

Stock Return and Exchange Rate Risk: Evidence from Asian Stock Markets Based on A Bivariate GARCH Model

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ABSTRACT

This paper presents a bivariate conditional variance model to analyze individual national stock returns in Asian countries and their interaction to the foreign exchange rate changes. Using lagged national stock return as a local factor, our evidence indicates that most markets display significant autoregressive process, rejecting random walk hypothesis. Our findings also conclude that the regional and world factors, proxied by Japanese and US stock returns, respectively, have a positive effect on the Asian stock returns. The estimated results suggest that the national stock returns and the value of national currency are positively related, suggesting that a higher stock returns is encouraged by an appreciation of national currency. Finally, the model has been estimated in the framework of a bivariate GARCH(1,1) process. The results derived from this study indicate that both variance and covariance terms are time varying. This suggests that, in pricing international assets, the conditional variance-covariance process should be more explicitly built into the model in order to account for the time-varying risk.

JEL classification: F31, F36, G15

Keywords: Exchange rate risk; Stock return; Bivariate GARCH; Asian stock markets

I. INTRODUCTION

Market crashes in October 19, 1987 and August 31, 1998 indicate that the stock markets are frequently subject to big changes, especially when the markets have been experienced a substantial gain for a given period of time. In reviewing recent stock market behavior, we find that stock price changes are not necessarily associated with the big event. Rather, the following time series behavior is present. First, the national stock price indexes have been drifting in a persistent fashion although the randomness is still an important component in dictating the series movements. Particularly, it has been observed that in the short run, the prices are more likely to follow an extrapolative behavior; however, in a longer time horizon, they display a mean-reversion phenomenon. Second, price movements are extremely volatile. The source of volatility is not necessarily coming from domestic market. Rather, the reaction of market volatility is oftenly contagious to global occurrence. Third, recent market developments have highlighted growing interactions among global financial markets. These interactions not only come from the stock markets *per se* but also spill from other markets, such as bond and foreign exchange markets. We have witnessed the significant impact on stock markets due to the collapse of the foreign exchange markets in major Asian countries since the mid of 1997. In response to these market phenomena, empirical research has developed into the following paths.

The first approach attempts to examine the relationship between expected returns and risk, particular attention has been given to the cause and modeling of risk. For instance, French, *et al.* [14] find evidence that expected market risk premium of stock portfolio is positively related to the predictable volatility of stock returns. Lee and Ohk [26] and Glosten, *et al.* [15] employing ARCH-M and GARCH-models, respectively, present additional evidence on the relationship between risk and return for the US data.¹

The second line of approach emphasizes the significance of co-movements of international stock indices. Researchers such as Jeon and Chiang [17] and Kasa [21] tackle the issue of international stock linkages by exploring time series factors that are commonly shared by individual national markets. By employing multivariate cointegration tests, Jeon and Chiang and Kasa find evidence to support the existence

of a common stochastic trend in a system formed by the major stock exchanges.

Besides, attention has been directed to examine the nature and the lead and lag pattern of information transmitting. For instance, in their investigation of an international transmission mechanism in stock market movements, Eun and Shim [12] found that innovations in the US market are rapidly transmitted to the rest of the world. King and Wadhvani [23] also demonstrated a contagion effect - in that price changes in one market can be transmitted to other markets through information assessment and inference. Moreover, Hamao, *et al.* [16] reported that price volatility spills over across markets. Theodossiou and Lee [33] and Chiang and Chiang [5] concluded that national stock market volatility is caused mainly by U.S. stock return volatility, although a weaker effect was found in the risk measured by macroeconomic volatility and exchange rate variations. In sum, the accumulated evidence indicates that international linkages and interactions among international stock markets have increased in 1990s, indicating that national markets have grown more interdependent (Koutmos and Booth [24]).

Despite a substantial amount of empirical research analyzing stock market behavior, most of the studies concentrate on a few major developed stock markets. Their investigations are focused on the relationship between national stock returns. Very few attempts have been devoted to: (1) the study of the newly industrial countries such as Taiwan, Hong-Kong, South Korea, and Singapore, etc. on the comparable research and (2) examining the interactions between the foreign exchange rate changes and the stock returns.

In light of current impact of Asian financial market crisis, in this paper we present a bivariate conditional variance model to analyze individual national stock returns and their interaction to the foreign exchange changes. Thus, in modeling national stock behavior, the return equation is assumed to be explained by its own lags, the cross correlations and the changes of foreign exchange rates; while the variance equation is assumed to follow a bivariate GARCH(1,1) process.

