiwan's authorities agree that Securities Houses was allowed to issue third-party warrants in 1997, with a restriction that securities houses need to construct the cash position against the issuance of warrant. In 1997, securities houses are restricted from short-selling the underlying stocks for any reason, therefore, the short-selling restriction prevents securities houses from constructing a short position as a hedge portfolio against their own put warrant issuance. In 2003, the authorities deregulated the short-selling constraints on securities houses, authorities agree that securities houses may short-sell underlying stocks for hedging purposes only, but they can only borrow the underlying stocks from small shareholders. The Securities Borrowing and Lending (SBL) center opened in June 2003, allows securities houses to borrow said underlying stocks from small shareholders. Third-party put warrants were officially introduced to Taiwan's market in July 2003.

after the introduction of third-party put warrant. We construct a simultaneous model, it extends Engle's (2002) dynamic GARCH model, to provide a multivariate framework in order to describe the time-varying conditional correlations between price dynamics and put warrant issuing effect both on trivariate and bivariate basis.

The empirical results suggest that: the time-varying conditional correlation between stock return and the expected change of implied volatility is significantly negative (consistent with French, Schwert, and Stambaugh (1987), Campbell and Hentschel (1992), etc.). However, the conditional correlations between growth rate of trading volume and the expected change of volatility is significantly negative after the issuance of third-party put warrants, the result is consistent with Alkeback and Hagelin (1998). Moreover, last period's random shock on correlations between the growth rate of trading volume and the expected change of volatility is significant positive for all samples. On the other hand, we find no conclusive relationship between the growth rate of trading volume and stock return.

Regarding third-party put warrant listing effect, our result shows that price dynamic response sharper to others after that listing day of third-party put warrant. Time-varying pair-wise correlation between price dynamics shift closely toward +1 and -1[3] by the introduction of put warrants; the relationship among stock return, growth rate of trading volume and the expected change of implied volatility is more related. By knowing the three highly closed relationships between price dynamics, lots of investors expect to realize an upward or downward trend on warrantable stocks[4] after the issuance date of warrant. When lots of investors expect an increase in price on

[3] If the correlation among stock price, trading volume, and implied volatility is negative for the before-put-warrant period, then the coefficient is more negative to one on the after-put-warrant period. If the correlation among stock price, trading volume, and implied volatility is positive for the before-put-warrant period, then the coefficient is more positive to one for the after-put-warrant period

[4] The warrantable stock is defined as the underlying stock of a single-name warrant.

warrantable stocks on the listing date of warrant, longing the underlying stocks on the day before warrant listing by investors may generate positive profits. Therefore, the tighter interactions within a security's price dynamics increase the probability of engaging in a profitable trading strategy since they induce the explanatory power of the price dynamics.

The remainder of this study is organized with the next two sections describing the empirical methodology and sampling data used in this study. 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 conditional correlation coefficients simultaneously with the conditional variance-covariance matrix. By allowing conditional correlations to vary over time, his 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 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 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, $\mathbf{H_t}$, be positive definite for all values of $\boldsymbol{\varepsilon}_\mathbf{t}$ in the sample. We also assume that conditional mean $\mu_{i,t}$ has the following formation as:

$$\mu_{i,t} = \Phi_0 + \Phi_1 x_{i,t-1}, \ \forall \mathrm{i}. \tag{2}$$

Here, Φ_1 measures the autoregression effect in data series. In the traditional multivariate GARCH framework, the conditional variance-covariance matrix can be written as:

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

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

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

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 lag 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:

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

$$Q_t = \left(q_{ij,t}\right)$$

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

In order to standardize the residual error term, Engle sets $\mathbf{z_t} = \mathbf{G_t^{-1}\varepsilon_t}$, 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

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

The time-varying correlation coefficients in the DCC-GARCH model can be divided into two parts. The first part indicated on the right-hand side of equation (6), $\overline{\rho}_{ij}$, represents 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 can show 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.

Extend 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 the third-party call warrant's listing day, and ends on the 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 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

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

Term t^* represents the put warrants' availability day, and indicator I denotes a dummy variable indicating the put warrant's issuing day. The coefficient δ is used to capture 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 trading volume, stock price, and volatility will be more related. We then 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. DATA

Sampling Criterions

In order to realize the lagged third-party put warrant listing effect only, we exclude the third-party call warrant listing effect. Hence, the sampling period is focused on the after-call-before-put warrant and after-put warrant periods. Since we are concerning about the warrant listing effect on first issuance, our interest focus on the third-party put warrant which issued in 2003. As of October 2005, there were a total of 74 issues of put warrants listed from 2003 to 2005. The numbers of put warrant issuances in Taiwan were 42, 8, and 24 for the years 2003, 2004, and 2005, respectively. Almost 60% (42 of 74) of put warrants were introduced in year 2003.

If warrantable stocks are not continuous being the underlying asset of the third-party warrant, the data property could be distorted by collecting discontinuous data together, therefore, we omit the issues where warrantable stock is not continuous being the underlying of the warrant. Take Taiwan Semiconductor Corporation (TSMC) issue as an example, as of October 2005, there were a total of four third-party put warrants issued on TSMC. The third issue started on 14 January 2004 and ended on 9 July 2004, but the fourth issue did not start until 8 July 2005. This means that TSMC stock cannot be thought of as a warrantable stock from 9 July 2004 to 8 July 2005. In order to study the listing effect on third-party put warrant, data series of the TSMC issue omit the trading days between 9 July 2004 and 8 July 2005, and treat the observations on 9 July 2004 and 8 July 2005 as a continuous time series.

