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International Transmission of Stock Price Movements among Taiwan and Its Trading Partners: Hong Kong, Japan and the United States

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This study uses a cointegration analysis and vector autoregressive models to investigate the transmission of stock price movements among Taiwan and its major trading partners, Hong Kong, Japan and the United States. The results of Johansen cointegration test indicate that four stock markets considered are cointegrated with one cointegrating vector, which violates the semi-strong form of the market efficiency hypothesis. The results from Granger-causality test based on error-correction models suggest the relative leading roles of the U.S. and Japanese markets in driving fluctuations in the other two markets. In order to capture the impacts of the economic shocks, two dummy variables are incorporated into the models taking into account the U.S. stock crash of October 1997 (D97) and the previous spreading Asian finance crises (Dac). The results indicate that D97 significantly affects the U.S. stock market, but shows no significant impact on the others. The Dac, however, shows significant impacts on both the Japanese and the U.S. markets. The robustness of the relative leading roles of the U.S. and Japanese markets are further supported by the variance decompositions and impulsive response functions indicators. The Taiwan and Hong Kong markets are somewhat affected more by regional countries such as Japan than by the U.S.

Keywords: Stock price; Market efficiency hypothesis; Causality based on ECM; Impulse response; Variance decomposition.

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1. Introduction

Over the past two decades, the globalization of international stock markets have generated a large number of studies on international stock market relationships, especially since the stock crash of 1987. However, previous studies focus most on the earlier 1980s' and 1990s' sample periods. This study represents our attempt to re- investigate the transmission of stock price movements among Taiwan and its major trading partners, Hong Kong, Japan, and the United States, using more recent daily data. The main reason for us to choose these countries is that the share of exports and imports from Taiwan to these three countries were relatively high. Table 1 shows that the total volume of exports and imports are about 43% and 53%, respectively, at the end of 1997.

Table 1. Interntional Trade between Taiwan and its Trading Partners, 1995–1997

Year	Hong Kong	Japan	USA	Subtotal	Rest
Panel A: % Share of exports to countries out of total exports					
1995	23.38	11.78	23.65	58.81	41.19
1996	23.10	11.78	23.17	58.06	41.94
1997	23.50	9.58	24.21	57.29	42.71
Panel B: % Share of imports from countries out of total imports					
1995	1.78	29.23	20.06	51.07	48.93
1996	1.67	26.86	19.51	48.03	51.97
1997	1.74	25.36	20.31	47.41	52.59

Sources: Monthly Statistics of Finance, May 1998. Department of Statistics, Ministry of Finance, Taiwan

According to international capital-goods trade hypothesis, the presence of international trade in real capital goods could lead to a reallocation of these goods such that the real marginal product of capital would be equated internationally. Because stock prices are related to the real marginal product of capital, the stock prices in the different countries would tend to exhibit a common movement in the long run even though some or all of the stock markets remained financially segmented from each other.[1] Therefore, it is interesting for us to investigate the transmission of stock price movements among these four countries. Among the related literature, Eun and Shim (1989), King and Wadhwani (1990), Koch and Koch (1991), and Chowdhury

[1]See: Bachman, Choi and Jeon (1996).

(1994) used the traditional statistical methodologies to investigate the interrelationship among the stock index of various countries for data from the 1980s. They consistently found short-run interrelationships among national equity prices. Park and Fatemi (1993), however, found that the Pacific-Basin markets exhibit a weak linkage to the U.S., U.K., and Japanese equity markets. Moreover, the ambiguous results are found in papers applying the VAR technique to examine the linkages and dynamic interactions among stock markets of different economic regions. (e.g., Shachmurove (1995) found that none of the South American markets is completely independent; Elyasiani, Perera and Puri (1998) found no discernible interdependence between the Sri Lankan market and the equity markets of the US and the Asian markets considered; whereas, Friedman and Shachmurove (1996) studied the transmission of innovations among European stock markets and found differential effects for the small and large markets.)

The impact of the turmoil on the dynamic linkages among equity markets has drawn attention of some economists within this decade. The elaborate work on the issue of the influence of the October 1987 stock market crash can be found in Malliaris and Urrutia (1992), Arshanapalli and Doukas (1993), Arshanapalli, Dukas and Lang (1995), Hassan and Naka (1996), Choudhry (1996b), and Masih and Masih (1997).They mostly found a significant influential power since the dynamic relationships among stock markets had experienced some change from pre to post October 1987 crash.

Other evidence for the dynamic linkage among stock markets can also be found in, based on different economic regions, Chan, Gup and Pan (1997) for the global markets, Chung and Liu (1994), Corhay, Rad and Urbain (1995), and Ghosh, Saidi and Johnson (1999) for the Pacific-Basin markets, and Choudhry (1996a) and Gerrits and Yuce (1999) for the European markets. Most of these papers used the US market as a core to examine the long-run and short-run dynamic relationships among stock markets.

