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Analysis of long-run benefits from international equity diversification between Taiwan and its major European trading partners: an empirical note

Tsangyao Chang^{a,*}, Chien-Chung Nieh^b and Ching-Chun Wei^c

^aDepartment and Graduate Institute of Finance, Feng Chia University, Taichung, Taiwan

^bDepartment and Graduate Institute of Banking and Finance, Tamkang University, Taipei, Taiwan

^cDepartment of Finance, Providence University, Taichung, Taiwan

This paper employs four cointegration test approaches, PO, HI, JJ and KSS, to test for pairwise long-run equilibrium relationships between Taiwan's stock price index and each of the stock price indexes of four European markets – French, German, Dutch, and British stock markets. The results from these four tests are robust and clearly consistent in suggesting that the Taiwan stock market is not pairwise cointegrated with the four European stock markets. This provides strong evidence that there exist long-run benefits for Taiwan investors diversifying in the equity markets of Taiwan's major European trading partners, France, Germany, Holland, and the UK, over the sample period considered from 6 January 1998 to 30 May 2002. These findings could be valuable to Taiwan individual investors and financial institutions holding long-run investment portfolios in the equity markets of France, Germany, Holland, and the UK.

I. Introduction

Over the past two decades, the globalization of international stock markets has generated a vast amount of research using cointegrating techniques (Taylor and Tonks, 1989; Chan *et al.*, 1992; Kasa, 1992; Arshanapalli and Doukas, 1993; Chowdhury, 1994; Kwan *et al.*, 1995; Masih and Masih, 1997; Kanas, 1998, 1999; Chang, 2001) to investigate whether there exist long-run benefits from international equity diversification.

According to these studies, asset prices from two different efficient markets cannot be cointegrated. Specifically, if a pair of stock price is cointegrated, then one stock price can be forecasted by the other, thus suggesting that there are no gains from portfolio diversification.

This empirical note represents our attempt to explore whether there exist any long-run benefits from international equity diversification for Taiwan investors who invest in the equity markets of its major European trading partners, namely, France,

*Corresponding author. E-mail: tychang@fcu.edu.tw

Germany, Holland and the UK. The main reason for selecting these countries is that they are Taiwan's major trading partners in Europe, with their total respective share of exports to and imports from Taiwan relatively high at about 57% to 62% and 61% to 67% through the years 2001 to 2003.¹ We explore the potential for long-run diversification benefits for Taiwan investors by examining whether the Taiwan market is pairwise cointegrated with the stock markets of these four countries. In this empirical note, four techniques of cointegration testing, PO, HI, JJ and KSS approaches, are used to test for pairwise long-run equilibrium relationships between Taiwan's stock price index and each of the stock price indexes of four European markets – French, German, Dutch, and British stock markets.² The results from all four tests conclusively demonstrate that the Taiwan market was not pairwise cointegrated with the markets of France, Germany, Holland and the UK during the period 6 January 1998 to 30 May 2002 period. The finding of no cointegration can be interpreted as evidence that there is no long-run linkage between the Taiwan–France, Taiwan–Germany, Taiwan–Holland and the Taiwan–UK markets and that, accordingly, there exist potential gains for Taiwan investors that diversify in the equity markets of these four countries. These results are invaluable to Taiwan investors and financial institutions holding long-run investment portfolios in French, German, Dutch, and British equity markets.

There are several major motivations for this empirical study. First, Taiwan is a rapidly expanding, emerging market and a significant number of Taiwan investors have adopted diversification benefits as the primary criterion in investing overseas. International mutual funds in Taiwan have increased from 30 billion New Taiwan Dollars in 1997 to over 100 billions in 2001. Among these international funds, European stock funds have increased from nothing in 1997 to 34 in 2002,³ meaning that within the past half-decade, European equity markets become strikingly more important to Taiwan investors. Second, the rapid growth in the Taiwan economy has attracted the attention of international investors and both Dow Jones and Morgan Stanley have been listing Taiwan stocks on their international indexes since September 1997. This suggests that the

issue of international linkages of the Taiwan share market is of practical interest to a significant number of international investors. As a third reason, increasing trade relations between Taiwan and these four European countries have made this research more valuable not only for international investors but also for financial institutions holding long-run investment portfolios in these equity markets. These reasons aside, until now little evidence has been reported either on the long-run linkages of the Taiwan share market and the European equity markets or on the implications for long-run benefits from international equity diversification for investors, both local and foreign alike (Masih and Masih, 1997).