The exclusion of trading days before and after put warrant issuance that are far from approximately equivalent is represented as the third sampling standard. Trading days for the before-put warrants period are calculated from the first issuance date of the call warrant on the underlying stock to the first issuance date of the put warrant. It is important to note that trading days before call warrant listing are excluded from the data. This is done to eliminate the effects of introducing call warrants. Take CMC Magnetics Corporation issue as an example, the trading dates before-put and after-put warrant issuance are 1381 and 281, respectively. The number of trading days before-put warrant is much larger than the after-put warrant period, the impact on days before-put warrant issuance may dominate the impact on days after-put warrant issuance in DCC-GARCH models, thus, this kind of underlying stock is omitted. For time series studies, the larger the dataset is, the more accurate the GARCH estimator is. In order to generate reliable empirical results, the put issues whose maturity is less than six months are not included in the sample.

Our study uses daily stock returns, growth rate of trading volumes, and expected change of implied volatility to investigate the issuing effect of put warrants. Data are gathered from the Taiwan Economic Journal (TEJ). Data series for China Steel Corporation (CSC hereafter) is from 8/19/2002 to 6/17/2004, which represents 450 data points; for Acer Inc. (Acer hereafter) the data is collected from 9/5/2002 to 6/1/2004, represents 423 data points; for SYNNEX Corporation (SYNNEX hereafter) the sampling data is gathered from 12/11/2002 to 8/18/2004 represents 420 data points; as for Hon Hai Precision Industry Company Ltd. (Hon-Hai hereafter), data is range from 11/14/2002 to 7/22/2004 represents 416 data points. The relative change of all data series are analyze in this study. We analysis the relative change to stock price, relative change to trading volume, and relative change to implied volatility, in stead of stock price, trading volume, and implied volatility itself.

Table 1 shows that eight put warrants are selected. These represent four underlying stocks with put issues that satisfy our selection criteria. It is shown that there is more than one third-party put warrant outstanding at the same trading day on the warrantable stock. As we can see from Table 1, the put warrant issues around the sampling period for CSC, Acer, SYNNEX, and Hon-Hai are 4, 2, 1, and 1, respectively. In one trading day, there may be several warrants outstanding on the market, but since we need one datapoint for one trading day. If there are four put issues outstanding on the same day, then the implied volatility of each put warrant is different in size owing to their trading frequency. To avoid the liquidity risk implicit in the warrant market, we choose the sampling data with the largest trading volume on that sampling day. The choice of the most liquid put avoids the liquidity risk implicit in warrant return and volatility. Therefore, the implicit volatility from the most liquid put warrant is selected according to the liquidity concern.

<INSERT TABLE 1 ABOUT HERE>

IV. EMPIRICAL FINDINGS

Table 2 summarizes the return, growth rate of trading volume, and expected change of implied volatility statistics for the underlying stocks of third-party put warrants. The Ljung-Box Q statistics is implemented in order to test the heteroskedastic property which underlies the GARCH family. As reported in Table 2, the heteroskedastic phenomenon appears in all sampling stocks and justifies the implementation of GARCH model to Taiwan's stock market.

<INSERT TABLE 2 ABOUT HERE>

We also implement Jarque-Bera test for the normality in the sampling stocks, as shown in Table 2, the Jarque-Bera coefficients are significant at the 1% level, which indicates that the stock return, growth rate of trading volume, and the expected change of implied volatility series are generally not normally distributed. Since ARCH residuals are observed in all time series, an AR(1) framework is implemented to capture the autocorrelation effect in the mean equation. The coefficient Φ_1 in Table 3 reveals the autoregressive effect in mean equation parameters for price dynamics. The growth rate of trading volume reveals a negative autocorrelation effect, while the expected change of implied volatility shows a positive autocorrelation effect. After considering the autocorrelation effect with our empirical framework, the Ljung-Box Q statistics ($Q^2(8)$ and $Q^2(24)$) in Table 3 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 3 ABOUT HERE>

The coefficient Φ_0 in Table 3 reveals the long-term mean of price dynamics. The long-term mean of the growth rate of trading volume is significantly positive at the 1% level for all sampling stocks. In addition, the long-term mean of the expected change of implied volatility is significantly positive for CSC, Acer, and SYNNEX, and is significantly negative for Hon-Hai. By incorporating non-normality properties into time series data, we adopt the multivariate GARCH model to investigate the changes in time-varying conditional volatility in the event of put warrant issuance.

Bivariate Time-Varying Conditional Correlations

The corresponding interrelationship between price dynamics is investigated by the bivariate GARCH framework, this framework is conducted to see whether corresponding correlations between stock return, growth rate of trading volume, and the expected change of implied volatility are significantly increased after put warrant issuance. When we observed tighter correlations between price dynamics, the formation of a profitable trading strategy regarding a put warrant issuance event can be realized.

We firstly provide the interdependences between price dynamics, as we can see, stock return is significantly positively correlated with the growth rate of trading volume for SYNNEX and Hon-Hai at the 1% level. In contrast, stock return is significantly negative with regard to the growth rate of trading volume for CSC and Acer at the 1% level. Therefore, our empirical results suggest no conclusive findings on the relationship between stock return and the growth rate of trading volume.

