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Chien-Chung Nieh ^a; Jeng-Bau Lin ^b; Yu-Shan Wang ^c

^a Department of Banking and Finance, Tamkang University, Tamsui, Taiwan

^b Department of Business Administration, National Chung Hsing University, Taiwan
 ^c Department of Money and Banking, National Kaohsiung First University of Science and Technology, Taiwan

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Regime-switching analysis for the impacts of exchange rate volatility on corporate values: a Taiwanese case

Chien-Chung Nieh^a, Jeng-Bau Lin^b and Yu-Shan Wang^{c,*}

^aDepartment of Banking and Finance, Tamkang University, Tamsui, Taiwan ^bDepartment of Business Administration, National Chung Hsing University, Taiwan

^cDepartment of Money and Banking, National Kaohsiung First University of Science and Technology, Taiwan

A second-moment, regime-switching model with not only a switching intercept and a switching slope, but also a switching error variance, is applied to examine the impacts of exchange rate volatility (ERV) on corporate values (CV) for the 10 industries investigated in Taiwan. Two different regimes categorized as strong-impact and weak-impact are identified. The dominant power varies from one industry to another. The Wald statistics for the null of equality are ambiguous, which show that if the Markov-switching (MS) model is plausible, then the ERV might not be one major factor, but another factor that could switch the CV of Taiwan's industries. For the model's volatility influence, the data of 8 out of 10 industries are shown to fit a two-state model when the volatility is stimulated. A two-state, first-order MS model is appropriate for the 'goodness of fit' analysis at the 10% significant level.

I. Introduction

The empirical issue of the impact of exchange rate volatility (ERV) on exporting volume remains controversial. In the past, most literature mainly concentrated on the issue that the increased volatility on exchange rates would hurt a country's exports under the case where firms are risk-averse. A significantly negative relationship between the volatility and the exporting flows is found in the articles of Arize (1995), Hassan and Tufte (1998), Smith (1999), Chou (2000), Sukar and Hassan (2001) and Nieh (2002). Relevant studies which focused on the relationship between volatility and trading volumes

exhibit similar results from the works of Gupta (1980) and Rana (1981) for South Korea, Taiwan and the Philippines, Coes (1981) for Brazil, Cushman (1983) for 6 out of 14 developed countries and Akhtar and Hilton (1984) for the United States and Germany. Other research reaching the same result can be found in Arize (1997), Broll *et al.* (1999) and Arize *et al.* (2000). However, the theoretical result in Broll and Eckwert (1999) indicates that a higher volatility increases the potential gains from trade, which in turn stimulates exports, and thus a positive relationship between ERV and exports is asserted. The empirical evidence in the articles of Franke (1991), and Broll and Eckwert (1999) shows an opposite

^{*}Corresponding author. E-mail: yushan@ccms.nkfust.edu.tw

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result whereby a positive relationship exists between the volatility and the volume of trade.

For an export-led country, the corporate values (CV) of exporting industries may be influenced by their own exporting flows. Neglecting the possibility that the switching property exists in the influence of volatility on trading volumes or even CV and that a time-invarying measure may be inappropriate therein has indeed evoked further interest in studying this issue. In other words, the impact of volatility on CV has to account for regime-switching phenomena in which the persistence of a stronger or a weaker influence power of the volatility prevails.

The two-state, first-order Markov-switching (MS) model was first cited in Hamilton (1988) and has thereafter been widely employed to analyse economic and financial time series.¹ For example, Shen (1994) tests the hypothesis of the efficiency of the Taiwan-US forward exchange market, and Ho (2000a) tests the hypothesis for international capital mobility. Moreover, Huang (2000) and Ho (2000b) employ the same technique to examine the Sharpe-Lintner CAPM and the Phillips curve trade-off, respectively. The applications of the MS mechanism can also be found in Engel and Hamilton (1990), Engel (1994), Garcia and Perron (1996), Schaller and van Norden (1997), Amato and Tronzano (2000), Kirikos (2000), Marsh (2000), Chen (2001), Layton and Katsuura (2001), Ho (2003), Caporale and Spagnolo (2004), Chelley-Steeley and Li (2005), Kuo and Lu (2005) and Munehisa (2005). The hypothesis for the MS model is that samples are drawn from a finite mixture of distributions. The transition probabilities in the Markov-chain pattern offer the information that the description ability is time-varying. It also provides insight into the situation in which one regime dominates another. In this article, if the impact level is currently in regime I (strong-impact state or weakimpact state), then there is some probability for the next impact level to stay in the same regime.