The remainder of this empirical note is organized as follows. Section II presents the data used, while Section III presents the methodologies employed and discusses the findings. Finally, Section IV draws some conclusions.

II. Data

Daily closing price indexes from 6 January 1998 to 30 May 2002, collected from Finance.Yahoo.com, are used in the analysis. Data starting from 1998 limits the adverse effects of the 1997 Asian financial crisis. The stock indexes in this study are the Taiwan weighted average stock index (Taiwan), the CAC40 index (France), the DAX index (Germany), the AEX index (Holland) and the FTSE 100 index (UK). All indexes are based on local currencies. To compensate for gaps in the data caused by public holidays and other non-working days, the time series data in this study, following Chowdhury (1994), are adjusted by dropping some entries, including the Saturday entries, to guarantee that all countries have an entry on any given date.

III. Methodology and Empirical Results

Correlation coefficients among stock market index returns

We first examine how these five stock markets are correlated with each other. The summary statistics

¹ In order to catch the trading relationship between Taiwan and its major trading partners in Europe, Table 1 demonstrates the total trade volume, together with export and import volume for the period 2001 to 2003, to show their close trading relationship.

² PO, HI, JJ and KSS are abbreviations for the four cointegration tests: Phillips and Ouliaris (1990) multivariate trace statistic; Harris and Inder (1994) KPSS unit root-based; Johansen and Juselius (1990) maximum likelihood; and Kapetanios *et al.* (2003) nonlinear unit root-based approach, respectively.

³ Data is from the Securities Investment Trust and Consulting Association of ROC.

Table 1. Trading share of Taiwan to its major European trading partners

Year	Trading volume	Europe	UK	FR	GM	HL	Sum	Ratio
2001	Total	34 795	4771	3296	8726	5753	22 546	0.6479
	Export	19 807	3329	1165	4480	4229	13 203	0.6666
	Import	14 988	1442	2130	4245	1524	9341	0.6232
2002	Total	33 196	4265	2673	8257	5209	20 404	0.6147
	Export	18 553	2908	1122	3835	3771	11 636	0.6272
	Import	14 642	1356	1551	4421	1437	8765	0.5986
2003	Total	36 691	4300	2879	9171	5421	21 771	0.5937
	Export	20 451	2884	1250	4207	4126	12 467	0.6096
	Import	16 239	1416	1628	4964	1294	9302	0.5728

Notes: UK, FR, GM and HL are abbreviations for the countries UK, France, Germany and Holland, respectively.

Sum indicates the summation of the volumes of four European countries considered.

Ratio is the amount of sum divided by it of Europe.

Unit: Million NT dollars.

Table 2. Summary statistics and correlation coefficients

	RTN	RFR	RGM	RHL	RUK
Panel A. Summary statistics of stock price index returns					
Mean	-0.028%	0.004%	0.0144%	-0.0114%	-0.0135%
Std dev.	1.897%	1.475%	1.6354%	1.4417%	1.2191%
Minimum	-8.836%	-8.775%	-9.5756%	-9.4202%	-4.1625%
Maximum	8.519%	5.546%	6.428%	5.7241%	4.3451%
Skewness	0.02248	-0.2834	-0.2921	-0.4134	-0.5687
Kurtosis	4.9487	4.8507	4.9101	6.3196	3.5991
J-B	162.4414*	160.1615*	170.5653*	500.3427*	15.9011*
Panel B. Correlation matrix of stock price index returns (or log price changes)					
RTN	1.0000	0.1466	0.1331	0.1438	0.1002
RFR		1.0000	0.8096	0.8284	0.7663
RGM			1.0000	0.8102	0.7129
RHL				1.0000	0.7475
RUK					1.0000

Notes: TN, FR, GM, HL, and UK are the abbreviations for Taiwan, France, Germany, Holland and the UK, respectively.