<INSERT TABLE 4 ABOUT HERE>

The coefficient b in Table 4 shows the persistence between price dynamics of underlying stocks. The persistence between stock return and the expected change of implied volatility, and between the growth rate of trading volume and the expected change of implied volatility are significantly, negatively related with each other for all sampling stocks at the 1% level, our result is consistent with French, Schwert, and Stambaugh (1987), Campbell and Henstschel (1992), and Alkeback and Hagelin (1998). Moreover, the correlation effect of last period's random shock is measured by the coefficient a in Equation (6), it shows that the condition correlation between growth rate of trading volume and the expected change of implied volatility is significantly, positively affected by last period's random shock at the 1% level, which is consistent with Karpoff (1987) and Schwert (1989)'s study.

Put Warrant Listing Effect on Bivariate Correlation

Coefficient δ in Table 4 indicates the put warrant listing effect. Significantly positive

δ coefficient means the price dynamics become more related to each other after the issuance of put warrant. In table 4, the δ coefficients in the interactions between price dynamics are significantly positive for all stocks. We conclude that price dynamics of the underlying stocks are tightly correlated to each other after the put warrant issuing day. Since the interdependence between price dynamics are sharply related, the explanatory power of price dynamics to each other increases after the issuance of put warrant.

Time Patterns of Bivariate Conditional Correlations

Figure 1, 2 and 3 plotted the time-varying relationship between price dynamics. Figure 1 shows the time-varying relationship between stock return and growth rate of trading volume. The time-varying correlation coefficients between stock return and growth rate of trading volume are more volatile and more positively correlated to each other after the put listing day for all sampling stocks. Although the dynamic correlations between stock return and the growth rate of trading volume for Acer are significantly higher for the post-warrant period, one observes that the correlation coefficients significantly increased, though slightly in size, and lagged in time.

<INSERT FIGURE 1 ABOUT HERE>

Panel A in Figure 2 describes the dynamic correlation coefficients between stock return and the expected change of volatility for CSC, the correlation coefficients are more volatile right after the issuing date of a put warrant. Panels C and D in Figure 2 indicate the dynamic correlations for Hon-Hai and SYNNEX, respectively. From Panel

C, the correlation coefficients for Hon-Hai are volatile and shift to show a more negative correlation after the put warrant was issued. Panel D shows that the dynamic correlations for SYNNEX move toward to -1 right after the put warrant was issued. As described in Panel B, the time-varying correlation coefficients plotted for Acer cannot be distinguished very well after the issuance of a put warrant for the same reason that the δ coefficient for Acer shown in Table 4 is only 0.924.

<INSERT FIGURE 2 ABOUT HERE>

We next discuss the time-varying conditional correlation coefficient between growth rate of trading volume and the expected change of implied volatility. Panel A in Figure 3 indicates that the dynamic correlations between growth rate of trading volume and the expected change of implied volatility are dramatically volatile for CSC after the day of put issue. Moreover, the correlation coefficients for Hon-Hai and SYNNEX as in Panel C and Panel D become more volatile after put issuance. We also observe the lagged volatile effect on the time-varying relationship between growth rate of trading volume and the expected change of implied volatility for Acer.

<INSERT FIGURE 3 ABOUT HERE>

As we can see from Figure 1 to 3, the time-varying correlation coefficients between price dynamics are more volatile and are more tightly related to each other after the issuance of third-party put warrants.

Trivariate Conditional Correlations

In the bivariate DCC-GARCH framework, we realize the interdependencies between stock return, growth rate of trading volume, and the expected change of implied volatility. Will the unique correlation among the three price dynamics increase after the put warrant's issuance day is the next topic we would like to know. Since a unique indicator representing the interrelationship among the three price dynamics cannot be available by the bivariate framework, therefore, we conduct the trivariate GARCH model 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 that the persistence of last period's conditional correlations among stock return, growth rate of trading volume, and the expected change of implied volatility are significantly negative for CSC, and are significantly positive for Acer, SYNNEX, and Hon-Hai. Which means that last period's conditional correlations persistently, significantly influent today's conditional correlation coefficients. The introductory effect on put warrant issuance is revealed by the coefficient δ in Table 5. In Table 5 we show that the changes in correlation among three price dynamics are significantly increased after put warrant introduction for CSC, Acer, SYNNEX and Hon-Hai. The positive, significant sign of δ indicates that the resulting correlation among price dynamics increases by the introduction of put warrants. The interdependence among price dynamics is more tightly related, which induces better ability in forecasting the direction and size in correlation, and also enhances the probability of diversification.

<INSERT TABLE 5 ABOUT HERE>

V. CONCLUDING REMARKS

In Taiwan, due to regulatory constraint, third-party put warrant was launched six years lagged after third-party call warrant's launching. This special launching practice induced an issue whether the price dynamics with call and put warrant launched at the same time is different from the price dynamics with provide only call warrant but not the put warrant. Therefore, the lagged listing on put warrant at the Taiwan stock market offers an unique opportunity to realize the special structure on derivative's introduction, and the impacts on the underlying stock under the special structure. In order to understand the introductory effect on 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 conditional correlations of these price dynamics.

