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Exchange rate uncertainty and corporate values: evidence from Taiwan

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This article first presents a derivation of a theoretical model, which shows that, if the discount rate is large enough, the exchange rate uncertainty (volatility) affects positively the corporate values under the circumstance where competitive firms are risk-averse. Empirical studies are then implemented to test for the relationships between the uncertainty and the corporate values among ten industries investigated in Taiwan. The empirical evidence indicates that there exist long-run equilibrium relationships between the uncertainty and the corporate values among the industries of food, glass, electricity, paper, rubber and steel. The corporate values for each industry are also significantly affected by their previous-period values. Using the Granger causality test for the other four industries, the results find that this uncertainty only has a one-way leading effect on itself.

I. Introduction

The higher volatility (proxy for the uncertainty) in most of the major currencies has been an increasing concern since the beginning of the floating rates regime in March 1973. De Grauwe (1988) argues that the growth rate of international trade among industrial countries has declined by more than half since the inception of floating exchange rates, and the increased uncertainty in exchange rates have largely hurt a country's exports. However, in the derivation of a theoretical model associated with oligopolistic behaviours, Broll and Eckwert (1999) indicate that higher exchange rate volatility increases the potential gains from trade, which in turn stimulates the exports. In addition, the empirical issue of the impact of this volatility on the exporting volume remains still controversial.

Hooper and Kohlhagen (1978) find that a higher volatility of exchange rates leads to a lower volume of trade. A similar result is obtained in the work of Rana (1981) in studying some Asian countries including South Korea, Taiwan and the Philippines. Cushman (1983) obtains the result that six out of fourteen developed countries in bilateral trades have significantly negative impacts of volatility in exchange rates on the volume of exports. Akhtar and Hilton (1984) also conclude that the uncertainty of nominal exchange rates affects the volume of exports in the opposite direction for the cases of the United States and Germany. The same result is again found in Kenen and Rodrik (1986) that there is a negative relationship between exchange rate volatility and trading volume. Cushman (1988) further uses a new approach as a measure of the volatility of exchange rates and obtains the same results as what

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he found in 1983. Chowdhury (1993) shows that exchange rate volatility restricts the growth of trading volume. The negative relationship between exchange rate volatility and trading volume can also be found in the numerous papers of Broll *et al.* (1999), Arize *et al.* (2000), Chou (2000), Sukar and Hassan (2001) and Nieh (2002). Moreover, Iorio and Faff (2000), Dominguez and Tesar (2001), Chang (2002) and Crabb (2002) all indicate that exchange rate uncertainty cause the changes of corporate values.

The works of some economists show, empirically and theoretically, positive relationships between exchange rate volatility and the volume of trade. Gotur (1985) empirically shows that the exchange rate volatility really has a positive effect on US exporting volume. De Grauwe (1988) further finds that the more risk-averse are the firms and the higher uncertainty the exchange rate is, the more the increase will be in exporting volume. The theoretical derivation by Viaene and Vries (1992) offers a positive relationship between this volatility and the trading volume under certain specific conditions. Similarly, the paper by Broll and Eckwert (1999) demonstrates the positive relation of the volatility of exchange rates with the volume of trade in their theoretical framework.

The empirical results of some other studies nevertheless seem to be ambiguous about the relation of exchange rate uncertainty with trading volume. These ambiguous results can be found in the papers of Bailey *et al.* (1986), Baldwin and Krugman (1989), Asseery and Peel (1991), Doidge *et al.* (2000) and Griffin and Stulz (2001). To sum-up, the pros and cons of the exchange rate volatility to export remain a controversy and there is no consistent conclusion so far, as illustrated by Tharakan (1999), Pozo and Wheeler (2000), Higgins *et al.* (2004), Pradhan *et al.* (2004), Pattichis *et al.* (2004) and Kwek and Koay (2006).

In Taiwan, there have been two drastic changing periods of the NT dollar (NT\$) against the US dollar (US\$) ever since Taiwan's government abandoned the pegging rate regime and adopted a floating rate in February 1979. (Fig. 1) The continuing appreciation on its exchange rate reduced Taiwan's exporting volume and caused much speculative money to flow into the island's banking system during the period of 1986 to 1988. In late 1997, the Asian financial crisis significantly depreciated the exchange rate of NT\$ against the US\$. Therefore, not only did Taiwan's exports abroad drop sharply, but also Taiwan's stock market declined to near historically low levels in a short period of just 8 months. Because of this, many home enterprises went into bankruptcy. The corporate values of exporting industries may be influenced by their own exporting flows for most export-led countries such as South Korea, Singapore, Taiwan and Hong Kong. With the harmful experiences that are due to the large fluctuations of exchange rates in Taiwan, this article attempts to investigate the impacts of exchange rate volatility on Taiwan's corporate values among the 10 industries concerned. The article first constructs a theoretical model to show the relationship between exchange rate uncertainty and corporate values, and then, we try to test empirically for whether there exist a long-run and a short-run relationship between these two variables for the Taiwanese industries.

Though there are several ways in measuring the exchange rate volatility as a proxy for uncertainty, in this article, we follow the approach of Arize (1995, 1997), a measure of the exchange rate volatility extracted by GARCH (generalized autoregressive conditional hetroscedasticity) modelling. The methodologies employed for empirical analyses are unit-root tests for the stationarity of series and cointegration tests for the long-run equilibrium relationship between this volatility and the corporate values. Either the vector error correction model (VECM) or the Granger causality test is applied for the short-run causal relations based upon the outcomes of the cointegration test.