* indicates significances at the 5% level.

and correlation matrices for these five stock market index returns (or log price changes) can be visually appreciated in Table 2. The market's average daily index returns are -0.028%, 0.004%, 0.0144%, -0.0114%, and -0.0135% for Taiwan, France, Germany, Holland, and UK markets, respectively, indicative that the German market has the highest average daily returns of 0.0144% and the Taiwan market has the lowest average of -0.028% over this empirical sample period. Regarding the standard deviation, we find that the Taiwan market has the highest daily standard deviation of 1.897%, whereas the UK market has the lowest at 1.219% over the sample period. Table 2 also shows that index returns for each country are leptokurtic since the relative large value of the kurtosis statistic (larger than 3) suggests that the underlying data are leptokurtic, or heavily tailed and sharply peaked about the mean

when compared with the normal distribution. The Jarque-Bera test also leads to the rejection of normality in the data sets of these five markets' daily returns data sets. Regarding the correlation matrix, we find that all the correlations are positive and significant. The highest contemporaneous correlations with other markets are shown by the French and Dutch markets, while the lowest are shown for the Taiwan and British markets.

Unit root tests

Previous studies have found that many macroeconomic and financial time series, including stock price series, contain unit roots dominated by stochastic trends (Lee and Jeon, 1995). A necessary but not sufficient condition for cointegration is that each of the stock price indexes must be integrated of the same

Table 3. Unit root tests for stock price indexes (in logarithmic form) – 6 January 1998 to 30 May 2002

Level	ADF	DF-GLS	PP	KPSS
LTN	-1.290(0)	-0.883(0)	-1.385[4]	1.938[25]*
LFR	-1.359(0)	-0.929(0)	-1.349[7]	1.324[25]*
LGM	-1.503(0)	-1.503(0)	-1.528[3]	0.784[25]*
LHL	-1.621(0)	-1/631(0)	-1.653[8]	0.815[25]*
LUK	-1.718(2)	-1.748(2)	-1.649[12]	1.369[25]*
First-difference				
DITN	-30.715(0)*	-3.699(12)*	-30.799[6]*	0.091[5]
DIFR	-30.337(0)*	-1.927(14)*	-30.306[9]*	0.271[8]
DIGM	-30.226(0)*	-11.914(3)*	-30.227[1]*	0.131[1]
DIHL	-29.948(0)*	-5.848(9)*	-29.882[11]*	0.124[10]
DIUK	-24.798(1)*	-2.712(11)*	-30.318[16]*	0.111[14]

Notes: The numbers in parentheses indicates the selected lag length for ADF and DF-GLS model. Lags were chosen based on Campell and Perron's (1991) method.

The numbers in square brackets indicates the lag truncation for Bartlett kernel from the Newey–West test suggested by Newey and West (1987).

* indicates significance at the 5% level.

Critical values from Mackinnon (1991).

order, or $I(1)$ (Granger, 1986). In order to fully investigate the stationary property of each variable, this paper applies various unit roots techniques, which include ADF, DF-GLS (Elliot *et al.*, 1996), KPSS (Kwiatkowski *et al.*, 1992) and PP (Phillips and Perron, 1988) tests.⁴

Table 3 reports the results of non-stationary tests for Taiwan, France, Germany, Holland, and UK stock price indexes using ADF, DF-GLS, PP and KPSS tests. Each stock price index is nonstationary in levels and stationary in first differences, indicating that all the stock price indexes are $I(1)$ series. Based on the results that all the variables considered are integrated of the same first order, $I(1)$, we can further apply cointegration tests to examine their long-run equilibrium relationships. To affirm our findings, we employ four cointegration tests, PO, HI, JJ and KSS approaches, to test whether Taiwan's stock price index and each of the stock price indexes of the four European markets are cointegrated.