II. DATA AND TIME SERIES PROPERTIES

A. Data

In this paper, we employ daily data for the period from January 1, 1990 through February 10, 1998. The stock market indices and exchange rates are for Taiwan, Hong Kong, South Korea, Singapore, Malaysia, Philippines, Indonesia, Thailand, Japan, and the United States. The stock return is defined as the natural log-difference of daily stock prices. The exchange rate is defined as the units of national currency per U.S. dollar. All of the indices are expressed in local currency. All of the data are obtained from Data Stream International.

B. Autocorrelation and Cross Correlation

To obtain some basic information in relation to the time series properties for stock returns, $R_{s,t}^i$, and changes of exchange rates, $R_{x,t}^i$, (where superscript "i" refers to the indices for Taiwan, Hong Kong, South Korea, Singapore, Malaysia, Philippines, Indonesia, Thailand, and the first subscript "s" refers to stock prices and "x" for exchange rates), we calculate the autocorrelations for each market with a 5-day window. The results of stock returns and changes of exchange rates are, respectively, presented in Tables 1 and 2. Comparing the estimated coefficients with the corresponding standard error, the evidence shows that the coefficients of the autocorrelation function are positively significant for one or two day lag. However, changes in exchange rates present longer lags. Evidently, the random walk hypothesis is clearly rejected for most of the Asian countries, both for the daily stock returns and change in exchange rates. When we examine the jointly significant for the independence of ten-day lags, the null is uniformly rejected by the Ljung Box Q-statistics, indicating some degree of dependency existing over the 10 days window.

Next, we look into the cross correlations of stock return for each country with respect to that of the US and Japan. The statistics reported in Tables 3a and 3b are calculated from two-day leads to two-day lags (-2 to 2). With the exception of one or two instances, the evidence strongly indicates that the stock returns are significantly correlated with the US or Japanese market contemporaneously or with one-day lag, signifying a spillover effect in the mean equation.

Table 1
Summary Statistics of Daily Stock Returns: 1990/01/01 to 1998/02/10

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand	US
Mean	0.06	0.01	-0.04	-0.01	0.01	0.03	0.004	0.04	-0.02	0.05
Std. Dev.	1.6	1.27	1.48	1.59	1.5	1.61	1.13	1.54	1.8	0.79
Skewness	-0.09*	0.68***	0.38***	0.04	1.00***	0.06	0.22***	-0.11*	0.13**	-0.26***
Kurtosis	16.06***	22.46***	4.77***	8.04***	21.46***	4.86***	17.59***	2.81***	5.77***	6.12***
ρ_1	0.0067	0.2854***	-0.0087	0.1003***	0.1587***	0.2203***	0.1810***	-0.0166	0.1600***	0.0177
ρ_2	-0.0113	0.0704***	-0.0734***	-0.0274	0.0516**	0.0253	0.0434**	0.0397*	0.0036	-0.0171
ρ_3	0.1123***	-0.0224	0.0072	-0.0143	0.0125	0.0308	0.0293	0.0335	0.0357*	-0.0551**
ρ_4	-0.0448**	-0.0067	0.0185	-0.0616***	0.0489**	0.0377*	-0.0092	-0.0195	0.0368*	0.0007
ρ_5	0.0009	0.0313	-0.0152	-0.0033	0.0245	0.0065	-0.0257	0.0235	0.0104	-0.0134
Q(10)	50.89***	239.67***	23.76***	41.72***	84.65***	117.89***	106.36***	20.49***	76.89***	34.62***
ρ^2	0.4213***	0.1974***	0.1255***	0.2856***	0.1265***	0.1812***	0.3110***	0.1217***	0.3227***	0.2542***
ρ^2	0.1943***	0.1566***	0.1409***	0.2793***	0.2050***	0.1494***	0.2328***	0.1026***	0.2945***	0.0724***
Q ² (10)	862.06***	410.45***	252.89***	1191.12***	194.91***	257.53***	673.53***	129.77***	720.48***	202.66***

Notes:

- (1) The mean and standard deviation of stock returns are percentage returns. The standard error of the estimated ACF is approximately equal to 0.02174 (with 2116 observations).
- (2) Q(10) is the Ljung-Box Q-statistics that tests the joint significance of the autocorrelations of the daily returns series up to the 10th order. Q²(10) is the Ljung-Box Q-statistics that tests the joint significance of the autocorrelations of the squared daily returns series up to the 10th order.
- (3) *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels, respectively.