This article attempts to investigate the impacts of Taiwan's CV among industries due to the exchange rate volatility (ERV). Following Arize (1995, 1997) we first apply generalized autoregressive conditional heteroscedasticity (GARCH) modelling to extract the values of volatility as a measure of the ERU. Second, the use of the (OLS) approach tests for the effects of the volatility on the CV among different industries in Taiwan. Finally, the impact of the volatility on the CV is investigated by employing a two-state firstorder MS model. As suggested by Ho (2000a, 2000b) and Huang (2000), this article extends their simple first-moment switching model to a second-moment model to allow for the variance to be drawn from different states, which means that there exist a higher volatility regime and a lower volatility regime when the CV are influenced by the volatility.^{2,3} Here, we consider a MS model with not only a switching intercept and a switching slope, but also with a switching error variance.

This article is organized in the following way. The data sources are reported in Section II. Section III describes the way to extract the values of the exchange rate volatility and shows the results. Section IV presents the techniques of the traditional OLS and cumulative sum of residuals (CUSUM) tests. Section V illustrates the methodologies on the switching technique, and therefore the empirical results are reported and analysed. A concluding remark concerning this article is in Section VI. The theoretical model is derived to show the positive relationship between the volatility and the CV in the appendix.

II. Data

Monthly data are used in this article for the period running from January 1988 to February 2000. The data on the exchange rates of the NT dollar against the US dollar are collected from AREMOS of the Ministry of Education, Taiwan, whereas that of the CV is taken from TEJ (Taiwan Economic Journal) published monthly in Taiwan. The CV 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 10 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 a comparison, we then categorize three categories based on the percentage of the exporting volume for the export-led listed companies,

¹The elaborated work of Hamilton's MS model adopts the spirit of the probability switching mechanism by Goldfelt and Quandt's (1973) for heteroscedasticity, which categories two unobserved regimes (states), each with a fixed probability, by the observed data.

 $^{^{2}}$ The original MS model focuses on the mean behaviour of variables. We take into account the probability of conditional heteroscedasticity of the disturbance term in order to examine the time-varying, two-state unobserved variances, which emerged from the impulse of CVs to ERV.

³ The applications of the extended MS model accommodating the pattern of conditional volatility can be found in Hamilton and Lin (1996), Dueker (1997) and Ramchand and Susmel (1998).

LM - test 0.0035 8.8105 F-statistic P-value 8.3961 0.0038 TR^2 P-value Variance equation: $h_t = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \beta_1 h_{t-1}$ P-value Z-statistic Coefficient Estimator SD 0.0205 0.0081 2.5444 0.0109 α_0 0.6313 0.1422 4.4385 0.0001 α_1 0.3545 0.1069 0.0009 β_1 3.3138

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

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 NTD/USD included and 146 observations for each entity.⁴ 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 fluctuation.

For simplicity, each series is represented by symbols as follows: Y1 for chemical, 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.

III. GARCH Modelling for Exchange Rate Volatility

Following the application in Arize (1995, 1997), a GARCH model is employed for measuring the exchange rate volatility. A GARCH(1,1) modelling is as follows:

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

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

To generate the values of volatility, we assume that the exchange rates follow an AR(1) process. In Equation 1, μ_t is a realized disturbance term, e_t denotes the exchange rates, α , β , and π are the coefficients, and h_t is the heteroscedastic variance, which represents the volatility of exchange rates in this article. We first apply the LM-test for investigating the property of heteroscedasticity. As we observe from Table 2, when examining the residuals of this model by the LM-test, the null hypothesis of no GARCH effect is rejected at the 5% significance level. Therefore, the use of GARCH(1,1) modelling to extract the values of the exchange rate volatility is appropriate. Furthermore, from the estimation of the coefficients of α_1 and β_1 , we find that both of them are significantly away from zero at the 5% level. The estimates of α_1 and β_1 are also summed up to be one approximately, which supports evidence of a clutch phenomenon with persistent volatility (see Fig. 1).⁵

IV. The OLS and the CUSUM

In order to investigate the influence of the exchange rate volatility (ERV) on the CV of each industry, the OLS method is commonly used:

$$R_t = \alpha + \beta V_t + \varepsilon_t \tag{2}$$

where R_t denotes the CV, V_t is exchange rate volatility, and $\varepsilon_t \sim iid N(0, \sigma^2)$ is white noise.

The OLS estimation presented in Table 2 shows that the volatility possesses a positive effect on the CV of the chemical, electronics, plastic and rubber industries, and also has a positive effect on all three categories of the export ratios while it has a negative impact on that of the food industry. However, for the other five industries investigated, the exchange rate volatility does not show any significant explaining power.