Testing for cointegration

PO cointegration test based on the multivariate trace statistic \hat{P}_z . Following Phillips and Ouliaris (1990), we consider the following bivariate cointegrating regression

$$X_{1t} = a + bX_{2t} + Z_t \quad (1)$$

where Z_{1t} are the residuals of the cointegrating regression from Equation 1, and X_{1t} and X_{2t} are the two national stock price indexes to be tested for cointegration. According to Phillips and Ouliaris (1990), the \hat{P}_z statistic tests the null hypothesis of no cointegration, and is calculated as

$$\hat{P}_z = T \text{trace} \left[\Omega_p T^{-1} \sum_1^T X_t X_t' \right] \quad (2)$$

where $\Omega_p = T^{-1} \sum_1^T Z_t Z_t' + T^{-1} \sum_1^k W_{sk} \sum_{s+1}^T (Z_t Z_{t-s} + Z_{t-s} Z_t')$ for some choice of lag window such as $W_{sk} = (1 - s/(k+1))$, T is the sample size and $X_t' = (X_{1t}, X_{2t})$.

Table 4 reports the \hat{P}_z test results. The computed statistics are 13.1103, 19.3931, 22.7095, and 32.9808, respectively, for the Taiwan–France, Taiwan–Germany, Taiwan–Holland and the Taiwan–UK markets. These computed statistics are well below the critical value of 55.2202 and thus the null hypothesis of no cointegration cannot be rejected in any case.⁵ Given this, it is clear that the results from the \hat{P}_z test suggest that the Taiwan market was not pairwise cointegrated with any of these four markets during the 6 January 1998 to 30 May 2002 period.

HI cointegration test based on KPSS unit root. The Harris and Inder (1994) approach is basically an extension of the test proposed by Engle and Granger (1987) incorporating with the KPSS unit root test.

⁴ The null for KPSS is $I(0)$, whereas it is $I(1)$ for all other three tests, ADF, DF-GLS and PP.

⁵ According to Phillips and Ouliaris (1990, Table 4), the 5% critical value for the \hat{P}_z statistic for one explanatory variable is 55.2202.

Table 4. PO cointegration test based on the multivariate trace statistic \hat{P}_z

Countries	\hat{P}_z statistic
TN-FR	13.1103
TN-GM	19.3931
TN-HL	22.7095
TN-UK	32.9808

Notes: The reported \hat{P}_z statistic is based on a lag window of 10. Alternative lag windows of 12, 14, and 18 yield qualitatively similar results.

The 5% critical value for the \hat{P}_z statistic for one explanatory variable is 55.202 (see Phillips and Ouliaris, 1990, Table 4).

According to Harris and Inder (1994), the test is specified as

$$Y_t = X_t' \beta_0 + \delta_t + \varepsilon_t, \quad \varepsilon_t \sim IN(0, \sigma^2) \quad (3)$$

$$X_t = X_{t-1} + v_t \quad (4)$$

$$\delta_t = \delta_{t-1} + w_t \quad (5)$$

where Y_t is the dependent variable, X_t is a vector of nonstationary explanatory variables and δ_t is a random walk in the residuals of the cointegration Equation 3. If the Equations 3 to 5 are the true data generating processes, then the presence of the random walk components in the residuals will ensure Y_t and X_t not to be cointegrated. However, if the variance of the random walk component (σ_w^2) is restricted to zero then the random walk component reduces to a constant for all t . In this case, Equation 3 represents a cointegrating relationship between Y_t and X_t with constant and stationary residuals. As indicated by Harris and Inder (1994), testing the null hypothesis of $\sigma_w^2 = 0$ against the alternative $\sigma_w^2 > 0$ evaluates the null hypothesis of cointegration against the alternative of no cointegration. In the case of the Harris–Inder test, the first step is to estimate Equation 3 by OLS to obtain the error term, and then apply the KPSS test to check for the stationarity of the residuals. Table 5 reports the results from the Harris–Inder test and firmly demonstrates that the null hypothesis of cointegration is rejected for all four cases.