The empirical results show that: the interactions between each two of the price dynamics are more closely related to each other after the put warrants' issuing day. From this bivariate interrelationship, it is much easier for investors to forecast changing directions in stock returns by the growth rate of trading volume and the expected change of volatility for the reason that the relationships between each other are much stronger. By understanding the higher correlation between price dynamics, investors may initiate a profitable and diversifiable portfolio to gain positive profits. From trivariate DCC-GARCH model, we produce an overall correlation among the three price dynamics, the overall correlation increases after the issuing day of a put warrant and this leads to a higher probability in forming a diversifiable portfolio.

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Table 1: Data description for selected underlying stock on put warrant

Underlying Stocks on Put Warrant	CSC	Acer	SYNNEX	Hon-Hai
Number of put warrant issuance	4	2	1	1
Issuing date of put warrants	7/9/2003	7/30/2003	8/21/2003	11/26/2003
Closing date of put warrants	6/17/2004	6/1/2004	8/18/2004	7/22/2004
Maturity of third-party put warrants (years)	0.94	0.84	0.99	0.66
Trading dates before put warrants issuance	221	223	172	252
Trading dates after put warrants issuance	228	205	250	166

Table 2: Summary statistics

		Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera	Q(8)	Q(24)	$Q^2(8)$	$Q^2(24)$
CSC	Return	0.0016	0.0204	0.5623***	1.7381***	80.3582***	20.0259**	43.6094***	31.6196***	67.0375***
	Volume	0.1491	0.6828	2.1667***	6.3956***	1119.0266***	37.6302***	51.3949***	5.3445	12.8680
	Implied Volatility	0.6198	0.3699	6.0846***	44.7565***	40335.57107***	276.8727***	300.6225***	142.3258***	148.1924***
Acer	Return	0.0010	0.0261	-0.0302	2.2727***	91.1035***	8.0124	39.0044**	14.3388	25.6198
	Volume	0.1792	1.0943	9.6123***	138.6544***	345355.5079***	17.6792**	25.6474	0.0852	0.4014
	Implied Volatility	0.6322	0.3130	4.2091***	22.3324***	10039.2123***	1232.5385***	2119.1518***	852.1886***	1019.7934***
SYNNEX	Return	0.0001	0.0259	-0.2932**	2.5020***	115.5707***	13.5740*	23.3301	32.7603***	47.9865***
	Volume	0.3276	1.4989	7.0091***	78.3466***	110857.3187***	19.4742**	43.1574***	0.2612	0.7650
	Implied Volatility	0.5945	0.2086	8.2634***	103.7156***	193026.2659***	264.9687***	454.8883***	69.6668***	70.0791***
Hon-Hai	Return	0.0003	0.0214	0.0212	1.4847***	38.2396***	17.4321**	36.1684**	8.1022	15.1829
	Volume	0.1589	0.6829	2.1068***	7.4531***	1270.6040***	45.2800***	57.8222***	4.2763	13.1333
	Implied Volatility	0.5897	0.3544	-16.2120***	307.2460***	1654491.4239***	30.1813***	36.4508**	0.3988	0.7979

1. Data series for CSC is from 8/19/2002 to 6/17/2004, log difference on daily data is used, which represents 450 data points.
2. Data series for Acer is from 9/5/2002 to 6/1/2004, log difference on daily data is used, which represents 423 data points.
3. Data series for SYNNEX is from 12/11/2002 to 8/18/2004, log difference on daily data is used, which represents 420 data points
4. Data series for Hon-Hai is from 11/14/2002 to 7/22/2004, log difference on daily data is used, which represents 416 data points
5. ***, ** and * represent significance at the 1% , 5 % and 10% levels, respectively.
6. 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 3: The conditional mean equation in AR(1) process

The conditional mean equation as an autoregression (AR1) process is $\mathbf{x_t} = \boldsymbol{\mu}_t + \boldsymbol{\varepsilon}_t$, where $\boldsymbol{\varepsilon}_t|\boldsymbol{\Omega}_{t-1} \sim N(\mathbf{0}, \mathbf{H}_t)$, where $\boldsymbol{\mu}_t = E[\mathbf{x}_t \| \boldsymbol{\Omega}_{t-1}]$ is the conditional expectation of $\mathbf{x_t}$ given the past information $\boldsymbol{\Omega}_{t-1}$, and $\boldsymbol{\varepsilon}_t$ is a vector of errors in the autoregression AR(1). We also assume that $\boldsymbol{\mu}_t$ has the following formation as: $\mu_{i,t} = \Phi_0 + \Phi_1 x_{i,t-1}, \forall i$.
(2)

		Φ_0		Φ_1		Q(8)	Q(24)	$Q^2(8)$	$Q^2(24)$
CSC	Return	0.0015	(1.5692)	-0.1207	(-2.1247)**	11.9651	30.2436	4.6769	4.82917
	Volume	0.1421	(5.1186)***	-0.2169	(-7.2250)***	18.4011**	33.7250*	10.4750	18.5676
	Implied Volatility	0.0237	(3.0961)***	0.9580	(7.5893)***	7.6751	33.2803*	10.4750	18.5676
Acer	Return	0.0008	(0.6917)	-0.0730	(-1.3695)	2.7821	2.90097	2.51290	4.2986
	Volume	0.2554	(10.3961)***	-0.6460	(-15.4798)***	12.9097	34.4358*	2.4001	16.7108
	Implied Volatility	0.0450	(4.3686)***	0.9127	(4.4063)***	0.7855	2.9939	0.7855	2.9939
SYNNEX	Return	0.0003	(0.3389)	-0.0002	(-0.0040)	10.8750	17.1763	9.1094	20.8254
	Volume	0.4909	(8.9861)***	-0.3235	(-4.4108)***	6.0575	27.1755	0.5849	2.3880
	Implied Volatility	0.0276	(3.3185)***	0.9490	(6.0219)***	10.2952	24.7848	0.5849	2.3880
Hon-Hai	Return	0.0003	(0.3212)	0.06354	(1.1835)	14.6277*	3.68349	3.7596	13.6754
	Volume	0.2040	(6.23926)***	-0.2717	(-4.7122)***	15.2247*	33.6468*	1.8672	9.6231
	Implied Volatility	-0.0190	(-3.7145)***	1.0189	(11.1922)***	5.8722	24.3911	1.8672	9.6231