To assert the findings of the OLS regression analysis, the 'stability' of the data set seems to be critical. To examine this point, the goodness-of-fit type tests of the CUSUM and CUSUM of squares based on recursive residuals are employed for the unknown structural break (Brown *et al.*, 1975). The equations for CUSUM and CUSUM of the squares models are respectively represented as follows:

$$W_m = \frac{1}{\hat{\sigma}} \sum_{t=k+1}^m w_t \quad m = k+1, \dots, T$$
 (3)

$$S_m = \frac{\sum_{t=k+1}^m w_t^2}{s^2}, \quad s^2 = \sum_{t=k+1}^T w_t^2 \quad m = k+1, \dots, T$$
(4)

volatility

⁴ All series are integrated of order one. In order to save space, we do not present these ADF results, but these are available from the authors upon request.

⁵ The result of an existing GARCH effect for the ERV of NTD/USD is consistent with those findings in Pozo (1992) and Arize (1995, 1997), which measure the ERV of the US and the G-7 countries.

Table 2. The OLS estimation

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13
$\hat{lpha} \\ \hat{eta} \\ R^2$	0.214* 0.062* 0.1305	0.488* 0.283* 0.1382	$0.351^{*} \\ -0.030^{*} \\ 0.0385$	0.343* 0.002 0.0001	0.473* 0.007 0.0052	0.546* 0.027 0.0114	0.951* 0.057* 0.0472	0.206* 0.028* 0.0986	1.011* 0.011 0.0001	0.350* 0.023 0.0174	0.439* 0.212* 0.1379	0.513* 0.057* 0.0647	0.600* 0.058* 0.0820

Note: * indicates significant at the 5% critical value.



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

where w_t denotes the recursive residual and σ is the estimated SD. If the path of W_m [Equation 3] or S_m [Equation 4] crosses the boundary for some *m*, say, the 5% significance level, then we reject the null hypothesis of no structural break, which is the case of being unstable.

Although we analyse the impacts of the volatility on the CV of industries concerned from Table 2, the relatively lower R^2 seems as if the OLS results are not reliable. This can be recognized by examining the results of the CUSUM and CUSUM of the squares tests from Fig. 2. These figures show that, from all the plots, the paths of recursive residuals cross the boundary. The null of 'stability' is thus rejected significantly at the 5% level. This evidential existence of structural breaks in the model provides the possibility of a relatively lower R^2 .

V. Markov Switching

Even though we analyse the parameters of the OLS formula to describe the impacts of the volatility on the CV, the realized lower R^2 implies that the predicted power of the OLS model seems inadequate. The two observed structural changes within the sample period of the exchange rate volatility and

the property of 'nonstationarity' for most of the series might be the reasons for reducing the values of $R^{2.6}$. This can also be explained by rejecting the null of 'stability' from the CUSUM and CUSUM of squares plots as described earlier in this article. Moreover, the constant estimated parameters from the OLS are inappropriate in the description of the time-varying relationships between the two variables considered.

To remedy these problems, we employ the basic idea of Hamilton's (1988, 1989) settings of the two-state, first-order MS model with maximum likelihood, and further extend to consider the time-varying error variance as suggested by Ho (2000a, 2000b) and Huang (2000). Under this circumstance, the OLS model, $R_t = \alpha + \beta X_t + \varepsilon_t$, is thus transferred to the following MS setting with MS mean and variance:

$$R_{it} = \alpha_{is_t} + \beta_{is_t} V_t + \varepsilon_{it}, \quad \varepsilon_{it} \sim N(0, \sigma_{is_t}^2)$$
(5)

where R_{it} denotes the CV for industry *i* at time *t*, V_t is the volatility at time *t*, s_t is the unobserved state variable presumed to follow a two-state Markov chain with transition probability (p_{ij}) , β_{is_t} is the influence parameter in state s_t , which measures the impacts of the volatility on the CV for industry *i*, and σ_{is_t} are the SDs in state s_t , which capture the risks from the CV of industry *i*.