Since the previous studies focus most on the earlier 1980s and 1990s sample periods, this study re-investigate the transmission of stock market fluctuations between Taiwan and its major trading partners, Hong Kong, Japan, and the United States, using recent daily data. This paper differs from previous studies in several ways. The major difference is that we incorporate two dummy variables taking into account the two turmoil within our sample period—the U.S. stock crash of October 1997 (D97) and the previous spreading Asian finance crisis (Dac)—into the ECM models for the dynamic analysis. Other differences can be figured out as this study uses more recent daily data to re-investigate the transmission of stock price movements among Taiwan and its major trading partners, and that we employ the more advanced time-series techniques, including unit root test (ADF and PP tests), Johansen multivariate cointegration test, error-correction models (ECM), variance decomposition (VDC), and impulse response functions (IRF) to fully investigate the dynamic relationships among the stock markets considered.

We first examine how these four stock markets are correlated with each other. Correlation matrices for these four stock price index (log) changes indicate that all the correlations are positive and significant with the exception of Taiwan-U.S. markets which are negative and insignificant. The highest contemporaneous correlation with other markets is shown by the Hong Kong-Japan markets (0.386), while the lowest is shown by the Taiwan-U.S. markets (-0.019). Causal observation suggests that each stock price series appears to be nonstationary and that these four national stock price series tend to move more or less together over time, a result which is confirmed through the use of unit root and cointegration techniques. The results of Johansen multivariate cointegration test indicate that these four stock markets are cointegrated with one cointegrating vector. The main implication for this finding is that the EMH (Efficiency Market Hypothesis) is violated in this multivariate context and the investors may not yield portfolio diversification from these four markets in the long run. A similar conclusion was reached by Masih and Masih (1997). The results from Granger-causality tests based on error-correction models (ECM) suggest the relative leading roles of the U.S. and Japanese markets in driving fluctuations in the other two markets. For investigating the impact of the U.S. stock crash of October 1997 and the previous spreading Asian finance crisis on these markets, two dummy variables are incorporated into the models taking into account the U.S. stock crash of October 1997 (D97) and the previous spreading Asian finance crisis (Dac). The results indicate that D97 only significantly affects the U.S. stock market and this impact spreads out to the other three markets but shows no significant impact on them. On the other hand, the Dac shows significant impact on both the Japanese and the U.S. markets. Furthermore, we also incorporate the variance decompositions and impulsive response functions into this study. The results further support the relative leading roles of the U.S. and Japanese markets. However, the Taiwan and Hong Kong markets are somewhat affected more by regional countries such as Japan than by the U.S., a result that is mostly consistent with evidence provided by Ko and Lee (1991) and Liu, Pan and Shieh (1998).

This paper is organized as follows. The following section provides a brief review of previous empirical research in this area and the methodology used. Then the data set is described and the empirical results are outlined. Finally, conclusions are presented.

2. Methodology

2.1. *Unit root tests*

In order to avoid the "spurious regression", the series have to be carefully examined for "stationarity".[2] Since the non-stationary regressors invalidate many standard empirical results, econometrists thus developed a testing method the so-called "unit-root" test, for examining the stationarity of time series. The evidence from several empirical studies has found that many macroeconomic and financial time series, including stock price series, contain unit roots dominated by stochastic trends.[3] Several tests for the presence of unit roots in time-series data have appeared in the literature [e.g., Dickey and Fuller (1979, 1981), Phillips and Perron (1988), and Kwiatowski *et al.* (1992)].

Since Schwert (1989) compared several unit-root tests and argued that the ADF test by Dickey and Fuller (1981) with long lags is superior to the others, this paper first employs the ADF test for testing the stationarity of each series. Based on the model selecting procedure suggested by Doldado, Jenkinson, and Sosvilla-Rivero (1990), the appropriate model selected for all the series is the one including a drift and a time trend, which is presented as the following equation:

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

The null hypothesis for the ADF test is: H_0: $\delta = 0$, with the alternative H_1: $-2 < \delta < 0$. An appropriate lag length has to be pre-designated since the estimation might be biased if the lag length is not rigorously determined. This paper follows the suggestion by Reimers (1992) using Schwartz Bayesian Criterion (SBC) to select the appropriate lag length.

[2]Granger and Newbold (1974) have found by simulation that the F-statistic calculated from the regression involving the non-stationary time-series data does not follow the standard distribution. The findings of significant t and R^2, and lower DW value will invalidate the results of the traditional OLS regression method.

[3]See: Nelson and Plosser (1982) and Lee and Jeon (1995).

For robustness, we also perform Phillips-Perron (PP) (1988) test for testing the stationarity of four series considered. The PP test is more persuasive to a large number of specifications of serial correlation and time-dependent heteroskedasticity in the error term.

2.2. *Cointegration tests*

Given unit roots, the issue arises whether there exists a long-run equilibrium relationship among stock price series. This long-run equilibrium relationship is referred to in the literature as cointegration. According to Engle and Granger (1987), a set of variables, Y_t is said to be cointegrated of order (d, b)—denoted $\mathrm{CI}(d, b)$—if Y_t is integrated of order d and there exists a vector, δ, such that $\beta' Y_t$ is integrated of order $(d - b)$. The finding that a set of variables is cointegrated has important implications for the dynamic modeling of such variables. Engle and Granger (1987) point out that a vector autoregressive (VAR) in first differences will be misspecified because first differencing of all the nonstationary variables impose too many unit roots and any potentially important long-term relationship between the variables will be obscured. Therefore, they suggest an ECM instead of a first differencing VAR model to capture the correct conclusions.