JJ cointegration tests based on maximum likelihood ratio. Following Johansen and Juselius (1990), we construct a p -dimensional (2×1) vector autoregressive model with Gaussian errors, expressed by its first-differenced error correction form as

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \dots + \Gamma_{k-1} \Delta Y_{t-k+1} - \Pi Y_{t-1} + \mu + \varepsilon_t \quad (6)$$

Table 5. HI cointegration test based on KPSS unit root

TN-FR	2.381[25]*
TN-GM	2.517[25]*
TN-HL	0.847[25]*
TN-UK	1.184[25]*

* indicates significance at 5% level.

Critical values are taken from Kwiatkowski *et al.* (1992). The KPSS test based on lag windows of 10, 15 and 20 lags yields qualitatively similar results.

where Y_t are national stock price indexes studied, ε_t is i.i.d. $N(0, \Sigma)$, $\Gamma_i = -I + A_1 + A_2 + \dots + A_i$, for $i = 1, 2, \dots, k-1$, and $\Pi = I - A_1 - A_2 - \dots - A_k$. The Π matrix conveys information about the long-run relationship between Y_t variables, and the rank of Π is the number of linearly independent and stationary linear combinations of variables studied. Thus, testing for cointegration involves testing for the rank r of the Π matrix by examining whether the eigenvalues of Π are significantly different from zero.

Johansen and Juselius (1990) propose two test statistics for evaluating the number of cointegrating vectors (or the rank of Π): the trace (T_r) and the maximum eigenvalue (L-max) statistics. The likelihood ratio statistic for the trace test is

$$-2 \ln Q = -T \sum_{i=r+1}^{p-2} \ln(1 - \hat{\lambda}_i), \quad (7)$$

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

The null hypothesis to be tested is that there are at most r cointegrating vectors. That is, the number of cointegrating vectors is less than or equal to r , where r is 0, 1, or 2 in our case. In each case, the null hypothesis is tested against the general alternative.

Alternatively, the L-max statistic is

$$-2 \ln Q = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (8)$$

In this test, the null hypothesis of r cointegrating vectors is tested against the alternative of $r+1$ cointegrating vectors. Thus, the null hypothesis $r=0$ is tested against the alternative that $r=1$, $r=1$ against the alternative $r=2$; and so forth.

It is well known that the cointegration tests are very sensitive to the choice of lag length. The Schwartz Criterion (SC) is used to select the number of lags required in the cointegration test. A VAR model is first fit to the data to find an appropriate lag structure. The Schwartz Criterion (SC) suggests 3, 2, 6 and 6 lags, respectively, for the Taiwan–France, Taiwan–Germany, Taiwan–Holland and Taiwan–UK four bivariate VAR models. Table 6 presents

Table 6. JJ Cointegration test based on maximum likelihood ratio

	Trace test	5% critical value	L-max test	5% critical value
(A) TN-FR (VAR lag = 3)				
$H_0: r = 0$	8.112	15.41	5.253	14.07
$H_0: r \leq 1$	2.858	3.76	2.858	3.76
(B) TN-GM (VAR lag = 2)				
$H_0: r = 0$	7.307	15.41	3.987	14.07
$H_0: r \leq 1$	3.320	3.76	3.320	3.76
(C) TN-HL (VAR lag = 6)				
$H_0: r = 0$	9.031	15.41	5.685	14.07
$H_0: r \leq 1$	3.346	3.76	3.346	3.76
(D) TN-UK (VAR lag = 6)				
$H_0: r = 0$	5.989	15.41	4.373	14.07
$H_0: r \leq 1$	1.616	3.76	1.616	3.76

Notes: Critical values are taken from Osterwald-Lenum (1992).

r denote the number of cointegrating vectors. Schwarz criteria (SC) was used to select the number of lags required in the cointegrating test.