There are five parts in this article. In addition to an introduction in Section I, Section II shows a derivation of the theoretical model in which there is a positive relationship between exchange rate uncertainty and corporate earnings under some specific conditions. The data sources are reported in Section III. Section IV presents this article's other core, including the methodologies such as GARCH modelling, the unit-root test, the cointegration test, the VECM and the Granger causality tests, and the empirical reported results. A concluding remark is left for Section V.



Fig. 1. The exchange rate movement of NTD/USD (January 1988–February 2000)

II. Model Structure

Consider a competitive and risk-neutral firm with its production function in the Cobb-Douglas form, $Q_t = F(L_t, K_t) = A_t L_t^{\alpha} K_t^{1-\alpha}$, where L_t is the labour employed, K_t the capital used and Q_t the output produced. The subscript t denotes the time elapsed, A is the technical parameter and α and $1 - \alpha$ are the output elasticity with respect to labour and capital employed, respectively. The representative competitive firm hires labour at the fixed money wages, w and conducts gross investment through an increasing convex adjustment cost, $C(I_t)$, which is assumed to be $C(I_t) = \gamma I_t^{\beta}, \beta > 1$. The firm makes export quotations as to the domestic products in terms of foreign currency, P_t and then converts it to be the home price, π_t , by ways of current exchange rates (e_t) , where $\pi_t = e_t P_t$. Thus, the firm's cash flows at time t can be represented as:

$$C_{t} = \pi_{t} L_{t}^{\alpha} K_{t}^{1-\alpha} - w L_{t} - \gamma I_{t}^{\beta}$$

$$C_{t} = \pi_{t} L_{t}^{\alpha} K_{t}^{1-\alpha} - w L_{t} - \gamma I_{t}^{\beta}$$
(2.1)

The objective of the firm is to maximize the expected present value of its cash flows subject to the capital accumulation function:

$$dK_t = (I_t - \delta K_t)dt \tag{2.2}$$

where δ is the constant depreciation rate, and the behavioural equation of the output price is written as:

$$\frac{\mathrm{d}\pi_t}{\pi_t} = \sigma \mathrm{d}Z \tag{2.3}$$

where dZ is a Wiener process with zero mean and unit variance. Equation 2.3 describes the price process that transmits the output prices' uncertainty into exchange rate uncertainty in terms of the home currency, and that captures the following properties:

$$E_t(\pi_S) = \pi_t, s \ge t$$
 and $\operatorname{Var}\left(\frac{\pi_S}{\pi_t}\right) = (s-t)\sigma^2$

The value function of the firm can be specified as the function of the two state variables (K_t and π_t):

$$V(K_t, \pi_t) = \max_{I_s, L_s} E_t \int_t^\infty \left[\pi_s L_s^\alpha K_s^{1-\alpha} - w L_s - \gamma I_s^\beta \right] \\ \times e^{-r(s-t)} \,\mathrm{d}s$$
(2.4)

where r is the constant discount rate. The optimality condition for maximizing Equation 2.4 requires that the total returns required by the firm equal the total returns expected by the firm; that is, the following identity equation holds:

$$rV(K_t, \pi_t) dt = \max_{I_t, L_t} \left[\pi_t L_t^{\alpha} K_t^{1-\alpha} - wL_t - \gamma I_t^{\beta} \right] dt + E_t (dV)$$
(2.5)

where the term at the left-hand side of Equation 2.5 is the total returns required by the firm, and the terms at the left-hand side of Equation 2.5 are the total returns expected by the firm, consisting of the cash flows plus the expected capital gain or loss $E_t(dV)$. We apply Ito's lemma to calculate the capital gain or loss (dV):

$$dV = V_K dK + V_\pi d\pi + \frac{1}{2} V_{KK} (dK)^2 + \frac{1}{2} V_{\pi\pi} (d\pi)^2 + V_{\pi K} (d\pi) (dK)$$
(2.6)

Substituting Equations 2.2 and 2.3 into Equation 2.6, we get the expected change in the value of the firm given $E_t(dZ) = (dt)^2 = (dt)(dZ) = 0$:

$$E_{t}(\mathrm{d}V) = \left[(I_{t} - \delta K_{t})V_{K} + \frac{1}{2}\pi_{t}^{2}\sigma^{2}V_{\pi\pi} \right] \mathrm{d}t \qquad (2.7)$$

Again substituting Equation 2.7 into Equation 2.5, we obtain:

$$V(K_t, \pi_t) = \max_{I_t, L_t} \left[\pi_t L_t^{\alpha} K_t^{1-\alpha} - w L_t - \gamma I_t^{\beta} + (I_t - \delta K_t) V_K + \frac{1}{2} \pi_t^2 \sigma^2 V_{\pi\pi} \right]$$
(2.8)

From Equation 2.8, we can show that:

$$\max_{L_{t}} \left[\pi_{t} L_{t}^{\alpha} K_{t}^{1-\alpha} - w L_{t} \right] = \tau \pi_{t}^{1/1-\alpha} K_{t} \qquad (2.9)$$

where $\tau = (1 - \alpha)(\alpha/w)^{\alpha/(1 - \alpha)}$ and the term at the right-hand side of Equation 2.9 is the marginal revenue product of capital (MRP_k). Differentiating the term at the right-hand side of Equation 2.8 with respect to I_t yields:

$$\gamma \beta I_t^{\beta - 1} = V_k \tag{2.10}$$

By Equation 2.10, we recognize that the condition for the optimal investment of the firm requires that the marginal investment cost equal the marginal value of capital.