From the argument by Kremers, Erisccos and Dolado (1992) and the findings of the comparison among five cointegration estimations by Gonzalo (1994), we employ the most powerful methodology of Johansen maximum likelihood cointegration test.[4]

Following Johansen methodologies, we construct a p-dimensional (4×1) VAR model with Gaussian errors, which can be expressed by its first-differenced ECM as:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots + \Gamma_{k-1} \Delta Y_{t-(k-1)} + \Pi Y_{t-1} + \Psi D_t + \epsilon_t \tag{2}$$

where Y_t are stock price series studied, ε_t is a white-noise disturbance $\sim N(0, \sigma)$.

The testing hypothesis is formulated as the restriction for the reduced rank of Π, $H_0(r)$: $\Pi = \alpha\beta'$ for the reduced form ECM. The Π matrix conveys information about the long-run relationship between Y_t variables, and the

[4]Gonzalo (1994) compared several methods for estimating cointegration which include ordinary least squares, nonlinear least squares, maximum likelihood in an error correction model, principal components, and canonical correlations.

rank of Π is the number of linearly independent and stationary linear combination of stock price series studied. α and β are both $4 \times r$ matrices, and represent the speed of the adjustment parameter and cointegrating vector, respectively.

The likelihood ratio test statistic for the hypothesis with at most r cointegrating vector (i.e., $H(r)$: rank$(Pi) \leq r$) is:[5]

$$-2\ln Q(H(r)/H(p)) = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i) \tag{3}$$

where $\hat{\lambda}_{r+1} \ldots, \hat{\lambda}_p$ are the estimated $p - r$ smallest eigenvalues.

It is well known that the cointegration tests are very sensitive to the choice of lag length. According to Reimers (1992), we still use the SBC to select the number of lags required in the cointegration test.

2.3. *Causality tests based on ECM*

Granger (1988) points out that if there exists a cointegration vector among stock price series, there must be causality among these stock price series at least in one direction. Granger (1988) provide a test of causality which takes into account the information provided by the cointegrated properties of variables. This model is referred to the literature as an ECM.

$$\begin{aligned}\Delta Y_{it} = \alpha + \mu_{it} + \beta' Z_{t-1} + \sum_{t=1}^{m} a_i \Delta Y_{1,t-i} + \sum_{i=1}^{m} b_i \Delta Y_{2,t-i} \\ + \sum_{t=i}^{m} c_i \Delta_i Y_{3,t-i} + \sum_{t=i}^{m} d_i \Delta Y_{4,t-i} + \gamma D97 + \delta Dac + \varepsilon_t\end{aligned} \tag{4}$$

where Y_{it} denotes stock price index series for Taiwan and its trading partners, Hong Kong, Japan, and the U.S. $\beta' Zt - 1$ contains r cointegrating terms, reflecting the long-run equilibrium relationship among these four stock markets.

For investigating the impact of the U.S. stock crash of October 1997 and the previous spreading Asian financial crisis on these markets, two dummy variables, D97 and Dac, are incorporated into this model. From this system, the Granger-causality tests are examined by testing whether all the coefficients of $Y_{1,t-1}, \Delta Y_{2,t-1}, \Delta Y_{3,t-1}$, and $Y_{4,t-1}$ are statistically different

[5] Johansen (1988) and Johansen and Juselius (1990) propose two test statistics for testing the number of cointegrating vectors (or the rank of Π): the trace (Tr) and the maximum eigenvalue (L-max) statistics.

from zero as a group based on a standard F-test and/or the β's coefficient of error-correction term is also significant. Since the Granger-causality tests are very sensitive to the lag length selection, this study uses Hsiao's (1979, 1981) sequential procedure based on the Granger definition of causality and Akaike's (1974) minimum final prediction error (FPE) criterion to determine the lag lengths. This procedure is known as the stepwise Granger-causality technique, which provides a statistical criterion for choosing the optimum lag length using past information.[6] The FPE criterion is specified as follows:

$$FPE = [(T+k)/(T-k)]^{*}(\mathrm{SSR}/T)$$

where T is the number of observations, k is the number of arameters estimated, and SSR is the sum of squared residuals. Hsiao (1981) points out that "the FPE criterion balances the risk due to the bias when a lower order is selected and the risk due to the increase of variance when a higher order is selected, and choosing the order of the lags by minimum FPE is equivalent to applying an approximate F test with varying significance levels." However, if these four stock price series are found to hold no cointegration, we should analyze the intertemporal causality among these four stock markets as in Eq. (4) without the error-correction term.