Table 2
Summary Statistics of Daily Exchange Rate Returns: 1990/01/01 - 1998/02/10

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Mean	-0.0004	0.07	-0.007	0.05	0.01	0.03	-0.01	0.02	0.03
Std. Dev.	0.04	1.75	0.69	1.27	0.56	0.71	0.29	0.32	0.71
Skewness	-0.57***	2.84***	-0.68***	-0.04	-1.03***	4.08***	-0.03	2.46***	6.47**
Kurtosis	41.25***	135.79***	6.02***	120.42***	65.53***	57.81***	12.32***	51.50***	177.25***
ρ_1	-0.1965***	0.1031***	-0.0394*	0.3449***	0.1909***	0.1324***	-0.0112	-0.0198	0.0534**
ρ_2	0.0191	0.1147***	-0.0036	0.0825***	0.1752***	-0.0426**	0.0226	0.0488**	-0.0515**
ρ_3	0.0202	-0.0133	-0.0228	-0.2411***	0.0359*	-0.0499**	-0.0001	-0.027	-0.1476***
ρ_4	-0.0326	0.0386*	0.0185	-0.2830***	-0.0762***	-0.0833***	0.0184	0.0376*	0.1192***
ρ_5	-0.0241	-0.2429***	0.0216	-0.4395***	0.0338	-0.0306	0.0786***	0.0031	0.0827***
Q(10)	95.17***	288.50***	26.49***	1077.68***	244.55***	78.94***	45.94***	12.07	184.42***
ρ_1^2	0.3116***	0.2836***	0.0647***	0.1290***	0.1913***	0.1958***	0.3050***	0.2893***	0.0498**
ρ_2^2	0.0631***	0.2123***	0.0372*	0.1444***	0.2247***	0.0539**	0.3477***	0.1855***	0.0516**
$Q^2(10)$	233.02***	1644.26***	19.54**	1189.58***	895.16***	105.50***	992.50***	224.77**	103.72***

Notes:

- (1) The mean and standard deviation of stock returns are percentage returns. The standard error of the estimated ACF is approximately equal to 0.02174 (with 2116 observations).
- (2) Q(10) is the Ljung-Box Q-statistics that tests the joint significance of the autocorrelations of the daily returns series up to the 10th order. $Q^2(10)$ is the Ljung-Box Q-statistics that tests the joint significance of the autocorrelations of the squared daily returns series up to the 10th order.
- (3) *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels, respectively.

Table 3a
Cross Correlations for Pairwise Stock Returns:
1990/01/01 - 1998/02/10

Country	HK-US	IN-US	JP-US	KO-US	MA-US	PH-US	SG-US	TW-US	TH-US
γ_{-2}	0.0311	-0.0317	-0.019	-0.0103	-0.0256	-0.003	-0.0162	-0.0136	-0.0555**
γ_{-1}	-0.0299	0.0369*	-0.0536**	0.0122	0.0204	-0.0093	0.0609***	-0.0440**	0.0167
γ_0	0.1166***	0.006	0.1315***	0.0839***	0.1098***	0.0723***	0.1191***	-0.0146	0.0659***
γ_1	0.3407***	0.1723***	0.2415***	0.1012***	0.2327***	0.2229***	0.3234***	0.1129***	0.2332***
γ_2	-0.0486**	0.0307	0.0184	-0.0396*	0.024	0.0232	0.0117	0.0902***	0.0554**
Q(-5,5)	287.27***	92.97***	172.37***	37.27***	158.86***	135.10***	269.47***	41.09***	151.53***
HK-JP		IN-JP		KO-JP	MA-JP	PH-JP	SG-JP	TA-JP	TH-JP
γ_{-2}	-0.0149	0.0154		0.0425**	0.0055	-0.0322	0.0091	-0.0078	-0.0086
γ_{-1}	0.007	-0.0041		0.0673***	0.0291	-0.0022	0.0357	0.0049	0.0028
γ_0	0.2788***	0.1030***		0.0086	0.2083**	0.0904***	0.2739***	0.0819***	0.1465***
γ_1	-0.0255	0.0478**		0.0614***	0.0541**	0.1010***	0.0515**	0.0613***	0.0718***
γ_2	-0.0342	-0.0203		-0.0798***	-0.0248	-0.0206	0.0054	-0.0155	-0.0108
Q(-5,5)	170.92***	39.81***		32.37***	104.62***	51.70***	171.10***	18.14*	58.62***

Notes:

(1) *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels, respectively.