Further substituting Equations 2.9 and 2.10 into Equation 2.8 gives:

$$rV(K_t, \pi_t) = \tau \pi_t^{1/1-\alpha} K_t + (\beta - 1)\gamma I_t^{\beta} - \delta K_t V_K + \frac{1}{2} \pi_t^2 \sigma^2 V_{\pi\pi}$$
(2.11)

Both Equations 2.10 and 2.11 can be expressed as a set of nonlinear second-order partial differential equations. Following Mussa (1977) and Abel (1983), we have imposed enough structure on the two equations to obtain a set of explicit solutions as follows:

$$V(K_t, \pi_t) = b_t K_t + \frac{(\beta - 1)\gamma (b_t / \beta_{\gamma})^{\beta/\beta - 1}}{r - \theta \sigma^2}$$
(2.12)

where

$$b_{t} = \frac{\tau \pi_{t}^{1/1-\alpha}}{r+\delta - (\alpha \sigma^{2}/2(1-\alpha)^{2})}, \quad \theta = \frac{\beta(1-\alpha+\alpha\beta)}{2(1-\alpha)^{2}(\beta-1)^{2}}$$
(2.13)

$$I_t = \left(\frac{b_t}{\beta_{\gamma}}\right)^{1/\beta - 1} \tag{2.14}$$

In Equation 2.12, the value of the firm $V(K_t, \pi_t) > 0$ means that *r* must be greater than $\theta \sigma^2$. Since b_t in Equation 2.12 represents the present value of the expected MRP_k, both b_t (for all *t*) and θ in Equation 2.13 are greater than zero.

Partially differentiating b_t in Equation 2.13 with respect to σ^2 , and then differentiating I_t in Equation 2.14 with respect to b_t , we get:

$$\frac{\partial b_t}{\partial \sigma^2} = \frac{\tau \pi_t^{1/1-\alpha} [\alpha/(2(1-\alpha)^2)]}{[r+\delta - (\alpha \sigma^2/2(1-\alpha)^2]^2)} > 0$$
(2.15)

$$\frac{\mathrm{d}I_t}{\mathrm{d}b_t} = \frac{1}{\beta_{\gamma}(\beta - 1)} \left(\frac{b_t}{\beta_{\gamma}}\right)^{(2-\beta)/(\beta-1)} > 0 \qquad (2.16)$$

where an increase in σ^2 in Equation 2.15 represents an increase in the uncertainty of exchange rates. Further differentiating V_t in Equation 2.12 with respect to σ^2 , we get:

$$\frac{\partial V(K_t, \pi_t)}{\partial \sigma^2} = K_t \frac{\partial b_t}{\partial \sigma^2} + \frac{\left\{ (r - \theta \sigma^2)(b_t/\beta_\gamma)^{1/\beta - 1} \partial b_t/\partial \sigma^2 + (\beta - 1)\gamma \theta(b_t/\beta_\gamma)^{\beta/\beta - 1} \right\}}{(r - \theta \sigma^2)^2}$$
(2.17)

From Equation 2.17, we know that, since $\partial b_{t/} \partial \sigma^2 > 0$ in Equation 2.15 and $dI_t/db_t > 0$ in Equation 2.16, $\partial V(K_t/\pi_t)/\partial \sigma^2 > 0$, which means that the increased uncertainty in exchange rates leads to an increase in the present value of the expected cash flows or corporate value of the firm if the discount rate is large enough, i.e. $r > \theta \sigma^2$.¹

III. Data Source

Monthly data are used in this article for the period running from January 1988 to February 2000. The data on the exchange rates of NT dollar against US dollar are collected from AREMOS of the Ministry of Education, Taiwan, whereas, the data of the corporate values are from TEJ (Taiwan Economic Journal) which is published monthly in Taiwan. The corporate values are calculated from the closing prices multiplied by the outstanding shares of the export-led, listed companies for each industry in Taiwan's stock market. For the explaining power, this article only selects ten major industries associated with exports from more than 500 of the listed companies, which include food, rubber, textile, electricity, chemical, glass, steel, plastic, paper and electronics. For comparison, we then categorize three categories based on the percentage of the exporting volume for the export-led, listed companies, which are the industries with export ratios under 30%, between 30 and 50% and over 50%, respectively. Totally, we have 14 entities with the exchange rates of NT\$/US\$ included and 146 observations for each entity. In addition, for each series, the data are adjusted by the ratios to a moving average (multiplication) so as to remove the monthly cyclical seasonal fluctuations.

For simplicity, each series is represented by symbols as follows: Y1 for chemistry, Y2 for electronics, Y3 for food, Y4 for glass, Y5 for electricity, Y6 for paper, Y7 for plastic, Y8 for rubber, Y9 for steel, Y10 for textile, Y11 for the export ratio over 50%, Y12 for the export ratio under 30%, Y13 for the export ratio between 30 and 50% and RX for the exchange rate volatility.