1. Data series for CSC is from 8/19/2002 to 6/17/2004, log difference on daily data is used, which represents 450 data points.
2. Data series for Acer is from 9/5/2002 to 6/1/2004, log difference on daily data is used, which represents 423 data points.
3. Data series for SYNNEX is from 12/11/2002 to 8/18/2004, log difference on daily data is used, which represents 420 data points
4. Data series for Hon-Hai is from 11/14/2002 to 7/22/2004, log difference on daily data is used, which represents 416 data points
5. ***, ** and * represent significance at the 1% , 5 % and 10% levels, respectively.
6. 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.
7. Parentheses are T statistics.

Table 4: Brivariate time-varying conditional correlations on DCC-GARCH model with 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 $q_{ij,t} = (1 + \delta I_{t \geq t^*})[\bar{\rho}_{ij} + a(z_{i,t-1} z_{j,t-1} - \bar{\rho}_{ij}) + b(q_{ij,t-1} - \bar{\rho}_{ij})]$. $\bar{\rho}_{ij}$ represents the unconditional expectation of the cross product $z_{it} z_{jt}$, i.e. the unconditional correlation coefficient. $a\, z_{i,t-1} z_{j,t-1} + b\, q_{ij,t-1}$, shows the conditional time-varying covariance. Indicator I denotes a dummy variable indicating the put warrant's issuing day. The coefficient δ is used to capture the changing property on conditional covariance and conditional correlation.

		a		b		δ	
CSC	Return-Volume	0.0767	(12.2908)***	-0.0119	(-4.4510)***	7.7230	(4.1913)***
	Return-Implied Volatility	0.0378	(26.4215)***	-0.2663	(-7.9994)***	2.7141	(6.2010)***
	Volume-Implied Volatility	0.06697	(18.0983)***	-0.9597	(-11.6702)***	3.0434	(22.1156)***
Acer	Return-Volume	-0.0819	(-5.5622)***	-0.4530	(-13.5002)***	0.9707	(23.3457)***
	Return-Implied Volatility	0.0117	(9.5770)***	-0.7614	(-11.8991)***	0.9240	(5.09521***
	Volume-Implied Volatility	0.0137	(23.8579)***	-0.5323	(-6.2650)***	0.8918	(8.7674)***
SYNNEX	Return-Volume	-0.0190	(-22.5025)***	0.0778	(4.6684)***	59.4703	(4.5388)***
	Return-Implied Volatility	-0.0055	(-22.7769)***	-0.0026	(-7.1362)***	11.5036	(10.9861)***
	Volume-Implied Volatility	0.0246	(7.6449)***	-0.0080	(-4.9724)***	21.0936	(4.2552)***
Hon-Hai	Return-Volume	0.1047	(7.8251)***	0.1137	(4.3681)***	4.4029	(5.21921***
	Return-Implied Volatility	-0.0053	(-21.0470)***	-0.3667	(-7.5308)***	1.6493	(4.58357)***
	Volume-Implied Volatility	0.02293	(25.3045)***	-0.3258	(-10.7469)***	1.3283	(6.8113)***

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4. Data series for Hon-Hai is from 11/14/2002 to 7/22/2004, log difference on daily data is used, which represents 416 data points
5. ***, ** and * represent significance at the 1% , 5 % and 10% levels, respectively.
6. Parentheses are T statistics.

Table5: Trivariate time-varying conditional correlations on DCC-GARCH model with 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 $q_{ij,t} = (1+\delta I_{t \geq t^*})[\bar{\rho}_{ij} + a(z_{i,t-1} z_{j,t-1} - \bar{\rho}_{ij}) + b(q_{ij,t-1} - \bar{\rho}_{ij})]$. $\bar{\rho}_{ij}$ represents the unconditional expectation of the cross product $z_{it} z_{jt}$, i.e. the unconditional correlation coefficient. $a\, z_{i,t-1} z_{j,t-1} + b\, q_{ij,t-1}$, shows the conditional time-varying covariance. Indicator I denotes a dummy variable indicating the put warrant's issuing day. The coefficient δ is used to capture the changing property on conditional covariance and conditional correlation.

		a		b		δ	
CSC	Return Volume Implied Volatility	0.0120	(20.9532)***	-0.0131	(-4.3888)***	2.0010	(3.5412)***
ACER	Return Volume Implied Volatility	-0.0092	(-17.4139)***	0.0017	(19.0534)***	2.7133	(13.9444)***
SYNNEX	Return Volume Implied Volatility	0.0385	(3.0111)***	0.8717	(16.5723)***	0.2915	(7.6792)***
Hon-Hai	Return Volume Implied Volatility	0.0348	(12.4760)***	0.8594	(8.8729)***	10.4620	(11.4476)***