Equation 5 is assumed to follow a regimeswitching framework by quasi-maximum likelihood as described in Hamilton (1989). The testable scheme is expressed as follows:

$$\alpha_{iS_t} = \begin{cases} \alpha_{i1} & \text{if } s_t = 1\\ \alpha_{i2} & \text{if } s_t = 2 \end{cases} \quad \beta_{iS_t} = \begin{cases} \beta_{i1} & \text{if } s_t = 1\\ \beta_{i2} & \text{if } s_t = 2 \end{cases}$$
$$\sigma_{iS_t} = \begin{cases} \sigma_{i1} & \text{if } s_t = 1\\ \sigma_{i2} & \text{if } s_t = 2 \end{cases}$$

where the two states represent two regimes. The coefficients are $(\alpha_{i1}, \beta_{i1}, \sigma_{i1})$ in regime 1 and $(\alpha_{i2}, \beta_{i2}, \sigma_{i2})$ in regime 2, respectively. The evolution of the unobservable state variable is assumed to follow a two-state, first-order Markov

⁶ The nonstationary property is obtained from the ADF (Dickey and Fuller, 1981) unit-root test, which is omitted in this article; however, those references will be available upon request.

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Table 3. M	aximum	likelihood e	estimates	for state-tr	ansition esti	imation of Ma	ırkov switchi	ng								
Parameters	α_1		α_2		eta_1		β_2		σ_1		σ_2		p_{11}		p_{22}	
RX to Y1	0.173	(39.50)*	0.292	$(61.40)^{*}$	-0.029	(-1.09)	0.021	$(3.64)^{*}$	0.029	$(11.92)^{*}$	0.031	$(10.44)^{*}$	0.993	(5.76)*	0.992	$(5.35)^{*}$
RX to Y2	0.256	$(62.39)^{*}$	0.717	(22.78) *	0.034	(1.61)	0.151	$(3.41)^{*}$	0.023	$(9.06)^{*}$	0.253	$(12.62)^{*}$	0.992	$(5.28)^{*}$	0.993	$(5.81)^{*}$
RX to Y3	0.246	(41.69) *	0.365	(58.44) *	0.014	$(2.93)^{*}$	0.039	(1.16)	0.024	$(6.90)^{*}$	0.046	$(12.33)^{*}$	0.872	$(3.20)^{*}$	0.963	$(6.39)^{*}$
RX to Y4	0.299	$(60.78)^{*}$	0.425	(43.55)*	0.019	$(2.46)^{*}$	0.027	(0.52)	0.044	$(13.85)^{*}$	0.053	$(9.33)^{*}$	0.994	$(6.07)^{*}$	0.991	$(4.75)^{*}$
RX to Y5	0.445	$(105.80)^{*}$	0.503	(77.42)*	0.015	$(3.30)^{*}$	0.053	(1.88)	0.028	$(11.92)^{*}$	0.030	$(9.84)^{*}$	0.978	(6.40) *	0.970	$(5.39)^{*}$
RX to Y6	0.482	$(53.72)^{*}$	0.643	$(55.83)^{*}$	-0.057	(-1.09)	-0.018	(-1.31)	0.057	$(11.88)^{*}$	0.076	$(11.21)^{*}$	0.979	$(6.42)^{*}$	0.977	$(6.20)^{*}$
RX to Y7	1.038	$(120.3)^{*}$	0.842	$(70.17)^{*}$	0.015	(1.47)	0.156	$(2.30)^{***}$	0.056	$(11.04)^{*}$	0.064	$(10.65)^{*}$	0.963	(6.61)	0.945	$(6.21)^{*}$
RX to Y8	0.035	$(66.09)^{*}$	0.245	$(105.5)^{*}$	0.023	(1.27)	0.013	$(4.19)^{*}$	0.017	$(10.08)^{*}$	0.015	(8.65)*	0.990	$(5.93)^{*}$	0.988	$(5.51)^{*}$
RX to Y9	0.796	$(86.76)^{*}$	1.523	(22.23)*	0.08184	$(5.63)^{*}$	0.3214	(1.00)	0.084	$(14.12)^{*}$	0.3201	$(8.31)^{*}$	0.994	(66.0)	6.234	$(4.49)^{*}$
RX to Y10	0.392	$(24.22)^{*}$	0.327	$(51.79)^{*}$	-0.0004	(-0.02)	0.03565	(0.77)	0.097	$(9.10)^{*}$	0.036	$(10.77)^{*}$	0.981	$(2.47)^{**}$	0.9858	$(3.12)^{*}$
RX to Y11	0.290	$(61.76)^{*}$	0.651	$(25.63)^{*}$	0.0141	(0.52)	0.09276	$(2.83)^{*}$	0.030	$(11.26)^{*}$	0.184	$(11.53)^{*}$	0.993	$(5.58)^{*}$	0.9927	$(5.50)^{*}$
RX to Y12	0.577	$(103.0)^{*}$	0.420	$(22.66)^{*}$	0.017	$(2.30)^{***}$	0.213	(1.36)	0.042	$(12.25)^{*}$	0.078	$(10.47)^{*}$	0.991	(6.03) *	0.9770	$(5.72)^{*}$
RX to Y13	0.797	$(83.06)^{*}$	1.527	$(23.03)^{*}$	0.088	$(4.84)^{*}$	0.318	(0.96)	0.087	$(14.16)^{*}$	0.316	(8.42)*	0.994	$(6.24)^{*}$	0.9898	$(4.55)^{*}$
Notes: 1 The numb	ers in t	he narenthe	ses are t	the values o	f <i>t</i> -statistic											
pro ** * c	иер ***	ote sionific	ant at 1	5 and $10%$	lavel reco	بمامينامه										