(2) The standard error of the estimated cross auto-correlation is approximately equal to 0.07174 (with 2116 observations)

Table 3b
Cross Correlations between Stock Returns and Exchange Rate Returns:
1990/01/01 - 1998/02/10

	Hongkong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
γ_2	0.0337	-0.0816***	-0.0251	-0.0475**	-0.0027	-0.0367*	-0.0156	-0.0487**	-0.0163
γ_{-1}	-0.0079	0.0113	-0.0138	-0.3006***	-0.0999***	-0.034	-0.0640***	-0.0774***	-0.0922***
γ_0	-0.0973***	-0.1255***	0.0387*	-0.1712***	-0.2806***	-0.0206	-0.1252***	-0.1069***	-0.0695***
γ_1	0.0585***	-0.0555***	-0.0037	-0.0276	-0.1332***	-0.0043	-0.1046***	-0.0196	0.0740***
γ_2	0.0058	-0.0766***	0.0032	0.0759***	-0.1084***	-0.0631***	-0.0620***	-0.0018	0.0655***
Q(-5.5)	70.01***	159.77***	7.34	246.67***	275.46***	24.46**	101.32***	50.01***	71.68***

Notes:

- (1) *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels, respectively.
(2) The standard error of the estimated cross correlation is approximately equal to 0.02174 (with 2116 observations).

Finally, as shown in Table 3b, we investigate the cross correlation between stock return and exchange rate change. The evidence shows that the contemporaneous correlation is more significant although up to two day lags are also significant. One important information emerging from this test is that the exchange rate risk appears to be an important argument in explaining the stock returns.

III. THE STOCK RETURN AND CONDITIONAL VARIANCE

A. Univariate Model

A univariate stock return equation with a conditional variance model can be expressed as:

$$R_t^i = \beta' Z_{t-1}^i + \varepsilon_t^i, \quad (1)$$

$$h_t^i = h_0^i + A(L)\varepsilon_t^i\varepsilon_t^i + B(L)h_t^i, \quad (2)$$

where R_t^i is the daily stock return for market index, ε_t^i is an error term from the return equation, $h_t^i = E(\varepsilon_t^i\varepsilon_t^i)$ is a conditional variance and L is the lagged operator.^{2,3} Equation (1) states that the stock return is a linear function of information set defined by Z_{t-1}^i . The evidence from the studies of the advanced countries suggests that market returns depend on a set of information variables, Z_{t-1}^i , such as dividend yields, interest rates (term structure relationships), and risk factors (Glosten, *et al.* [15] and Longin and Solnik [27]).

Since daily observations for these variables are not readily available from the markets under investigation, we instead specify that Z_{t-1}^i consists of the information derived from local, regional, and world factors. Local (Country) information includes lagged market return ($R_{s,t-p}^i$) and change in exchange rate against US dollar ($R_{x,t}^i$). Regional and world variables are, respectively, measured by Japanese stock return ($R_{s,t}^{JP}$) and US stock return ($R_{s,t}^{US}$). Specifically, we define:

$$Z_{t-1}^i = \{R_{s,t-p}^i, R_{s,t}^{JP}, R_{s,t}^{US}, R_{x,t}^i\}.$$

The variance equation in (2) is assumed to follow a finite GARCH process. Notice that in a standard GARCH-M model, a conditional variance term is usually treated as an independent argument included in the return equation. The idea behind this is to capture the traditional two-parameter asset pricing models by relating the means to the variances (or standard deviations). Since the experience from finance literature suggests that the GARCH(1,1) is sufficient to describe the conditional volatility (Bollerslev, *et al.* [3]) and our empirical experiment also indicated that the conditional variance variable produces statistical insignificance, the variance equation seems reasonably to be specified in a GARCH (1,1) instead of a GARCH (1,1)-M process.