2.4. *Impulse response function and variance decomposition*

Since the estimated coefficients of a VAR are difficult to interpret, we need to look at the impulse response functions and variance decompositions of system to draw conclusions. An impulse response function (IRF) traces the response of one market to a change in one of the market's innovations. This function enables us to characterize the dynamic interactions among markets, and observe the speed of adjustment of markets in the system. For example, IRFs show the expected responses of market i to a typical change in market j. A variance decomposition measures the percentage of a market's forecast error variance that occurs as a result of a shock from a market in the system. Sims (1982) notes that if a variable is truly exogenous with respect to the other variables in the system, its own innovations would explain all of the variable's forecast error variance. Following Sims (1980) and Hamilton (1994), a p-dimensional (4×1) vector autoregressive model

[6]Thornton and Batten (1985) found Hsiao's method to be superior to both arbitrary lag length selection and several other systematic procedures for determining lag length.

with kth order can be expressed as

$$Y_t = \alpha + \sum_{i=1}^{k} A_i Y_{t-1} + \varepsilon_t \tag{5}$$

where ε_t is a 4×1 vector of disturbances and α is also a 4×1 vector of constants. The A_i are 4×4 matrices that are determined by the orthogonality conditions as $E[\varepsilon_t] = 0$ and $E[\varepsilon_t | Y'_{t-i}] = 04 \times 4$ for $i = 1, 2, \ldots k$. We can rewrite equation (5) in terms of the innovations which is the vector moving representation (VMA).

$$Y_t = \alpha' + \sum_{t=0}^{\infty} C_i \varepsilon_{t-1} \tag{6}$$

where α' is a 4×1 vector of constants and Ci is a 4×4 matrix with $C_0 = I_p$. In order to construct a moving average representation with disturbance process that is orthogonal contemporaneously as well as at all lags, we make the following transformation for ε_t such that $\varepsilon_t = F u_t$, where F is a 4×4 lower triangular matrix. Then a moving representation in terms of orthogonal innovations at all lags is given by

$$\begin{aligned} Y_t &= \alpha' + \sum_{i=0}^{\infty} C_i F u_{t-i} \\ &= \alpha' + \sum_{i=0}^{\infty} D_i u_{t-i} \end{aligned} \tag{7}$$

where $D_i = C_i F$. This is the Choleski decomposition of the ut vector. Hence any choice of $u_t = F^{-1}\varepsilon_t$ that makes $E[u_t u'_t] = F\Sigma F^{-1}$ diagonal can be utilized to derive a moving average representation in terms of an innovation process that is orthogonal contemporaneously at all lags and leads. Equation (7) can then be used to derive the impulse response functions. From Eqs. (6) and (7) the k-step-ahead errors in forecast Y_t from its own past is given by:

$$\begin{aligned} Y_t - \hat{E}_{t-k} Y_t &= C_0 \varepsilon_t + C_1 \varepsilon_{t-1} + \ldots + C_{k-1} \varepsilon_{t-k+1} \\ &= D_0 u_t + D_1 u_{t-1} + \ldots + D_{k-1} u_{t-k+1} \end{aligned} \tag{8}$$

The variance-covariance matrix of the k-step-ahead forecast errors is given by the following expression

$$\begin{aligned} &E(A_t - \hat{E}_{t-k} A_t)(A_t - \hat{E}_{t-k} A_t) \\ &\quad = D_0 E(\mu_t \mu'_t) D'_1 + D_1 E(\mu_t \mu'_t) D'_1 + \ldots + D_{k-1} E(\mu_t \mu'_t) D'_{k-1} \end{aligned} \tag{9}$$

The diagonal terms of Eq. (9) give the decompositions of the variance of k-step-ahead forecast errors into the parts attributable to shocks in the n components of u_t.

King *et al.* (1991) point out that as there are more than one common trend in the models, different ordering of the variables may affect the results of impulse responses and variance decompositions if the common trends are not absolutely uncorrelated.[7] In this paper, the presumed exogenous orderings are adopted from the previous findings of the Granger causality tests based on ECM.

3. Data

Our empirical analysis employs daily data on stock price indexes for Taiwan and its major trading partners, Japan, Hong Kong, and the United States over the period of January 2, 1997 to April 30, 1998. Figure 1 contains plots of the observed stock price indexes for these four countries. The representative indexes used in the analysis are shown in Table 2. The daily closing price indices are collected from the Taiwan Stock Exchange and the AREMOS of the Ministry of Education, Taiwan. All the indexes are based on local currencies.

Table 2. The Representative Stock Price Indexes

Country	Index
Taiwan	Weighted Index
Hong Kong	Heng Seng Index
Japan	Nikkei Stock Average
USA	Dow Jones Industrial

In order to take care of the data gap caused by public holidays and other non-working days, the time series data in this study, following Chowdury (1994), have been adjusted by dropping some entries, including the Saturday entries, to guarantee that each country has an entry on a given date. The total number of observations for each country is 371. All series are measured in natural logs. Causal observation suggests that each stock price series

[7]Stock and Watson (1988) show that cointegrated variables are driven by common trends. That is, for a set of p integrated variables, if they share r cointegrating relationships, there must exist $k = p - r$ stochastica trends driving the co-movements of the cointegrated variables.