IV. Methodologies

Measuring uncertainty

The exchange rate volatility can be measured as a proxy for uncertainty in several ways, e.g. moving average deviation approach and GARCH modelling.

¹Of course, if $r < \theta \sigma^2$, then the above result will not hold; that is, the uncertainty of exchange rates affecting the corporate value is rather ambiguous.

LM-test				
<i>F</i> -Statistic TR^2	8.8105 8.3961	<i>p</i> -Value	0.0035	
Variance equation	$h_t = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \mu_{t-1}^2$	$\beta_1 h_{t-1}$	0.0056	
Coefficient	Estimator	SD	Z-Statistic	<i>p</i> -Value
α_0	0.0205	0.0081	2.5444	0.0109
α_1	0.6313	0.1422	4.4385	0.0001
β_1	0.3545	0.1069	3.3138	0.0009

Table 1. GARCH(1, 1) modelling for the exchange rate volatility

The moving average deviation of the growth rate of the exchange rate is indeed a time-varying proxy for the exchange rate uncertainty. Following Chowdhury (1993) and Arize and Shwiff (1998), the moving average deviation of the growth rate of the exchange rate is formulated as follows.

$$\sigma_t = \left[\left(\frac{1}{m}\right) \sum_{i=1}^m \left(\log e_{t+i-1} - \log e_{t+i-2}\right)^2 \right]^{0.5}$$
(4.1)

where *e* denotes the exchange rate, σ represents the exchange rate uncertainty and *m* is the number for the seasonal consideration.²

Nevertheless, since the ARCH and GARCH models have recently become very popular in that they enable the econometrician to estimate the variance of a series at a particular point in time, we employ a GARCH (1,1) modelling for measuring exchange rate volatility. A GARCH (1,1) modelling is expressed as follows.

$$e_{t} = \pi_{0} + \pi_{1}e_{t-1} + \mu_{t}$$

$$h_{t} = \alpha_{0} + \alpha_{1}\mu_{t-1}^{2} + \beta_{1}h_{t-1}$$
(4.2)

To generate the values of the exchange rate uncertainty, we assume that the exchange rate follows an AR(1) process. In Equation 4.2, μ_t is a realized disturbance term, e_t denotes the exchange rate, α , β and π are the coefficients, and h_t is the hetroscedastic variance, which implies exchange rate uncertainty (that is, σ^2 in Equation 2.17) in this article.

We first apply the LM-test for investigating the property of hetroscedasticity. As we observe from Table 1, when examining the residuals of the model by the LM-test, the null of no GARCH effect is rejected at the 5% significance level. Therefore, using



Fig. 2. GARCH(1, 1) modelling for the exchange rate volatility

GARCH(1, 1) modelling to extract the value of exchange rate volatility is appropriate. In addition, from the estimation of the coefficients of α_1 and β_1 , we find that both of them are away from zero at the 5% level. The estimates of α_1 and β_1 are at the same time summed-up to close to one, which supports evidence of a clutch phenomenon of persistent volatility (Fig. 2).³

Unit-root test

Various recently-developed methodologies are explored to fully investigate the dynamic relationships between NT\$/US\$ exchange rates and each of the industrial weighted-average corporate values.

Since Schwert (1989) compares several unit-root tests and argues that the ADF test by Dickey and Fuller (1981) with long lags is superior to the others, this article simply employs the ADF test for testing the stationarity of each series. Based on the model selecting procedure suggested by Doldado *et al.* (1990), the appropriate model selected for all the

² In our article, the application of the time-varying moving average deviation approach for measuring the exchange rate uncertainty gets the similar result as that from GARCH modelling, we thus merely employ GARCH modelling to measure our exchange rate uncertainty.

³ The existing result of a GARCH effect for the exchange rate uncertainty of NT\$/US\$ is consistent with those findings in Arize (1995, 1997), which measure the exchange rate uncertainty of the US and the G-7 countries.

Tests for level		Tests for difference				
Variable	$ au_{ au}$	Variable	$ au_{ au}$			
Y1	-4.051 (1)*	<i>Y</i> 1	-9.123 (3)*			
Y2	-1.117 (1)	Y2	-17.037 (0)*			
Y3	-1.938 (6)	Y3	-8.050 (5)*			
Y4	-2.507 (2)	Y4	-11.456 (1)*			
Y5	-1.999 (3)	Y5	-8.516 (3)*			
<i>Y</i> 6	-3.098 (2)	<i>Y</i> 6	-9.636 (2)*			
Y7	-3.013 (12)	Y7	-4.016 (11)*			
Y8	-1.563 (3)	Y8	-10.498 (2)*			
Y9	-1.243 (1)	Y9	-6.500 (11)*			
Y10	-3.519 (7)*	Y10	-7.968 (4)*			
Y11	-0.9866 (1)	Y11	-17.863 (0)*			
Y12	-2.311 (5)	Y12	-7.741 (4)*			
Y13	-2.398 (9)	Y13	-11.783 (1)*			
RX	-3.431 (4)	RX	-8.638 (3)*			

Table 2. ADF unit-root tests

Notes: ^aThe number in the parentheses is the optimal lag length selected based on the SBC. ^bBy the BDE (1975) procedure, all the models selected for the ADF unit-root test are the ones with a drift and a trend, and the τ_{τ} -statistics are thus used.