The computed Ljung–Box Q -statistics indicate that the residuals are white noise.

the results from the Johansen and Juselius (1990) cointegration test. As shown in this table, both Trace statistic and L-max statistic suggest that the null hypothesis of no cointegration cannot be rejected in any case.

KSS cointegration tests based on nonlinear unit root. Incorporating Kapetanios *et al.*'s (2003) approach with the nonlinear unit root test is also an extension of the Engle and Granger (1987) cointegration test. According to Kapetanios *et al.* (2003), the test is specified as

$$Y_t = X_t' \beta_0 + \delta_t + \varepsilon_t, \quad \varepsilon_t \sim IN(0, \sigma^2) \quad (9)$$

$$\Delta \varepsilon_t = \gamma \varepsilon_{t-1} \{1 - \exp(-\theta \varepsilon_{t-1}^2)\} + \nu_t \quad (10)$$

where Y_t is the dependent variable, X_t is a vector of nonstationary explanatory variables and $-2 < \gamma < 0$. The testing hypothesis is the null of $\theta = 0$ against the alternative $\theta > 0$. Under the null that $\theta = 0$, ε_t follows a linear unit root process (no cointegration), whereas it is a nonlinear stationary exponential smooth transition autoregressive (ESTAR) process under the alternative (nonlinear cointegration). However, the parameter is not identified under the null hypothesis. Luukkonen *et al.* (1988) and Kapetanios *et al.* (2003) use a first-order Taylor series approximation to $(1 - \exp(-\theta \varepsilon_{t-1}^2))$ under the null $\theta = 0$ and approximate Equation 10 by the following auxiliary regression:

$$\Delta \varepsilon_t = \xi + \delta \varepsilon_{t-1}^3 + \sum_{i=1}^k b_i \Delta \varepsilon_{t-i} + \nu_t, \quad t = 1, 2, \dots, T \quad (11)$$

Table 7. KSS cointegration tests based on nonlinear unit root

Countries	t -statistic on $\hat{\delta}$
TN-FR	-1.6967
TN-GM	-2.3992
TN-HL	-2.7059
TN-UK	-3.0344

Note: The critical values for the t -statistic on $\hat{\delta}$ are tabulated in Table 1 of Kapetanios *et al.*'s (2003) paper.

Then, the null hypothesis and alternative hypotheses are expressed as $\delta = 0$ (no cointegration) against $\delta < 0$ (nonlinear ESTAR cointegration). The simulated critical values for different K are tabulated at Table 1 of the KSS paper.

Table 7 reports the results from the KSS test which further demonstrates that the null hypothesis of no cointegration cannot be rejected for all four cases. These results reveal that there is no long-run relationship between the Taiwan and France, Germany, Holland and UK stock markets and, thus confirm our conclusions from PO, HI and JJ approaches. The lack of a long-run relationship suggests that there exist long-run diversification benefits for Taiwan investors who invest in French, German, Dutch, and UK equity markets.

IV. Conclusions

This note provides clear, substantive evidence that there exist long-run benefits for Taiwan investors diversifying in the equity markets of France,

Germany, Holland and the UK over the period 6 January 1998 to 30 May 2002. The evidence is based on tests for a pairwise long-run equilibrium relationship between Taiwan's stock price index and each of the stock price indexes of four European markets – French, German, Dutch, and British stock markets – by employing four cointegration test techniques, namely, PO, HI, JJ and KSS approaches. The results from these four tests are robust and consistent in suggesting that the Taiwan stock market is not pairwise cointegrated with each of the French, German, Dutch and British stock markets. These findings should be of considerable value to Taiwan individual investors and financial institutions holding long-run investment portfolios in French, German, Dutch and British equity markets.

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