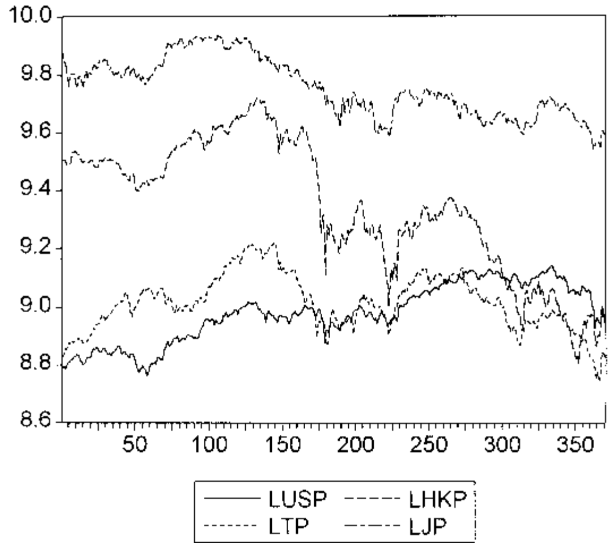


Fig. 1. Stock Prive Indexes for Four Countries: January 3, 1997 to April 30, 1998

appears to be non-stationary and that these four national stock price indexes tend to move more or less together over time, a result which is later confirmed through the use of cointegration technique.

4. Empirical Results

4.1. *Correlation coefficients among stock market index returns*

We first examine how these four stock markets are correlated with each other. Table 3 reports the summary statistics and correlation matrices for these four stock market index returns (or the log price changes). The market's average daily index returns are 0.05%, −0.07%, −0.06%, and 0.09%, respectively, for Taiwan, Hong Kong, Japan, and the U.S. markets. These results indicate that the U.S. market has the highest average daily returns 0f 0.09% and the Hong Kong market has the lowest average daily returns of −0.07% over this sample period. Regarding the standard deviation, we find the market's daily standard deviation are 1.47%, 2.56%, 1.59%, and 1.07%, respectively, for Taiwan, Hong Kong, Japan, and the U.S. markets. These results indicate that the Hong Kong market has the highest daily standard deviation of 2.56% and the U.S. market has the lowest standard deviation of 1.07% over this sample period. Table 3 also shows that index returns for each country are leptokurtic, since the relatively large value of the kurtosis

Table 3. Summary Statistics and Correlation Coeffieicents

Panel A: Summary Statistics of Stock Price Index Returns

	ΔTN	ΔHK	ΔJP	ΔUS
Mean	0.0005	−0.0007	−0.0006	0.0009
Std.Dev	0.0147	0.0256	0.0159	0.0107
Minimum	−0.0609	−0.1473	−0.0544	−0.0745
Maximum	0.0555	0.1746	0.0765	0.0476
Skewness	−0.3629	0.8907	0.1223	−0.4997
Kurtosis	4.6169	17.7842	5.5139	11.0988
J-B test	48.4258*	3418.585*	98.3502*	1026.605*

Panel B: Correlation Matrix of Stock Price Index Changes (Returns)

	7ΔTN	ΔHK	ΔJP	ΔUS
ΔTN	1.00			
ΔHK	0.229	1.00		
ΔJP	0.145	0.386	1.00	
ΔUS	−0.019	0.219	0.065	1.00

Note:

1. TN, HK, JP, and US are the abbreviations for Taiwan, Hong Kong, Japan, and the US, respectively.
2. Δ implies the first differencing.
3. * indicates significance at the 5% level.

statistic (larger than three) suggests that the underlying data is leptokurtic, or heavily tailed and sharply peaked about the mean when compared with the normal distribution. The Jarque-Bera test also leads to rejection of normality on these four markets' daily returns data set.

Regarding the correlation matrix, we find that all the correlations are positive and significant with the exception of Taiwan and the U.S. markets is negative and insignificant. The highest contemporaneous correlation with other markets is shown by the Hong Kong and Japanese markets, while the lowest is shown by the Taiwan and U.S. markets.

4.2. *Unit root tests of national stock price indices*

A necessary but not sufficient condition for cointegration is that each of the stock price index series should be integrated of the same order. [or I(1), see Granger (1986) and Masih and Masih (1997)]. Panel A of Table 4 reports the results of non-stationary tests for Taiwan, Hong Kong, Japan and the U.S. stock price indexes by using augmented Dickey-Fuller tests (ADF test). According to the applicable test statistics reported by Mackinnon (1991), non-stationarity cannot be rejected for the levels of each stock price series at the 5-percent significance level based on ADF test. In contrast, when the data are differenced, non-stationarity can be rejected for all data series. These results imply that each stock price series are integrated of order one (or I(1)). Table 4 also reports the appropriate order of the autoregressive process, n, in Eq. (1). The results from the PP test, as shown in Panel B of Table 4, further confirm the ADF test indicating all the stock price series are integrated of order one.

Table 4. Unit Root Tests for Stock Price Indices: January 3, 1997 to April 30, 1998

	Panel A: Augmented Dickey-Fuller		Panel B: Phillips-Perron	
		Levels		
TN	−2.349	(4)	−2.485	[5]
HK	−1.269	(4)	−1.356	[5]
JP	−0.831	(4)	−1.256	[5]
US	−0.834	(4)	−0.781	[5]
		First-differences		
TN	−9.457*	(4)	−18.752*	[5]
HK	−7.926*	(4)	−21.613*	[5]
JP	−9.505*	(4)	−20.652*	[5]
US	−10.209*	(4)	−20.552*	[5]

Note:

1. The number in the parenthesis indicates the appropriate lag length of the model.
2. The number in the bracket indicate the lag truncation for Bartlett kernel suggested by Newey-West test (1987).