^cThe critical values are adopted from MacKinnon (1991).

*Denotes significance at the 5% level. The 5% critical value is -3.4480.

series is the one that includes a drift and a time trend, which is presented as the following equation⁴:

$$\Delta y_t = \alpha + \phi y_{t-1} + \gamma t + \sum_{i=2}^p \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (4.3)$$

The null hypothesis for the ADF test is

$$H_0: \phi = 0$$
, against the alternative $H_1: -2 < \phi < 0$

An appropriate lag length has to be pre-designated for the unit-root test and cointegration test since the estimates might be biased if the lag length is not accurately determined. This article follows the suggestion by Reimers (1992) using Schwartz's (1978), Bayesian Criterion (SBC) to select the appropriate lag length.⁵ The SBC formula is as follows:

$$\operatorname{SBC}(n) = T * \log\left(\frac{\operatorname{SSR}}{T}\right) + n * \log T$$
 (4.4)

where n denotes the number of the parameters, T is the sample size and SSR is the abbreviation of the sum squared of residuals.

The results of the ADF test for the single unit root for each series are reported in Table 2. With the exception that the chemical and textile industries are I(0) series, all the others are I(1) series, which show the nonstationary properties in the level and are significantly away from the unit-root hypothesis above the level term (first- and second-differences). Based on the above findings, the pairwise Granger causality test will be conducted in the following section to present the preceding relationship between the exchange rate volatility and each of the corporate values of the chemical and textile industries. The cointegration test and the vector error correction model (VECM), on the other hand, will be employed for examining the long-run equilibrium and the short-run dynamic relationships between the two variables concerned for the other industries.

Cointegration test

To avoid the 'spurious regression' problem, the cointegration test is applied to capture the long-run equilibrium relationships between the variables.⁶ From the findings of the comparison among the five cointegration estimations by Gonzalo (1994), we employ the most powerful methodology of the Johansen maximum likelihood cointegration test.⁷

⁴ Doldado *et al.*'s (1990) ADF model selecting procedure is: testing for the significance of coefficients of the model with a drift and a trend first, and then the model with only drift. If both coefficients are insignificant, then, we adopt the model without drift and a trend term.

⁵ Hall (1994) and Ng and Perron (1995) also argue that the lag length selected by SBC is more appropriate.

⁶See Granger and Newbold (1974).

⁷ Gonzalo (1994) compares several methods of estimating the cointegration, which include ordinary least squares, nonlinear least squares, maximum likelihood in an error correction model, principle components and canonical correlations.

Exchange rate uncertainty and corporate values

The testing hypothesis is formulated as the restriction for the reduced rank of Π ,

$$H_0(r)$$
: $\Pi = \alpha \beta'$ for the reduced form error correction
model (ECM)

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-(k-1)}$$

+ $\Pi X_{t-1} + \Psi D_t + \epsilon_t$ (4.5)

where ε_t is a white-noise disturbance, α and β are both $p \times r$ matrices and they represent the speed of the adjustment parameter and cointegrating vector, respectively. The likelihood ratio test statistic for the hypothesis with at most *r* cointegrating vectors (i.e. H(r): rank $(\Pi) \le r$) is:

$$-2\ln Q\left(\frac{H(r)}{H(p)}\right) = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_{i})$$
(4.6)

This elaborate work has been developed from Johansen (1988) to Johansen (1994), which can be summarized as the following five Johansen VAR models with ECM^8 :

$$H_0(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha \beta' X_{t-1} + \Psi D_t + \epsilon_t$$
(4.7)

$$H_{1}^{*}(r): \Delta X_{t} = \Gamma_{1} \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha(\beta', \beta_{0}) (X_{t-1}', 1)' + \Psi D_{t} + \epsilon_{t}$$
(4.8)

$$H_1(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \Psi D_t + \epsilon_t$$
(4.9)

$$H_{2}^{*}(r): \Delta X_{t} = \Gamma_{1} \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha(\beta', \beta_{1})(X_{t-1}', t)' \mu_{0} + \Psi D_{t} + \epsilon_{t}$$
(4.10)

$$H_{2}(X): \Delta X_{t} = \Gamma_{1} \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha \beta' X_{t-1} + \mu_{0} + \mu_{1} t + \Psi D_{t} + \epsilon_{t}$$
(4.11)

To analyse the deterministic term, Johansen decomposes the parameters μ_0 and μ_1 in the directions of α and α_{\perp} as $\mu_i = \alpha \beta_i + \alpha_{\perp} \gamma_i$, and thus, we have $\beta_i = (\alpha' \alpha)^{-1} \alpha' \mu_i$ and $\gamma_i = (\alpha' \Delta_{\perp})^{-1} \alpha'_{\perp} \mu_i$. The nested sub-models of the general model of null hypothesis $\Pi = \alpha \beta'$ are therefore, defined as:

$$H_0(r): Y = 0$$
$$H_1^*(r): Y = \alpha \beta_0$$

$$H_1(r): Y = \alpha\beta_0 + \alpha_\perp\gamma_0$$
$$H_2^*(r): Y = \alpha\beta_0 + \alpha_\perp\gamma_0 + \alpha\beta_1t$$
$$H_2(r): Y = \alpha\beta_0 + \alpha_\perp\gamma_0 + (\alpha\beta_1 + \alpha_\perp\gamma_1)t$$