1. Data series for CSC is from 8/19/2002 to 6/17/2004, log difference on daily data is used, which represents 450 data points.
2. Data series for Acer is from 9/5/2002 to 6/1/2004, log difference on daily data is used, which represents 423 data points.
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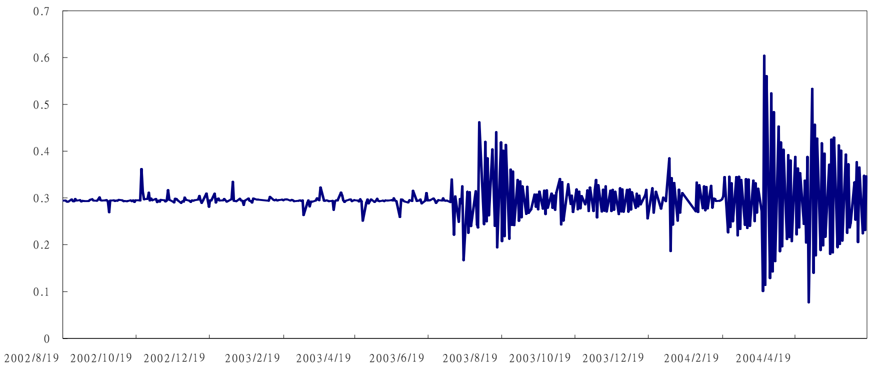
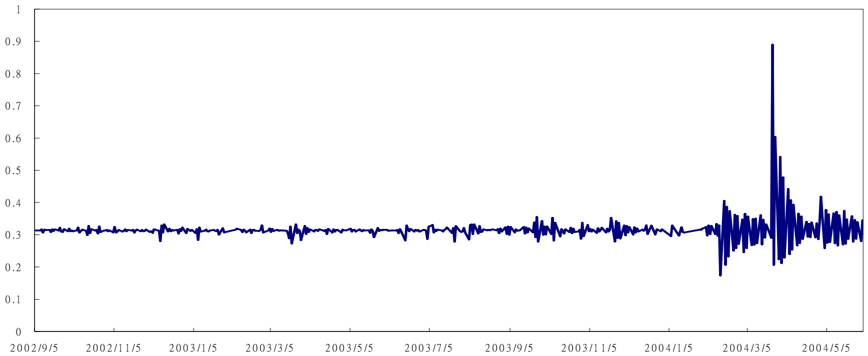
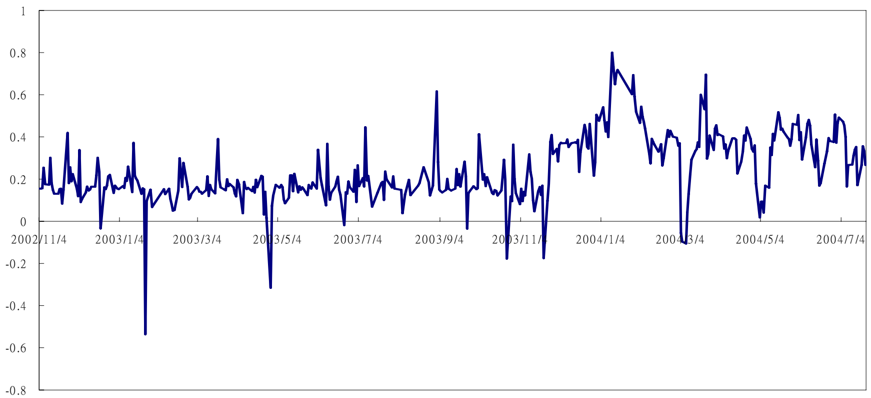
5. ***, ** and * represent significance at the 1% , 5 % and 10% levels, respectively.
6. Parentheses are T statistics.