B. A Multivariate Conditional Variance-Covariance Model

A drawback of a univariate GARCH(1,1) process such as equation (2) is that the model fails to take into account the information of covariance between national stock return and exchange rate change. In their recent research paper, Longin and Solnik [27] show that the correlation matrix of international asset returns provides a useful information in forming an optimal international portfolio. Moreover, the knowledge of covariance between national stock market and foreign exchange market can be employed as an important input in formulating international investment strategy. To highlight this feature, the stock return and exchange-rate change will be estimated jointly with a vector GARCH(1,1) process.

$$R_{s,t}^i = \alpha_0 + \sum_{j=1}^k \alpha_{1,j} R_{s,t-j}^i + \sum_{j=0}^l \alpha_{2,j} R_{s,t-j}^{JP} + \sum_{j=0}^m \alpha_{3,j} R_{s,t-j}^{US} + \sum_{j=0}^n \alpha_{4,j} R_{x,t-j}^i + \varepsilon_{s,t}^i \quad (3)$$

$$R_{x,t}^i = \beta_0 + \sum_{j=1}^k \beta_{1,j} R_{x,t-j}^i + \varepsilon_{x,t}^i \quad (4)$$

$$h_{s,t}^i = d_0 + d_1 \varepsilon_{s,t-1}^i \varepsilon_{s,t-1}^i + d_2 h_{s,t-1}^i \quad (5)$$

$$h_{x,t}^i = e_0 + e_1 \varepsilon_{x,t-1}^i \varepsilon_{x,t-1}^i + e_2 h_{x,t-1}^i \quad (6)$$

$$h_{sx,t}^i = f_0 + f_1 \varepsilon_{sx,t-1}^i \varepsilon_{sx,t-1}^i + f_2 h_{sx,t-1}^i \quad (7)$$

where $R_{s,t}^i$ is the daily stock return for market index i (i applies to Hong Kong, Indonesia, South Korea, Malaysia, Philippines, Singapore, Taiwan, and Thailand), $R_{x,t}^i$ is changes of exchange rates, $\varepsilon_{s,t}^i$ and $\varepsilon_{x,t}^i$ are, respectively, the error term for stock return and changed exchange rate equation.

Equations (3) and (4) are mean equations. Equation (3) states that a national stock return is a function of its own autoregressive process, a distributed lags of stock returns from Japanese and US markets and changes of exchange rate, the latter captures the exchange rate risk. Equation (4) specifies that changes of exchange rate are assumed to follow an autoregressive process. In estimating the dynamic relationship such as (3) and (4), it is crucial to determine the lag length. Usually, Akaike, Schwartz, or Final Prediction Error methods is recommended. In this paper, we shall rely on the significance tests on autocorrelations and the cross correlation functions shown in Tables 1, 2 and 3. We believe this method is more consistent with the parsimonious principle.

Equations (5) and (6) are variance equations for national stock return and exchange rate, respectively, while (7) is a covariance equation. All these equations are assumed to follow GARCH(1,1) process.

IV. THE ESTIMATING RESULTS

The estimated results for equations (3) and (4) are reported in Table 4. Several empirical findings are obtained from these Tables. First, with the exception of Taiwan, the stock return series consistently display a significant AR process. Second, the estimated results indicate that coefficients on the cross returns for both Japan and US have positive sign and are statistically significant at the current and lagged one day. Third, the coefficients on the exchange rate terms are negative and statistically significant, meaning that stock returns are positively correlated with the currency appreciation. As far as the exchange rate equation as concerned, with the exceptions of Japan and Singapore, all

the other exchange rates show certain types of AR process. Particularly, Hong Kong's market displays a negative AR(1) pattern, while the other Asian currencies have a positive AR(1) process, indicating that a depreciation (appreciation) of the national currency tends to have further depreciation of the currency. This underlying pattern provides a useful information in manipulating the market, rejecting the efficient market hypothesis.

Taking the evidence together, the estimated results show that the local, regional, and world factors all have explanatory power. Interpreting this evidence differently, the stock returns in Asian countries are highly correlated with the stock returns in Japan and US as well as the value of the national currency.

Since the $Q^2(10)$ for both stock return and exchange rate equations are all highly significant, the constant variance assumption for the residuals is uniformly rejected. We estimate equations (3) through (7) jointly. The estimates of the return equation are reported in Table 5. The evidence from the return equation produces very similar results as that we obtained from Table 4. Particularly, the stock return for each country is positively correlated to its own lags (except Japan and Taiwan) and also positively correlated with Japan and US in current and/or one-day lag. The only exception is in the Korean market, we do not find any evidence signifies a significant correlation with these two advanced countries. As before, the exchange rate is also statistically significant in explaining the stock return although the time lag varies from country to country. A general information revealing from the estimates indicates that the coefficient has a negative sign, meaning that the stock return is positively correlated with the appreciation of the national currency. One possible explanation of this is that an appreciation of the national currency signifies the strength of the national economic power, especially in its performance in the foreign sector, creating a confidence and optimistic perspective in stock market. Since most of the Asian countries are exported oriented, the currency appreciation leads to stock market appreciate as well.