Johansen (1994) emphasizes the role of the deterministic term, $Y = \mu_0 + \mu_1 t$, including the constant and linear terms in the difference, which implies the presence of linear and quadratic trends in the level of the Gaussian VAR. An appropriate model has to be determined to fully describe the relationships among the variables. This article follows Nieh and Lee's (2001) decision procedure among the hypotheses H(r) and $H^*(r)$ for Johansen's five models and presents it in the following way:

$$H_0(0) \rightarrow H_1^*(0) \rightarrow H_1(0) \rightarrow H_2^*(0) \rightarrow H_2(0)$$

$$\rightarrow H_0(1) \rightarrow H_1^*(1) \rightarrow H_1(1) \rightarrow H_2^*(1) \rightarrow H_2(1)$$

$$\rightarrow \cdots \rightarrow \cdots \rightarrow H_0(p-1) \rightarrow H_1^*(p-1)$$

$$\rightarrow H_1(p-1) \rightarrow H_2^*(p-1) \rightarrow H_2(p-1)$$

This selecting procedure diagnoses models one by one from left to right until the model cannot be rejected for the null.

The empirical findings for the long-run relationships with the consideration of a linear trend and a quadratic trend between this volatility and each of the corporate values are presented in Table 3.

The cointegration test can simply be applied when the variables in the Johansen's VAR model have the same order of integration. Based on the results of unit-root tests, we thus proceed to do eleven cointegration tests. The results of the cointegration relationships for 11 pairs of series are presented in Table 3. We observe that, with the exception of the electronics and plastic industries, the volatility and the what of the other nine series on corporate values share the long-run common trends in the economy. Following the decision procedure by Nieh and Lee (2001), the results show that all nine pairs of the long-run equilibrium relationships carry one cointegration rank and present no linear trend and no quadratic trend.

Vector error correction model (VECM)

Based on Engle and Granger's (1987) 'Granger representation theorem', the error correction and

⁸ Johansen (1992, 1994) develops a testing procedure based on the ideas developed by Pantula (1989) to determine the number of cointegrating rank in the presence of a linear trend (Johansen, 1992) and a quadratic trend (Johansen, 1994). In our article, Equation 4.7 is from Johansen (1988), Equations 4.8 and 4.9 are from Johansen and Juselius (1990), whereas Equations 4.10 and 4.11 are from Johansen (1994).

Rank	$T_0(r)$	<i>C</i> ₀ (5%)	$T_{1}^{*}(r)$	$C_1^*(5\%)$	$T_1(r)$	<i>C</i> ₁ (5%)	$T_{2}^{*}(r)$	$C_2^*(5\%)$	$T_2(r)$	C ₂ (5%)
Cointegr	ation relati	onship betwe	en RX and	1 Y2						
r=0	29.72	12.53	29.76	19.96	20.14	15.41	$\frac{24.11}{51}$	25.32	18.87	18.17
$r \leq 1$	12.21	3.84	12.23	9.24	2.84	3.70	0.51	12.25	1.49	3./4
AIC	2		2		2		2		2	
Cointegr	ation relati	onship betwe	en RX and	1 Y3					10.50	10.15
r=0	15.11	12.53	33.31	19.96	33.27	15.41	40.74	25.32	40.69	18.17
$r \leq 1$	0.03	3.84	10.98	9.24	10.95	3.70	15.48	12.23	15.47	3.74
AIC	2		2	1	2		2		2	
Cointegration $r = 0$	ation relati	onship betwe	$\operatorname{en} RX$ and 23.04	1 Y4 10 06	23.03	15 /1	27.38	25 32	27.34	18 17
r = 0 r < 1	0.46	3.84	23.04	9.24	23.03	3.76	9.10	12.25	9.09	3.74
AIC	2	0.01	2	,	2	0.70	2	12120	2	5171
Cointegr	- ation relati	onshin betwe	en RY and	1 V5	2		2		-	
r=0	15.09	12.53	23.84	19.96	23.83	15.41	25.63	25.32	25.59	18.17
$r \leq 1$	0.02	3.84	8.47	9.24	8.46	3.76	8.97	12.25	8.96	3.74
AIC	2		2		2		2		2	
Cointegr	ation relati	onship betwe	en RX and	1 Y6						
r = 0	15.95	12.53	24.70	19.96	24.39	15.41	34.34	25.32	34.24	18.17
$r \leq 1$	0.01	3.84	7.95	9.24	7.67	3.76	16.51	12.25	16.51	3.74
AIC	2		2		2		2		2	
Cointegr	ation relati	onship betwe	en RX and	1 Y7	00.05					10.15
r = 0	15.67	12.53	20.38	19.96	20.37	15.41	22.99	25.32	22.58	18.17
$1 \ge 1$	0.01	5.64	4.17	9.24	4.15	5.70	2.04	12.23	2.23	5.74
AIC	ے بر ایس ایس ا			1 1/0	Z		2		Z	
r = 0	1672	12 53	$\frac{2010}{2010}$	1 18	19 74	15 41	26.24	25 32	26.15	18 17
r = 0 r < 1	0.12	3.84	2.52	9.24	2.16	3.76	8.64	12.25	8.58	3.74
AIC	2		2		2		2		2	
Cointegr	ation relati	onshin betwe	en RX and	1 <i>Y</i> 9						
r=0	19.95	12.53	22.94	19.96	21.88	15.41	27.42	25.32	25.12	18.17
$r \leq 1$	2.83	3.84	5.42	9.24	4.35	3.76	4.44	12.25	2.16	3.74
AIC	4		4		4		4		4	
Cointegr	ation relati	onship betwe	en RX and	d Y11						
r = 0	30.40	12.53	31.07	19.96	22.67	15.41	28.45	25.32	18.87	18.17
$r \leq 1$	12.79	3.84	13.43	9.24	5.20	3.76	10.59	12.25	1.36	3.74
AIC	2		2		2		2		2	
Cointegr	ation relati	onship betwe	$\operatorname{en} RX$ and	1 Y12	40.10	1.5 41	42.25	25.22	12.02	10.17
r = 0 r < 1	27.57	12.53	40.21	19.96 0.24	40.19	15.41	43.35	25.32	43.03	18.17
$\frac{1}{2}$	1	5.64	12.00).2 4	12.05	5.70	15.05	12.23	13.30	5.74
AIC	1 :+-1			1 1/1 2	1		1		1	
r=0	26 62	12 53	$\frac{1}{35.98}$	1996	35.95	15 41	45.60	25 32	45 35	18 17
$r \leq 1$	0.05	3.84	9.40	9.24	9.37	3.76	14.62	12.25	14.37	3.74
AIC	1		1		1		1		1	