4.3. *Cointegration tests*

Given that the four stock price index series are integrated of order one, the next stage in our study is to test for the presence of cointegration in our four-market VAR model. A VAR model is first fit to the data to find an appropriate lag structure. The SBC suggests six lags for our four-market VAR model. Table 5 presents the results from the Johansen (1988) and Johansen and Juselius (1990) multivariate cointegration tests. Trace statistics and L-max statistics both suggest that there exists one cointegrating vector among these four stock markets. As Lee and Jeon (1995) argued that the more cointegrating vectors (i.e., the less common trends) there are in the system, the more stable in the system. The finding of only one cointegrating vector (i.e.,

Table 5. Johansen Maximum Likelihood Cointegrating Tests

	Trace test	Critical value	L-max test	Critical value
H0: $r = 0$	47.84*	47.21	28.84*	27.07
H0: $r \leq 1$	**18.17**	29.68	**9.71**	20.97
H0: $r \leq 2$	8.47	15.41	8.29	14.07
H0: $r \leq 3$	0.17	3.76	0.17	3.76

Note:

1. The computed Ljung-Box Q-statistics indicate that the residuals are white noise.
2. *indicates singnificance at the 5% level.
3. Schwartz Bayesian Criterion (SBC) was used to select the number of lags required in the cointegrating test. The lag length is found to be 6 for all the four stock indices.

three common trends in our study) among these four markets suggests that the long- run equilibrium relationship may not be very stringent compared to the case of more than one cointegrating vector. This also explains the rather loose comovements of these four national stock price index series as shown in Figure 1. Our finding of cointegration is quite compatible with the findings of Lee and Jeon (1995), Arshanapalli, Dukas and Lang (1995), Hassan and Naka (1996), and Masih and Masih (1997).

The multivariate cointegration result provides important implications. Since these four markets are cointegrated, the combination of these markets may not yield international portfolio diversification in the long-run. These results may be used to argue for and against the international stock market efficiency. According to the recent cointegration literature, [e.g., MacDonald and Taylor (1989)], asset prices from two different efficient markets cannot be cointegrated. Specifically, if a pair of stock prices is cointegrated, one stock price can be forecast (is Granger-caused) by the other. The finding of the cointegrated relations in our multivariate context violates the semi-strong form of the market efficiency hypothesis (MEH).

4.4. *Causality test results based on error-correction models*

Given the results of the cointegration tests, the causality tests are conducted by using ECMs to test for intertemporal causality among four stock markets considered. Table 6 reports the statistical analysis based on ECM on the causal relationships among these four stock markets using Hsiao's stepwise Granger-causality technique. The number in the brackets indicates the lag length selected by using the FPE criterion. The findings are that

Table 6. Granger Causality Test Based on VECM

TN	(3)	US	(1)		
US	(2)	TN	(2)	=>	U.S. Granger causes TN
TN	(3)	JP	(1)		
JP	(2)	TN	(1)	=>	JP Granger causes TN
TN	(3)	HK	(1)		
HK	(1)	TN	(2)	=>	TN and HK are independent
US	(2)	JP	(1)		
JP	(2)	US	(2)	=>	US Granger causes JP
US	(2)	HK	(1)		
HK	(1)	US	(1)	=>	US Granger causes HK
JP	(2)	HK	(4)		
HK	(1)	JP	(1)	=>	JP Granger causes HK

Note:

1. The number in the parenthesis indicates the lag length selected by using the FPE criterion.
2. This Granger causality test employs Hsiao's (1981) stepwise technique.

unidirectional causality running from the U.S. market to the other three markets, Taiwan, Hong Kong, and Japan, and from the Japanese market to Taiwan and Hong Kong markets. These results suggest the relative leading roles of the U.S. and Japanese markets in driving fluctuations in the other two markets. Our results are consistent with those found in Chowdhury (1994), Hassan and Naka (1996), and Masih and Masih (1997) suggesting the relative leading roles of the U.S. and Japanese markets. However, these results are not consistent with those found in Arshapanapalli and Doukas (1993) and Elaysiani, Perera and Puri (1998) suggesting no leading roles of the U.S. and Japanese markets. These studies do not find any interaction between the U.S. and Japanese markets.

In order to capture the impact of the U.S. stock crash of October 1997 and the previous spreading Asian finance crisis on these markets, two dummy variables—D97 and Dac—are incorporated into the models. The results indicate that D97 only significantly affects the U.S. stock market and this impact does spread out to the other three markets but shows no significant impact on them. On the other hand, the Dac shows significant impacts on both the Japanese market (showing negative and significant) and the U.S. market (showing positive and significant). Moreover, the Dac shows negative effect, but not significantly, on the Taiwan and Hong Kong markets.