Table 4
Estimation of Regression Model: 1990/01/01 - 1998/02/10

Country	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
A. Stock Return Equation									
Constant	0.0002 (0.79)	0.0001 (0.28)	-0.0007** (2.40)	-0.0003 (0.64)	-0.0001** (0.02)	0.00003 (0.08)	-0.0002 (0.86)	0.0004 (1.00)	-0.0004 (1.08)
R _{t-1}	0.2973*** (13.90)	0.2973*** (13.90)	0.0496* (1.78)	0.0997*** (4.82)	0.2013*** (9.68)	0.1367*** (6.50)	0.1371*** (6.50)		
R _{t-2}	-0.032 (1.50)	-0.0592*** (2.83)		0.0282 (1.41)	0.0012 (0.06)				
R _{t-3}	0.1059*** (5.39)								
R _{t-4}	-0.0336* (1.71)				-0.035 (1.30)	0.0789*** (3.93)			
R ^I _t	0.2105*** (9.75)	0.0625*** (3.44)		-0.0362 (1.08)	0.1424*** (6.82)	0.0395* (1.69)	0.1460*** (9.31)	0.0627** (2.24)	0.1110*** (4.25)
R ^I _{t-1}	-0.0589*** (2.75)	-0.0069 (0.39)		0.0687** (2.11)	0.0058 (0.28)	0.0669*** (2.94)	-0.0135 (0.85)	0.0590** (2.17)	0.0336 (1.31)
R ^{US} _t	0.1716*** (4.29)	-0.0358 (1.08)	0.2366*** (6.06)	0.1643*** (2.93)	0.1441*** (3.79)	0.1406*** (3.32)	0.1076*** (3.77)	-0.0275 (0.53)	0.1091** (2.30)
R ^{US} _{t-1}	0.5973*** (14.5)	0.2407*** (7.08)	0.4404*** (11.26)	0.1876*** (3.26)	0.3488*** (8.90)	0.3868*** (8.85)	0.3748*** (12.75)	0.1839*** (3.47)	0.4443*** (9.09)
R _{s,t}	-3.8555*** (5.38)	-0.0922*** (6.18)	-0.0795* (1.77)	-0.1798*** (5.10)	-0.7104*** (13.17)	-0.0367 (0.79)	-0.4214*** (5.50)	-0.4603*** (3.79)	-0.1301** (2.46)
Q(10)	15.67	48.07***	12.23	12.31	10.94	8.55	29.70***	22.36**	19.29**
Q ² (10)	750.77***	538.83***	267.09***	897.65***	322.46**	248.75***	478.18***	112.89***	657.52***

Table 4 (continued)

Country	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
B. Exchange Rate Return Equation									
Constant	-5.2×10^{-6} (0.56)	0.0007** (2.04)	-0.0001 (0.48)	0.0007** (2.32)	0.0001 (0.82)	0.0003* (1.86)	-0.0001 (1.13)	0.0001* (1.85)	0.0002* (1.62)
$R_{x,t-1}$	-0.1965*** (9.22)	0.0975*** (4.48)		0.2649*** (10.33)	0.1763*** (7.83)	0.1363*** (6.26)			0.0615*** (2.78)
$R_{x,t-2}$		0.1121*** (5.16)		-0.0117 (0.44)	0.1706*** (7.49)	-0.0604*** (2.75)		0.0489** (1.95)	-0.0321 (1.46)
$R_{x,t-3}$				-0.2221*** (8.56)		-0.0266 (1.21)			-0.1507 (6.94)
$R_{x,t-4}$				-0.0252 (0.94)	-0.1192*** (5.31)	-0.0765*** (3.51)			0.1355*** (6.16)
$R_{x,t-5}$		-0.2696*** (12.28)		-0.3418*** (13.30)					0.0573** (2.58)
Q(10)	19.65**	65.34***	26.49***	357.54***	65.97**	17.22*	45.94***	8.43	64.41***
Q ² (10)	289.15***	1735.94***	19.70**	2313.60***	924.06***	98.60***	1001.28***	218.51***	92.20***

Note: *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels respectively.