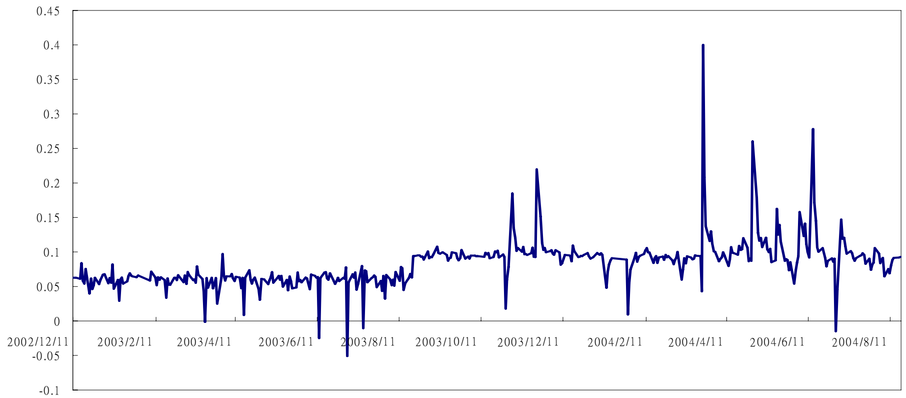
Panel A: CSC



Panel B: Acer



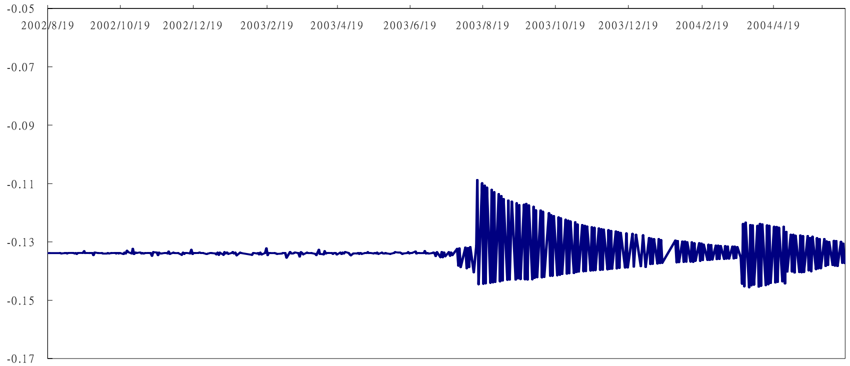
Panel C: Hon-Hai



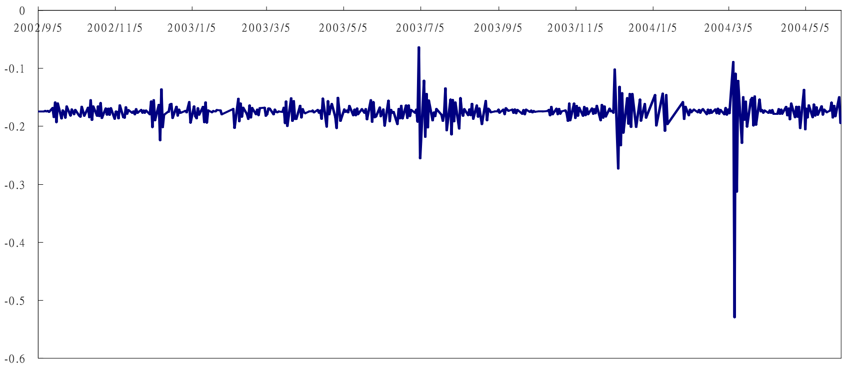
Panel D: SYNNEX

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

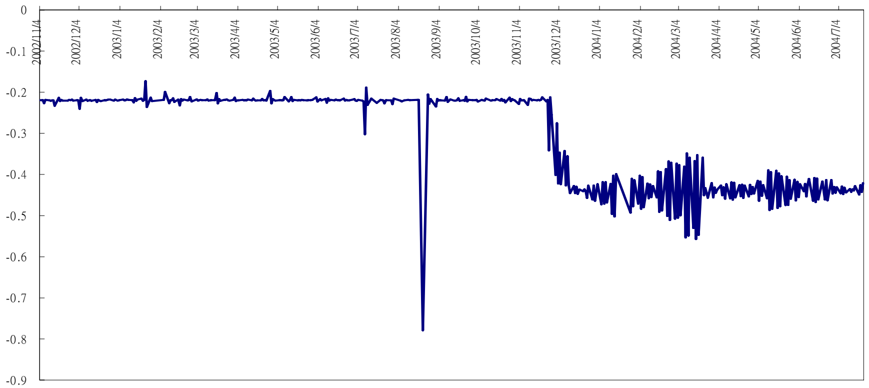
The listing day of third-party put warrant for CSC, Acer, Hon-Hai, and SYNNEX is 7/9/2003, 7/30/2003, 8/11/2003, and 11/26/2003, respectively. The dynamic correlations between stock return and the growth rate of trading volume for CSC are positive, which becomes much volatile after the put warrant issuance day. Moreover, the links of return and trading volumes are more positively related to each other for Hon-Hai and SYNNEX after the put warrant issuing day. However, we observe a lag volatile effect for Acer, since the changes in dynamic correlation coefficients between mean and trading volume are positively related and much volatile after put warrant has issued around six month.