4.5. *Variance Decompositions (VDC) and Impulse Response Function (IRF)*

We mentioned earlier that as there are more than one common trend in the models, different ordering of the variables may affect the results of IRF and VDC if the common trends are not absolutely uncorrelated. In this paper, the presumed exogenous orderings are adopted from the previous findings of the Granger causality tests based on ECM.[8]

The VDCs are generated by disturbing each variable in the estimated system by one standard deviation. Given this disturbance, the forecast error variance of any variable is decomposed into the proportion attributed to each of the random shocks. VDC, therefore, shows the proportion of forecast error variance for each variable that is attribute to its own innovations and to shocks to the other variables. It captures both direct and indirect effects. Table 7 shows the VDCs (up to ten days) for the model used in this paper.[9]

Several conclusions can be obtained by the VDC results as shown in Table 7. We first find that each forecast error variance of the four stock indices is accounted for by its own innovations. Secondly, innovations in both the US and Japanese stock markets lead to fluctuations in the stock market of Hong Kong. On the other hand, the forecast error variance of Japanese stock market is only explained by the shocks to the US stock market. This result is contrary to the results reported in both Arshanapalli and Doukas (1993) and Chowdhury (1994), but is consistent with those found in Eun and Shim (1989) and Liu, Pan and Shieh (1998).[10] Thirdly, the fluctuation in the Taiwan's stock market is not significantly described by any of the major markets considered in this study (only minor explaining powers are found by the Japan and the US stock markets). One justification for this finding is that the Taiwan market still has some restrictions on cross-country investing. These results are consistent with those found in Chowdhury (1994) and Liu, Pan and Shieh (1998) indicating Taiwan is the least interactive market. Fourthly, the results further suggest the relative leading roles of the US and Japanese markets. These results are consistent with those found

[8]The relative exogenity, from the results of causality tests based on ECM, is ordered as the US, Japan, Taiwan, and Hong Kong.

[9]For saving space the table only presents the results of days 1, 4, 7, and 10.

[10]Eun and Shim (1989) and Liu, Pan and Shieh (1998) show that the U.S. exerts substantial influence on the Japanese stock market, while the Japanese market fails to explain any substantial part of error variances of the U.S. market.

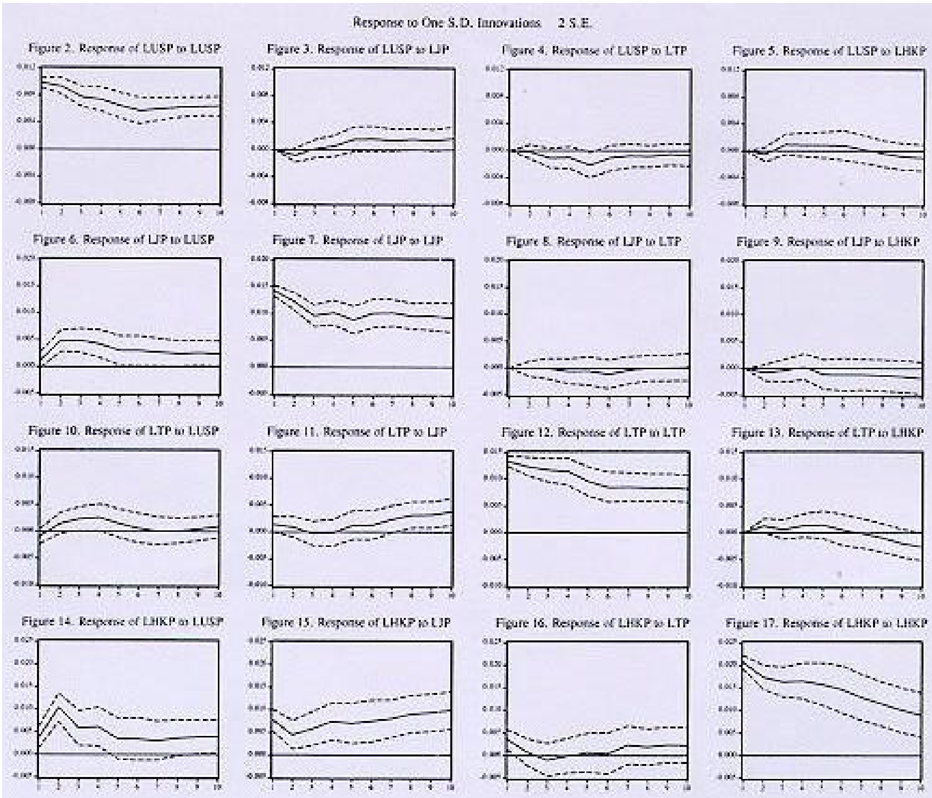
Table 7. Variance Decompositions

		Variance Decomposition of JP		
Period	US	JP	TN	HK
1	100.000	0.000	0.000	0.000
4	98.289	0.338	0.731	0.642
7	95.385	1.867	1.946	0.802
10	94.567	2.751	1.737	0.945
		Variance Decomposition of US		
Period	US	JP	TN	HK
1	0.817	99.182	0.000	0.000
4	10.716	89.074	0.063	0.148
7	9.792	89.462	0.228	0.518
10	8.971	89.854	0.178	0.997
		Variance Decomposition of TN		
Period	US	JP	TN	HK
1	0.411	1.147	98.442	0.000
4	2.558	0.503	96.276	0.663
7	2.126	1.427	95.669	0.778
10	1.743	4.279	92.402	1.577
		Variance Decomposition of HK		
Period	US	JP	TN	HK
1	2.859	11.628	2.431	83.081
4	11.789	10.218	0.851	77.142
7	9.125	13.561	0.800	76.514
10	8.662	19.305	1.093	70.940

Note: The relative exogenity, from the results of causality tests based on ECM, is ordered as the US, Japan, Taiwan, and Hong Kong.

in Chowdhury (1994), Hassan and Naka (1996), Masih and Masih (1997), and Liu, Pan and Shieh (1998), but are not consistent with those found in Elaysiani Perera and Puri (1998). The final finding from the VDC analysis is that the Taiwan and Hong Kong markets are somewhat affected more by regional country such as Japan than by the US, a result that is mostly consistent with evidence provided by Ko and Lee (1991) and Liu, Pan and Shieh (1998).