Table 5
Estimates of the Mean Equation in a Bivariate GARCH Model: 1990/01/01 - 1998/02/10

Country	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
A. Stock Return Equation									
Constant	0.0007*** (2.88)	-4.7*10 ⁻⁵ (0.27)	-0.0002 (0.74)	1.0*10 ⁻⁵ (0.03)	0.0003* (1.72)	0.0001 (0.42)	0.0002 (0.84)	0.0004 (1.11)	0.0001 (0.25)
R _{t-1}	0.2659*** (11.27)	0.0696** (2.19)		0.0696** (2.19)	0.1940*** (9.00)	0.2217*** (10.90)	0.1405*** (6.20)		0.1626*** (7.26)
R _{t-2}	0.0569*** (2.99)		-0.0177 (0.55)		0.0322 (1.48)		0.0137 (0.60)		
R _{t-3}	0.0361* (1.66)								
R _{t-4}	0.0056 (0.25)			-0.0055 (0.23)	0.0316 (1.48)				
RP _t	0.1928*** (12.10)	0.0431*** (3.90)		-0.0253 (1.11)	0.1104*** (7.72)	0.0028 (0.15)	0.1070*** (8.43)	0.0562** (2.35)	0.0580*** (3.10)
RP _{t-1}	-0.0215 (1.21)	0.0735*** (12.02)		0.0241 (0.93)	-0.0148 (1.11)	0.0393** (2.13)	-0.0009 (0.07)	0.0433* (1.77)	0.0363* (1.80)
R ^{US} _t	0.1060*** (4.18)	-0.0425** (2.03)	0.1621*** (5.45)	0.063 (1.41)	0.0900*** (3.69)	0.0750** (2.09)	0.0588*** (2.94)	-0.0433 (1.01)	0.044 (1.33)
R ^{US} _{t-1}	0.4648*** (17.44)	0.1194*** (6.72)	0.3710*** (12.67)	0.0511 (1.02)	0.2454*** (10.52)	0.2938*** (9.88)	0.3002*** (13.81)	0.1709*** (3.41)	0.3096*** (8.98)
R _{ν,t}	-2.0649*** (3.82)	-0.3135*** (9.45)	-0.0104 (0.16)	-0.2968*** (8.63)	-0.7762*** (33.25)	-0.1701*** (2.66)	0.0846 (0.86)	0.1135 (0.56)	-0.0691 (1.37)

Table 5 (continued)

Country	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
B. Exchange Rate Return Equation									
Constant	-2.51*10 ⁻⁶ (0.84)	0.0002*** 96.25)	-3.6*10 ⁻⁶ (0.03)	2.0*10 ⁻⁵ (0.47)	-0.0001* (1.71)	0.0001 (0.74)	-0.0001*** (2.98)	0.0001*** (2.65)	1.5*10 ⁻⁵ (0.51)
R _{x,t-1}	-0.1181*** (4.82)	0.0014 (0.05)		0.2559*** (8.72)	0.0161 (0.74)	0.0315 (0.94)			0.0003 (0.01)
R _{x,t-2}		-0.0828*** (3.63)		-0.0981*** (3.86)	-0.0243 (0.94)	-0.0329 (0.55)	-0.0407 (1.20)		-0.0227 (0.59)
R _{x,t-3}				-0.0111 (0.44)		-0.0167 (0.21)			-0.0467 (1.30)
R _{x,t-4}				0.0443* (1.80)	-0.0149 (0.75)	-0.0431 (1.06)			0.0306 (1.00)
R _{x,t-5}		-0.0319 (1.46)		0.0485** (2.16)					-0.0820*** (5.38)

Note: *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels respectively.

Table 6
Estimates of the Variance-Covariance Equations in a Bivariate GARCH Model: 1990/01/01 - 1998/02/10