Table 3. Johansen cointegration test in the presence of a linear trend and a quadratic trend Cointegration relationship between RX and Y2

Notes: ${}^{a}T_{0}(r)$, $T_{1}^{*}(r)$, $T_{1}(r)$, $T_{2}^{*}(r)$ and $T_{2}(r)$ are LR-test statistics for Johansen's five models. b The model selection follows Nieh and Lee's (2001) decision procedure, diagnosing models one by one until the model which cannot be rejected for the null.

 $^{\circ}C_0$ (5%), C_1^* (5%), C_1 (5%), C_2^* (5%) and C_2 (5%) are 5% LR critical values for Johansen's 5 models, which are from Osterwald-Lenum (1992).

^dThe bold numbers with an underline denote the selected model, which decides the number of cointegration vectors and considers the linear trend and quadratic trend.

^eThe lag lengths are based on SBC.

Variable	LL	$\hat{\mathbf{e}}_{t-1}$	DRX_{t-1}	DRX_{t-2}	DRX_{t-3}	DRX_{t-4}	$DY \#_{t-1}$	$DY \#_{t-2}$	$DY \#_{t-3}$	$DY #_{t-4}$
$\frac{\text{DRX}_t}{\text{DY3}_t}$	2 2	-0.30^{***} 0.01	-0.14^{*} 0.01	0.13* 0.01			0.70^{*} -0.67***	0.50 -0.35***		
DRX_t $DY4_t$	2 2	-0.31^{***} 0.01	-0.13^{*} -0.01	0.14* 0.02*			$-0.16 \\ -0.41^{***}$	$-0.20 \\ -0.22^{***}$		
DRX_t $DY5_t$	2 2	-0.32^{***} -0.01	$-0.12 \\ 0.01$	0.16** 0.02***			$-0.41 \\ -0.72^{***}$	-0.97 -0.28***		
DRX_t $DY6_t$	2 2	-0.33^{***} 0.01	-0.12^{*} -0.04^{***}	0.14* 0.01			$-0.20 \\ -0.55^{***}$	-0.29 -0.32***		
$\frac{\text{DRX}_t}{\text{DY8}_t}$	2 2	-0.34^{***} -0.01^{***}	$-0.10 \\ 0.01$	0.15** 0.01***			-2.69* -0.79	-1.75^{***} -0.04^{***}		
DRX_t $DY9_t$	4 4	-0.24^{***} 0.02	-0.18^{**} -0.01	0.12* 0.02	$-0.05 \\ -0.04^{**}$	-0.23^{***} -0.02	-0.37 -0.22***	$-0.02 \\ 0.01$	0.14 0.13**	0.21 0.10*
DRX_t $DY11_t$	2 2	-0.34^{***} -0.02^{***}	$-0.11 \\ -0.01$	0.16** 0.04***			-0.13 0.20***	$-0.38 \\ 0.04$		
DRX_t $DY12_t$	1 1	-0.29^{***} 0.01	-0.18^{***} -0.01				$-0.24 \\ -0.17^{***}$			
DRX_t $DY13_t$	1 1	-0.29^{***} 0.01	-0.14^{*} -0.02^{*}				$-0.22 \\ -0.25*$			

Table 4. Short-run dynamic relationship from VECM

Notes: ^aLL denotes the lag length determined by the SBC.

^bThe symbols ***, ** and * represent significance at the 1, 5 and 10% levels, respectively.

^cSymbolizes the number varying with each pair of estimations.

the cointegration are equivalent representations. The cointegration analysis is for the long-run relationship among variables, whereas the VECM not only diagnoses the long-run relationship, but also investigates the short-run dynamic relationship. Nine out of the eleven pairs of variables are found to cointegrate in the long run, and so, we apply the VECM for these nine pairs.