*, ** and *** denote significant at 1, 5 and 10% level, respectively.
 The 1, 5, and 10% significant level of *t*-statistics are 2.61, 2.35 and 1.98, respectively.

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Fig. 3. The diagrams of the inferred probabilities for industry's states

chain satisfying $p_{11} + p_{12} = p_{21} + p_{22} = 1$, where $p_{ij} = \Pr(s_t = j/s_{t-1} = i)$ gives the probability that state *i* is followed by state *j*.⁷ The state in each time point determines which of the two normal densities is used to generate the model. For our case of the ERV–CV relationship, it is assumed to switch between two regimes (say, strong-impact state and weak-impact state) according to transition probabilities. When the current ERV–CV relationship is in

regime 1, there is a p_{11} chance for the next ERV–CV relationship to stay in the same regime; the same argument can be applied to regime 2 for holding a p_{22} chance to stay in the same regime.

There are various ways to estimate the MS model (Kim and Nelson, 1999). In this article we estimate the MS setting of Equation 5 by the method of Garcia and Perron (1996), which employs Hamilton's (1989) MS estimation by quasi-maximum likelihood.⁸

⁷ The Markov property argues that the process of s_t depends on the past realizations only through s_{t-1} .

⁸Garcia and Perron (1996) employ Hamilton's (1989) MS model to explicitly account for regime shifts in an autoregressive model with three-state MS mean and variance.

Let $y_t = R_t$, $x_t = (1, V_t)'$ and $\delta_{s_t} = (\alpha_{s_t}, \beta_{s_t})$. Equation 5 can be expressed as⁹:

$$y_t = x_t \, \delta_{s_t} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_{s_t}^2)$$
 (6)

This MS model assumes that the variance is also shifting between regimes. Term s_t is the unobserved state variable presumed to follow a two-state Markov chain with transition probability (p_{ij}).

The results of the maximum likelihood estimation for the time-varying relationships between the variables concerned are reported in Table 3. The constant terms of α_1 and α_2 for both regimes are all shown to be significantly away from zero at the 1% level for all industries. However, the findings of the impact coefficients β_1 and β_2 of regime 1 and regime 2 are mixed. The results show that the strong-impact or weak-impact power exists in different regimes from industry to industry. As we can observe from Table 3, the impact coefficients' β_2 's of regime 2 (for industrial categories of Y1, Y2, Y7, Y8 and Y11) and the impact coefficients' β_1 's of regime 1 for (industrial categories of Y3, Y4, Y5, Y9, Y12 and Y13) are all significantly different from zero, which implies that the volatility has a strong-impact on the CV. Those β 's which are not shown to be significant imply a weak-impact phenomenon.

This article also investigates the switching possibility that exists in the variance (say, a high volatility regime and a low volatility regime) of the model when the CV are influenced by the volatility. The same results as those of constant terms are found, whereby no matter whether it is regime 1 or regime 2, all the volatility factors, σ_1 or σ_2 , are shown to be significant at the 1% level for all industries. These strong influence phenomena existing among all the industries illustrate that the volatility is not the only factor affecting the CV of industries, while the variance stirs up from the model. Investors having keen insights into the investment decisions should focus on the risks arising from the industry itself.

The associated transition probability can be used to analyse which regime has a stronger dominant power. The results reported in Table 3 show that the transition probabilities of regime 1 dominate that of regime 2 for the industrial categories of Y1, Y4, Y5, Y6, Y7, Y8, Y9, Y12 and Y13. On the other hand, for the industrial categories of Y2, Y3, Y10 and Y11, the transition probabilities of regime 2 dominate that of regime 1. To conclude these findings, we see that for the industries of Y1, Y3, Y5, Y7 and Y8, the influence level of the volatility on the CV is dominated by the weak-impact regime; those dominated by the strong-impact regime can be found in the industries of Y2, Y4, and Y9. In addition, we find that no matter for which exporting level (Y11, Y12, or Y13), the effects of the volatility on the corporate values are all dominated by the strong-impact regime. The final finding can be addressed on the industries of Y6 and Y10, which shows that the impact level is undetermined since for both regimes, the impact coefficients are insignificant.