Similar to the previous VDC analysis, IRF provides the dynamic response of each variable to innovations of this variable as well as of other variables included in the system. In other words, the IRF portrays the extent in which the shock of one market is transitory (or persistent) in terms of its effect on the other market in the system in addition to the market itself. The results of IRF can be described by the IRF diagrams as shown in Figure 2 to Figure 17.



Figs. 2–17. Diagrams of Impulse Response Function

The IRF diagrams show that the US stock market does not respond to shocks to any of the other markets in the system. This result is consistent with our earlier findings that the US stock market is relatively exogeneous in the system. On the other hand, a one-standard deviation shock to the U.S. stock market is rapidly transmitted to both the Japanese and Hong Kong stock markets. For Japanese and Hong Kong stock markets, the significant peak effect of a shock to the US market occurs on the second day and remains relatively high and significant on the fifth day. Because of that the Japanese and Hong Kong stock markets close when the US stock market starts to trade as, they are both expected to react to a shock to the US market with a one-day lag. Our results are similar to those reported in Eun and Shim (1989) and Chowdhury (1994) for the Hong Kong market. However, the effect tapers off after the fifth day for both markets. These results indicate that these two markets are somewhat sluggish in their response to a shock to the US market since the markets continue to reach noticeably through the second, the third, and the fourth days. The diagrams also show that shocks to the Taiwan and Hong Kong stock markets is not significantly influential to the Japanese stock market. Moreover, shocks to the US and the Japanese stock markets are not rapidly transmitted to the Taiwan stock market. The effect of shocks to the US and the Japanese stock markets on Taiwan stock market is significant at the third day and the eighth day, respectively. A shock to the Japanese stock market has a larger initial impact on the Hong Kong stock market than a shock to the Taiwan stock market. Finally, IRF diagrams find that a shock to the Japanese stock market is rapidly transmitted to the Hong Kong stock market and this shock never tapers off after the tenth day. This result indicates that the transmission of information between Japanese and Hong Kong markets is relatively inefficient. This result is consistent with our earlier cointegration tests result indicating that these two markets do not drift apart in the long run. However, the response of Hong Kong market to a shock to the Taiwan market fluctuates around zero (or tapers off) after the first day. This opposes the previous result and implies that the transmission of information between these two markets is relatively efficient.

5. Conclusion

The purpose of this study is to employ a sequence of time-series methodologies, including cointegration analysis, Granger causality test based on ECM, and VDC and IRF, to fully investigate the transmission of stock price movements among Taiwan and its major trading partners, Hong Kong, Japan and the United States. The daily data sets for all the stock indices are running from January 3, 1997 to April 30, 1998. The Johansen maximum likelihood cointegration tests find that the four stock markets considered are cointegrated with one cointegrating vector. This result has an implication in that the semi-strong form of the market efficiency hypothesis is violated in our multivariate context. The investors cannot yield portfolio diversification for the investment decision based on choosing these four countries as their investment markets in the long run. Similar conclusions were reached by Kwan, Sim and Cotsomitis (1995) and Masih and Masih (1997). The results from Granger-causality test based on ECM suggest the relative leading roles of the U.S. and Japanese markets in driving fluctuations in the other two markets. Two dummies in the models taking into account the U.S. stock crash of October 1997 (D97) and the previous spreading Asian finance crises (Dac) indicate that D97 significantly affects the U.S. stock market only. This impact does spread out to the other three markets but shows no significant impact on them. On the other hand, the Dac shows significant impact on both the Japanese and the U.S. markets.

From the VDC analysis, several results can be concluded. We first find that each forecast error variance of the four stock indices is accounted for by its own innovations. The VDC also shows that innovations in both the US and Japanese stock markets lead to fluctuations in the stock market of Hong Kong. On the other hand, the forecast error variance of the Japanese stock market is only explained by the shocks to the US stock market. The fluctuation in the Taiwan's stock market is not significantly described by any of the major markets considered in this study. One justification for this finding is that the Taiwan market still has some restrictions on cross-country investing. Moreover, the results of VDC suggest the relative leading roles of the US and Japanese markets, which confirm the previous findings of Granger causality tests. The final finding from the VDC analysis is that the Taiwan and Hong Kong markets are affected more by regional countries such as Japan rather than by the US. For the analysis of the IRF diagrams, the overall findings can be concluded as that we further confirm the relative leading roles of the US and Japanese markets, especially for the US stock market which is found to be relatively exogeneous in the system. The IRF diagrams also indicate that the Taiwan and Hong Kong markets are somewhat affected more by regional country such as Japan than by the US.

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