Country	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
A. Conditional Variance Equation of Stock Return									
d_0	4.1*10 ⁻⁶ *** (6.90)	6.4*10 ⁻⁶ *** (8.81)	7.7*10 ⁻⁶ *** (10.46)	2.3*10 ⁻⁶ *** (17.61)	7.3*10 ⁻⁶ *** (11.66)	4.8*10 ⁻⁶ *** (5.89)	5.9*10 ⁻⁶ *** (18.18)	2.1*10 ⁻⁵ *** (7.56)	1.1*10 ⁻⁵ *** (8.59)
d_1	0.0945*** (11.40)	0.3290*** (15.56)	0.1141*** (10.98)	0.1664*** (8.69)	0.1923*** (11.61)	0.0986*** (10.82)	0.1395*** (12.65)	0.0723*** (7.15)	0.1555*** (12.54)
d_2	0.8855*** (109.48)	0.6785*** (39.00)	0.8508*** (79.18)	0.7084*** (38.74)	0.7749*** (64.53)	0.8896*** (110.28)	0.7982*** (116.31)	0.8478*** (49.97)	0.8120*** (75.19)
B. Conditional Variance Equation of Exchange Rate Return									
e_0	1.3*10 ⁻⁹ *** (7.95)	3.1*10 ⁻⁸ *** (26.29)	1.7*10 ⁻⁶ *** (7.90)	3.4*10 ⁻⁷ *** (20.46)	3.0*10 ⁻⁷ *** (20.82)	5.4*10 ⁻⁷ *** (26.33)	2.4*10 ⁻⁷ *** (12.04)	5.2*10 ⁻⁷ *** (18.60)	7.0*10 ⁻⁸ *** (21.29)
e_1	0.3066*** (36.30)	0.0730*** (36.66)	0.0407*** (8.96)	0.4049*** (15.60)	0.2645*** (21.27)	0.0363*** (20.57)	0.1384*** (13.83)	0.2426*** (29.97)	0.0686*** (26.26)
e_2	0.8024*** (208.93)	0.9428*** (1061.11)	0.9259*** (135.44)	0.5168*** (36.34)	0.7263*** (86.75)	0.9594*** (665.56)	0.8385*** (92.49)	0.7419*** (88.19)	0.9203*** (413.75)
C. Conditional Covariance Equation of Stock and Exchange Rate Return									
f_0	-7.2*10 ⁻⁸ *** (10.19)	2.2*10 ⁻⁸ (0.67)	-8.9*10 ⁻⁷ (0.18)	3.6*10 ⁻⁷ (0.87)	5.6*10 ⁻⁹ * (1.62)	3.8*10 ⁻⁸ (1.14)	5.89*10 ⁻⁷ ** (2.34)	-1.2*10 ⁻⁷ (1.13)	9*10 ⁻⁸ (0.75)
f_1	0.0319* (1.65)	0.0422*** (2.72)	0.0306* (1.82)	0.001 (1.15)	-0.0030*** (4.50)	-0.0008 (0.63)	0.0663*** (3.62)	0.0244* (1.89)	0.0052 (0.32)
f_2	-0.7798*** (3.67)	0.8902*** (16.40)	-0.7857*** (4.90)	-1.0050*** (81.10)	1.0018*** (411.81)	0.9680*** (475.71)	0.0828 (0.24)	0.9468*** (32.53)	0.9010*** (2.89)

Note: * ** and *** indicate statistically significant at 10%, 5% and 1% levels respectively

Table 6 gives the estimated results of the variance-covariance equations. The coefficients in Panels A and B show significant GARCH(1,1) effects for all countries. Interestingly, the estimates of the conditional covariance in Panel C are found to be significantly explained by the cross product of past shock and/or its lagged value, indicating that the covariances are time varying. This evidence is consistent with the findings by Engel and Rodrigues [10] in that the time-varying conditional variance-covariance process should be more explicitly built into international asset pricing models.

V. CONCLUDING REMARKS

In this paper, a multivariate conditional variance-covariance framework is used to analyze the behavior of various Asian stock markets. This paper explores information derived from local, regional, and world factors to interpret the national stock returns. First, using lagged national stock return as a local factor, our evidence indicates that most markets under investigation display significant autoregressive process, rejecting random walk hypothesis. Our findings also conclude that the regional and world factors, proxied by Japanese and US stock returns, respectively, have a positive effect on the Asian stock returns, although the lag length varies from country to country.

Next, the estimated results suggest that the national stock returns and the value of national currency are positively related, suggesting that a higher stock returns is encouraged by an appreciation of national currency.

Finally, the model has been estimated in the framework of a bivariate GARCH(1,1) process. The results derived from this study indicate that both variance and covariance terms are time varying. This suggests that, in pricing international assets, the conditional variance-covariance process should be more explicitly built into the model in order to account for the time-varying risk.

NOTES

1. In literature, evidence has shown conflict signs for the relationship between return and risk. This is reconciled by Glosten, *et al.* [15] by arguing that the investor may want to save more in the current

- period against the uncertainty of the future. As a result, a lower risk premium is demanded.
2. Due to lack of daily risk-free asset returns in these markets, that prevented us from using excess return variable in the return equation (Baillie and DeGennaro [1], Chou [6], Choudhry [7], and Kim and Kon [22]).
 3. The error term may be specified as an MA(1) process to capture the effect of non-synchronous trading (Ballie and DeGennaro [1]).

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