Specification tests

Based on Hamilton (1996), this article further concerns the specification tests of the MS model. Four hypotheses considered for testing are presented as follows:

$$H_0^1: \alpha_1 = \alpha_2; \quad H_0^2: \beta_1 = \beta_2; \\ H_0^3: \sigma_1 = \sigma_2; \quad H_0^4: p_{11} = (1 - p_{22})$$

where the first three hypotheses are self-evident, while the last one tests for the transition probability. Under the null hypothesis,

$$\Pr(s_t = 1/s_{t-1} = 1) = \Pr(s_t = 1/s_{t-1} = 2) = \Pr(s_t = 1),$$

and the distribution of s_t is independent of s_{t-1} .

The Wald test statistics for the above testing hypotheses are respectively:

$$\frac{(\hat{\alpha}_1 - \hat{\alpha}_2)^2}{\operatorname{Var}(\hat{\alpha}_1) + \operatorname{Var}(\hat{\alpha}_2) - 2\operatorname{Cov}(\hat{\alpha}_1, \hat{\alpha}_2)} \sim \chi^2(1) \quad (7)$$

$$\frac{(\hat{\beta}_1 - \hat{\beta}_2)^2}{\operatorname{Var}(\hat{\beta}_1) + \operatorname{Var}(\hat{\beta}_2) - 2\operatorname{Cov}(\hat{\beta}_1, \hat{\beta}_2)} \sim \chi^2(1) \quad (8)$$

$$\frac{(\hat{\sigma}_1 - \hat{\sigma}_2)^2}{\operatorname{Var}(\hat{\sigma}_1) + \operatorname{Var}(\hat{\sigma}_2) - 2\operatorname{Cov}(\hat{\sigma}_1, \hat{\sigma}_2)} \sim \chi^2(1) \quad (9)$$

$$\frac{[\hat{p}_{11} - (1 - \hat{p}_{22})]^2}{\operatorname{Var}(\hat{p}_{11}) + \operatorname{Var}(\hat{p}_{22}) - 2\operatorname{Cov}(\hat{p}_{11}, \hat{p}_{22})} \sim \chi^2(1) \quad (10)$$

As we observe from Table 4, the Wald statistics for the null of equality are ambiguous. From the viewpoint of all of Taiwan's industries, it is hard to conclude that the data are drawn from two different states since the null of no strong-weak impact of switching can only be rejected for the three industry categories of Y2, Y4 and Y7 at the 5% significance level. However, the nulls of no drift switching of the MS model are all shown to be significant even at the 1% level. This implies that if the MS model is appropriate, then the volatility may not be one major factor, but another factor, which could switch the CV

⁹ For simplicity, the following analysis is based only on one industry. We thus omit the symbol.

Null hypothesis	$H_0^1: \alpha_1 = \alpha_2$	$H_0^2:\beta_1=\beta_2$	$H_0^3: \sigma_1 = \sigma_2$	$H_0^4: p_{11} = p_{22}$
RX to Y1	368.3*	3.391***	0.339	3.729***
RX to Y2	214.6*	5.707**	127.9*	3.717***
RX to Y3	233.5*	0.544	18.21*	5.255**
RX to Y4	214.6*	5.707**	127.9*	3.717***
RX to Y5	132.9*	0.025	1.833	3.507***
RX to Y6	135.5*	0.518	5.539**	5.307**
RX to Y7	227.3*	7.341*	1.059	6.531**
RX to Y8	347.9*	0.307	0.603	4.022**
RX to Y9	111.5*	0.557	36.43*	3.308***
RX to Y10	12.79*	0.470	26.59*	4.126**
RX to Y11	197.4*	3.466***	3.740***	3.740***
RX to Y12	70.03*	1.560	19.37*	4.152**
RX to Y13	119.6*	0.484	36.06*	3.354***

Table 4. Specification tests

Notes:

1. The number is the Wald statistic.

2. *, ** and *** denotes significant at 1, 5 and 10% level, respectively.

3. The 1, 5, and 10% significant level of $^{2}(1)$ are 6.63, 3.84 and 2.72, respectively.

of Taiwan's industries. Furthermore, the model's volatility influence can be illustrated by the coefficient values of the volatility. As shown in Table 4, 6 out of Taiwan's 10 industries considered are shown to fit a two-state model when the volatility is stimulated.