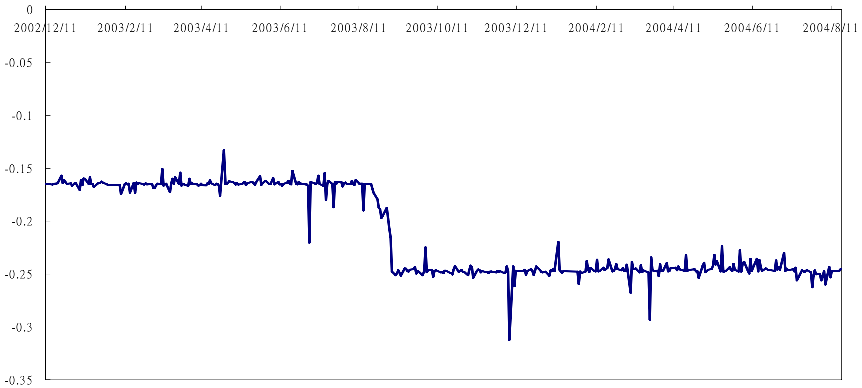
Panel A: CSC



Panel B: Acer



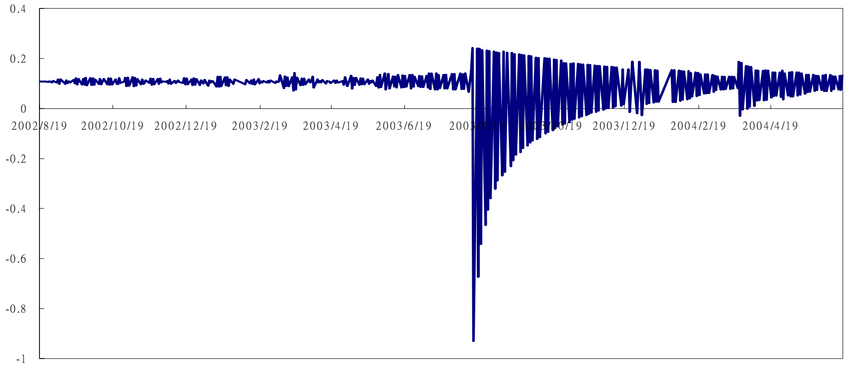
Panel C: Hon-Hai



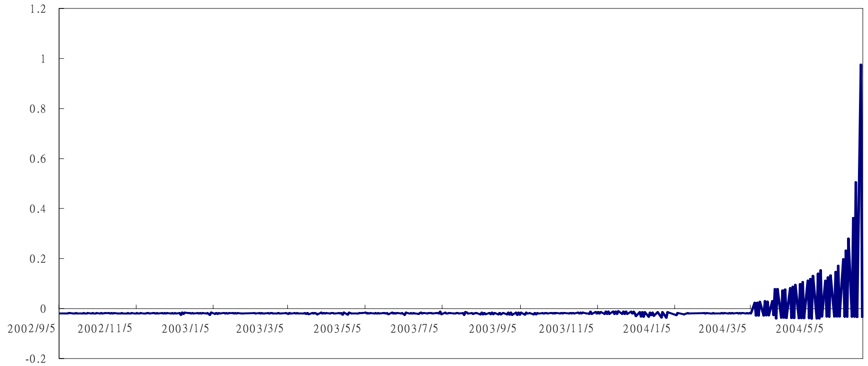
Panel D: SYNNEX

Figure 2: Brivariate time-varying conditional correlation coefficient between stock return and the expected change of implied volatility

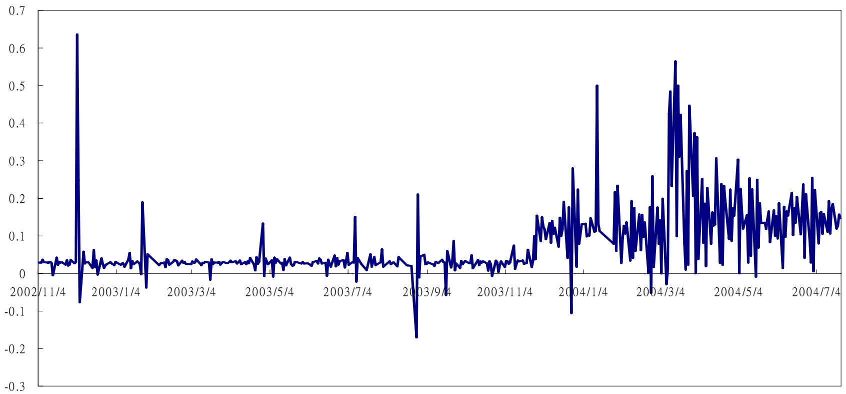
The listing day of third-party put warrant for CSC, Acer, Hon-Hai, and SYNNEX is 7/9/2003, 7/30/2003, 8/11/2003, and 11/26/2003, respectively. As we can see, the time-varying correlations between stock return and the expected change of volatility for CSC become much volatile after the put warrant issuance day. On the other hand, the relationship between return and implied volatility for Hon-Hai and SYNNEX are more negatively related to each other after the third-party put warrant has issued. However, the changes in dynamic correlation coefficients between return and implied volatility for Acer cannot be identified by simply observation.



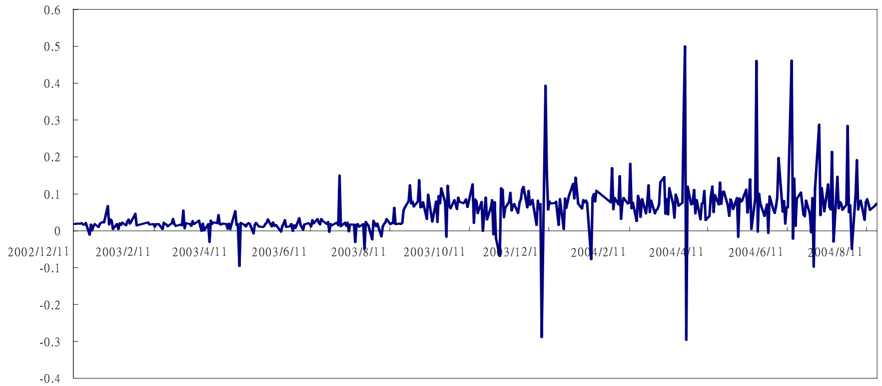
Panel A: CSC



Panel B: Acer



Panel C: Hon-Hai



Panel D: SYNNEX

Figure 3: Brivariate time-varying conditional correlation coefficient between the growth rate of trading volume and the expected change of implied volatility

The listing day of put warrant for CSC, Acer, Hon-Hai, and SYNNEX is 7/9/2003, 7/30/2003, 8/11/2003, and 11/26/2003, respectively. The time-varying correlations for CSC become negatively correlated after four month of put warrant issuance, then the dynamic correlations become positive again. Totally speaking, the time-varying correlation for CSC is much volatile after the put warrant issuance day. The dynamic correlations for Acer become much volatile after six month of put warrant issuance day. For the Hon-Hai and SYNNEX case, the interdependences between trading volume and implied volatility are more positively related and volatile.