The appropriate model without the presence of a linear trend and a quadratic trend selected from the previous section is used for the VECM. For a two-variable case, the model of the VECM can be represented as follows.

$$\Delta X_{t} = \alpha_{1} + \alpha_{X} \hat{e}_{t-1} + \sum_{i=1}^{n_{1}} \alpha_{11}(i) \Delta X_{t-i} + \sum_{j=1}^{m_{1}} \alpha_{12}(j) \Delta Y_{t-j} + \epsilon_{Xt}$$
(4.12)

$$\Delta Y_{t} = \alpha_{2} + \alpha_{Y} \hat{e}_{t-1} + \sum_{i=1}^{n_{2}} \alpha_{21}(i) \Delta X_{t-i} + \sum_{i=1}^{m_{2}} \alpha_{22}(j) \Delta Y_{t-j} + \epsilon_{Yt}$$
(4.13)

where X denotes the exchange rate volatility, Y is the symbol for corporate values of a certain industry and ε_{xt} and ε_{yt} are stationary random processes intended to capture other pertinent information not contained

Table 5. Granger causality tests

In the level te	rm	In the difference term				
Causality	F-statistics	Causality	F-statistics			
RX => Y1 Y1 => RX RX => Y10 Y10 => RX	4.09* 0.63 10.34* 1.56	DRX => DY2 DY2 => DRX DRX => DY7 DY7 => DRX	13.14* 1.06 4.66* 1.96			

Note: * Denotes significant at the 5% level.

in the lagged values of X_t and Y_t , respectively. The lag length is again decided by SBC.

The VECM examines both the short-run dynamic and the long-run equilibrium relationships between the variables, because the error correction term, \hat{e}_{t-1} , which represents the previous period's disequilibrium $(X_{t-1} - \beta_y Y_{t-1})$, can capture the long-term memory and all α 's link with the short-run dynamic relationships. The results of the VECM for each pair of variables with different lag lengths are shown in Table 4. The existence of a long-run relationship between the volatility and the corporate values of each industry is secured from the statistically significant findings of the speed of adjustment coefficients, α_x and α_y .

The traditional test statistics (e.g. *t*-test and *F*-test) for the VAR analyses are employed for estimating the parameters of all the α 's for the short-run

dynamic relationships. From Table 5, we observe that the feedback relationships exist in the pairs of RXwith Y8 and RX with Y13.⁹ Furthermore, there are six pairs carrying on a one-way causal relationship, which include RX with Y3, Y4, Y5, Y6, Y9 and Y11. The causal relation of RX with Y12, however, cannot be found in either direction. Another significant finding from the VECM is that all the variables considered are significantly affected by their own time lags. This implies that, when making an investment decision, decision makers should consider not only the risk from the exchange rate volatility, but also the corporate values' conditions from their past information.

Granger causality test

Econometrists argue that the pairs of I(0) series should consider the traditional Granger (1969) causality test in the level term for the causal relations, whereas the pairs of series integrated of order one, I(1), in which no cointegration exists, should go for the same test in the difference. In this article the values of the chemical and textile industries are found to be I(0) series, and the Granger (1969) causality test in these levels is thus applied for the causal relation between the volatility and each of these industries. Nonetheless, Granger causality tests in the difference are further employed for the causal relations between each of the values for the electronics and plastic industry and the volatility, because they are found to have no longrun relationships.

The form of Granger (1969) causality is as follows:

$$X_{t} = c + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \mu_{xt} \qquad (4.14)$$

$$Y_{t} = c + \sum_{i=1}^{k} \alpha_{2i} Y_{t-i} + \sum_{i=1}^{k} \beta_{2i} X_{t-i} + \mu_{yt} \qquad (4.15)$$

where k is the lag length selected by SBC. The series Y_t fails to Granger cause X_t if $\beta_{1i}=0$ (i=1,2, 3,...,k) and the series X_t fails to cause Y_t . if $\beta_{2i}=0$. Only one-way causal relations are found from Table 5 on which all the values for the four industries (chemical, electronics, plastic and textile) are significantly proceeded by the volatility, whereas no causal relation exists in the opposite direction.

V. Concluding Remark

This article shows theoretically that, under the circumstances where a competitive firm is riskaverse, if the discount rate is large enough, the increased uncertainty in exchange rate raises the corporate values among industries.

The volatility is extracted by employing a GARCH modelling. The result of this study empirically finds that, from the cointegration test and the VECM, there exist long-run equilibrium relationships between the volatility and the values among the industries of food, glass, electricity, paper, rubber and steel. The coefficients of the vector error correction terms are significantly negative for these industries, which implies that, as the economic system is in a state of disequilibrium, a steady-state convergence would proceed and eventually reach a state of equilibrium. Moreover, the VECM test shows that the corporate values among industries are significantly affected by their previous period's values. The final finding in the analysis of four industries, when using the Granger causality test, is that this volatility only contributes to a oneway leading effect on itself.

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⁹ Here, RX denotes the exchange rate volatility, Y8 is the earnings of the plastic industry and Y13 is the weighted-average values of companies with an export ratio between 30 and 50%.

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