From Table 4 again, under the null of the distribution of s_t that s_t is independent of s_{t-1} , only 6 out of 13 entities are rejected at the 5% significance level. However, based on the 10% level, we can reject the null of 'no regime switching' and then conclude that a two-state, first-order MS model is appropriate for the 'goodness of fit' analysis.

VI. Concluding Remark

Among the controversies of the effects of exchange rate volatility on exporting volumes, this article attempts to investigate the impacts of volatility on the CV for the industries concerned in Taiwan based on an application of a regime-switching regression. To allow for variance to be drawn from different states, this article extends the first-moment switching model to a second-moment model in which a MS model is considered that has not only a switching intercept and a switching slope, but also a switching error variance.

We first employ the traditional OLS approach and find that the volatility has a significantly positive impact on the values among the chemical, electronics, plastic and rubber industries, but has a negative impact on that of the food industry. However, the structurally unstable phenomena from the CUSUM and CUSUM of squares tests during the estimation period reduce the explaining power of the volatility affecting the CV when the OLS regression is applied.

Two different regimes registered as strong-impact and weak-impact are identified by the values of impact coefficients. For the chemical, food, electricity, plastic and rubber industries, the influence level of the volatility on the CV is dominated by the weakimpact regime; those dominated by the strong-impact regime are found in the electronics, glass and steel industries. We also find that the effects of the volatility on the CV are all dominated by the strong-impact regime for all three export ratio levels. However, the paper and textile industries show that the impact level is undetermined since for both regimes, the impact coefficients are insignificant.

Even though the null of no drift switching is shown to be significant for all of Taiwan's industries, it is hard to conclude that the data are drawn from two different states since the null of no strong-weak impact switching can only be rejected for the three industry categories of electronics, glass and plastic. If the MS model is appropriate, then the volatility may not be one major factor, but another factor, which could switch the CV of Taiwan's industries. Nonetheless, for the model's volatility influence, the data of eight out of the ten industries are shown to fit a two-state model when the volatility is stimulated.

When testing for the transition probability, under the null of the distribution of whether the two states are mutually independent, only 6 out of 14 entities are rejected at the 5% level. However, the null of 'no regime change' is rejected at the 10% level, and Downloaded By: [2007 Tamkang University] At: 11:00 28 February 2008

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a two-state, first-order MS model is then appropriate for the 'goodness of fit' analysis.

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Appendix

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 is the capital employed, and Q_t is 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 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 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:

$$C_t = \pi_t L_t^{\alpha} K_t^{1-\alpha} - w L_t - \gamma I_t^{\beta}$$
(A1)

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

$$\mathrm{d}K_t = (I_t - \delta K_t)\mathrm{d}t \tag{A2}$$

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

$$\frac{\mathrm{d}\pi_t}{\pi_t} = \sigma \mathrm{d}Z \tag{A3}$$

where dZ is a Wiener process with zero mean and unit variance. Equation A3 specifies the price process that transmits the output prices' uncertainty into the exchange rate uncertainty in terms of the home currency, and that captures the following

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properties:

$$E_t(\pi_s) = \pi_t, \quad s \le t \quad \text{and} \quad \operatorname{Var}\left(\frac{\pi_s}{\pi_t}\right) = (s-t)\sigma^2$$

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

$$V(K_t, \pi_t) = \max_{I_s, L_s} E_t \int_t^\infty \left[\pi_s L_s^\alpha K_s^{1-\alpha} - w L_s - \gamma I_s^\beta \right] \\ \times e^{-r(s-t)} \,\mathrm{d}s \tag{A4}$$

where r is the constant discount rate. The optimality condition for maximizing Equation A4 requires that the total returns required by the firm equal the total returns expected by the firm; that is, the following identity equation holds:

$$rV(K_t, \pi_t) dt = \max_{I_t, L_t} [\pi_t L_t^{\alpha} K_t^{1-\alpha} - wL_t - \gamma I_t^{\beta}] dt + E_t(dV)$$
(A5)

where the term at the left-hand side of Equation A5 is the total returns required by the firm, and the terms at the left-hand side of Equation A5 are the total returns expected by the firm which consist 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):

$$dV = V_K dK + V_\pi d\pi + \frac{1}{2} V_{KK} (dK)^2 + \frac{1}{2} V_{\pi\pi} (d\pi)^2 + V_{\pi K} (d\pi) (dK)$$
(A6)

Substituting Equations A2 and A3 into Equation A6, we get the expected change in the value of the firm given $E_t(dZ) = (dt)^2 = (dt)(dZ) = 0$:

$$E_t(\mathrm{d}V) = \left[(I_t - \delta K_t) V_K + \frac{1}{2} \pi_t^2 \sigma^2 V_{\pi\pi} \right] \mathrm{d}t \qquad (A7)$$

Again substituting Equation A7 into Equation A5, we obtain:

$$rV(K_{t}, \pi_{t}) = \max_{I_{t}, L_{t}} [\pi_{t} L_{t}^{\alpha} K_{t}^{1-\alpha} - wL_{t} - \gamma I_{t}^{\beta} + (I_{t} - \delta K_{t}) V_{K} + \frac{1}{2} \pi_{t}^{2} \sigma^{2} V_{\pi\pi}]$$
(A8)

From Equation A8, we can show that:

$$\max_{L_t} [\pi_t L_t^{\alpha} K_t^{1-\alpha} - wL_t] = \tau \pi_t^{1/(1-\alpha)} K_t$$
(A9)

where $\tau = (1 - \alpha)(\alpha/w)^{\alpha/(1-\alpha)}$ and the term at the right-hand side of Equation A9 is the marginal revenue product of capital (MRP_k). Differentiating the term at the right-hand side of Equation A8 with respect to I_t yields:

$$\gamma \beta I_t^{\beta - 1} = V_k. \tag{A10}$$

By Equation A10, 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 A9 and A10 into Equation A8 gives:

$$rV(K_t, \pi_t) = \tau \pi_t^{1/(1-\alpha)} K_t + (\beta - 1)\gamma I_t^{\beta} - \delta K_t V_K + \frac{1}{2} \pi_t^2 \sigma^2 V_{\pi\pi}$$
(A11)

Both Equations A10 and A11 can be expressed as a set of nonlinear, second-order partial differential equations. Following Mussa (1983) and Abel (1983), we have imposed enough structure on the two equations to obtain a set of explicit solutions as follows:

$$V(K_t, \pi_t) = b_t K_t + \frac{(\beta - 1)\gamma (b_t/\beta_\gamma)^{\beta/(\beta - 1)}}{r - \theta\sigma^2}$$
(A12)

where

$$b_{t} = \frac{\tau \pi_{t}^{1/(1-\alpha)}}{r + \delta - (\alpha \sigma^{2}/2(1-\alpha)^{2})}, \quad \theta = \frac{\beta(1-\alpha+\alpha\beta)}{2(1-\alpha)^{2}(\beta-1)^{2}}$$
(A13)

and

$$I_t = \left(\frac{b_t}{\beta_{\gamma}}\right)^{1/\beta - 1} \tag{A14}$$

In Equation A12, 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 A12 represents the present value of the expected MRP_k, both b_t (for all *t*) and θ in Equation A13 are greater than zero. Partially differentiating b_t in Equation A13 with respect to σ^2 , and then differentiating I_t in Equation A14 with respect to b_t , we get:

$$\frac{\partial b_t}{\partial \sigma^2} = \frac{\tau \pi_t^{1/(1-\alpha)} [\alpha/2(1-\alpha)^2]}{[r+\delta - (\alpha \sigma^2/2(1-\alpha)^2)]^2} > 0$$
(A15)

$$\frac{\mathrm{d}I_t}{\mathrm{d}b_t} = \frac{1}{\beta_{\gamma}(\beta - 1)} \left(\frac{b_t}{\beta_{\gamma}}\right)^{(2-\beta)/(\beta - 1)} > 0 \qquad (A16)$$

where an increase in σ^2 in Equation A15 represents an increase in the uncertainty of exchange rates. Further differentiating V_t in Equation A12 with respect to σ^2 , we get:

$$\frac{\partial V(K_t, \pi_t)}{\partial \sigma^2} = K_t \frac{\partial b_t}{\partial \sigma^2} + \frac{1}{(r - \theta \sigma^2)^2} \{ (r - \theta \sigma^2) (b_t / \beta_\gamma)^{1/(\beta - 1)} (\partial b_t / \partial \sigma^2) + (\beta - 1) \gamma \theta (b_t / \beta_\gamma)^{\beta/(\beta - 1)} \}$$
(A17)

From Equation A17, we know that since $b_t/\sigma^2 > 0$ in Equation A15 and $dI_t/db_t > 0$ in Equation A16, $V(K_t/\pi_t)/\sigma^2 > 0$. This means that the increased uncertainty in exchange rates would lead 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., $r > \theta\sigma^2$. Of course, if $r < \theta\sigma^2$, then the aforementioned result is rather ambiguous.

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