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CO-MOVEMENTS OF PACIFIC-BASIN STOCK MARKETS: PORTFOLIO DIVERSIFICATION IMPLICATIONS

ABSTRACT

This paper studies the co-movements of and the linkages between twelve Pacific-Basin stock markets during the June 1995-May 2005 period. We use the principal components analysis (PCA) technique to group the stock markets into statistically significant principal components in terms of the similarities of their index return movements. The rolling correlation analysis results show that correlation between the Pacific-Basin stock markets has considerable time-varying volatility. The Granger causality test results indicate that the weekly index returns of most Pacific-Basin stock markets are weak-form efficient and that most Pacific-Basin stock markets have significant lead/lag linkages. The study investigates the portfolio diversification implications of the linkages between the Pacific-Basin stock markets.

Key Words: Pacific-Basin stock markets, principal components analysis, time-varying correlation, Granger causality, portfolio diversification

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INTRODUCTION

The co-movements of the world's national stock markets have long been a popular research topic in finance (see, e.g., Makridakis and Wheelwright 1974, Joy et al. 1976, Hilliard 1979, Maldonado and Saunders 1981, Philippatos et al. 1983). Low correlation between national stock markets is often presented as evidence supporting the benefit of global portfolio diversification (see, e.g., Levy and Sarnat 1970, Solnik 1974, Lessard 1976, Watson 1978, Meric and Meric 1989). Empirical studies indicate that correlation between national stock markets has been increasing and the benefit of global portfolio diversification has been decreasing (see, e.g., Longin and Solnik 1995, Aggarwal and Leal 1997, Meric and Meric 1998; 2004). Goetzmann et al. (2001) find that the current global diversification benefit is lower than in any of the previous periods during their 150-year sample.

As world economies become more integrated and move closely together during global events, it is becoming increasingly more difficult for investors to achieve effective global diversification. Several empirical studies focus on the portfolio diversification benefit of investing in a given geographical region of the world. Meric and Meric (1997) use data for the 1975-1994 period to show that correlation between the European stock markets has been increasing and that the portfolio diversification benefit with these stock markets has been decreasing. Meric et al. (1998, 2001a) investigate the portfolio diversification opportunities in the Latin American stock markets. Meric et al. (2000) study the linkages between the ASEAN-5 stock markets and they find that these markets moved closely together during the 1997-1998 emerging markets crisis. In a recent study, Aggarwal and Kyaw (2005) demonstrate that the U.S., Canadian, and Mexican stock markets are more integrated during the 1994-2001 NAFTA period compared with the 1988-1993 pre-NAFTA period.

The portfolio diversification benefits of investing in the Pacific-Basin stock markets have not been studied sufficiently. The objective of this paper is to study the portfolio diversification implications of the co-movements of the Pacific-Basin stock markets with data for the June 1995-May 2005 period. Several previous studies use the principal components analysis (PCA) technique to study the co-movements of national stock market indexes (see. e.g., Makridakis and Wheelwright 1974, Philippatos et al. 1983, Meric and Meric 1989, Meric et al. 2005). Several other studies use the Granger causality technique to study the lead/lag linkages between national stock market indexes (see, e.g.,

Ratner and Leal 1996, Meric et al. 2002, Gu and Annala 2006, Meric et al. 2007). In this paper, we use both the PCA and Granger causality techniques to study the co-movements of and the linkages between the Pacific-Basin stock markets. The principal components analysis technique is used to study the contemporaneous co-movements of the markets. The Granger causality technique is used to study the lead/lag linkages between the markets. To our knowledge, this is the first empirical study that combines the findings of the PCA and Granger causality techniques to derive conclusions regarding the potential portfolio diversification benefits of investing in different national stock markets. Although the PCA technique is used in other studies to study the co-movements of the world's other stock markets, to our knowledge, this is the first empirical study that applies the PCA technique to the Pacific-Basin stock markets to investigate their contemporaneous co-movements.

A COMPARISON OF THE ECONOMIC CHARACTERISTICS OF THE PACIFIC-BASIN COUNTRIES

The population and GDP statistics for the twelve Pacific-Basin countries covered in the study are presented in Table 1. The population of just under two billion for the region accounts for over 30% of the world's population, with China representing two-thirds of the total for the region (1,314 million). Hong Kong, Singapore, and New Zealand have the smallest populations in the sample (6.9 million, 4.5 million, and 4.1 million, respectively).

The region's GDP of $10,346.7 billion accounts for 22.2% of the world's GDP, led by Japan with about half of this amount at $4,911 billion. Singapore, the Philippines and New Zealand have the smallest GDPs in the sample ($121.5 billion, $116.9 billion, and $98.8 billion, respectively).

The annual population growth rates vary widely from 0.02% for Japan to 1.8% for the Philippines. China, the most populous country in the region, has a very low growth rate of 0.59%. China, with the third lowest GDP per capita of $1,912, has the highest GDP growth rate of 10.5%. Japan has the highest and Indonesia has the lowest GDP per capita in the sample ($38,520 and $1,077, respectively). New Zealand has the lowest GDP growth rate (1.9%).

The average GDP per capita is $5,244 for the region versus $7,151 for the world. Although the average GDP growth rate is about the same for both the region and the world (5.1%), the region's population growth rate is considerably lower than that of the world (0.73% versus 1.14%).

Table 1. Descriptive Statistics for Selected Economic Characteristics of the Pacific-Basin Countries

Country	Population (Millions)	Population Growth Rate (%)	GDP (Official Ex. Rate - Bill. of U.S. $)	GDP – Real Growth Rate (%)	GDP – Per Capita
Australia	20.3	0.85%	$645.3	2.8%	$31,788
China	1,314.0	0.59%	$2,512.0	10.5%	$1,912
Hong Kong	6.9	0.59%	$187.1	5.9%	$27,116
Indonesia	245.5	1.41%	$264.4	5.4%	$1,077
Japan	127.5	0.02%	$4,911.0	2.8%	$38,518
Malaysia	24.4	1.78%	$131.8	5.5%	$5,402
New Zealand	4.1	0.99%	$98.8	1.9%	$24,098
Philippines	89.5	1.80%	$116.9	5.4%	$1,306
Singapore	4.5	1.42%	$121.5	7.4%	$27,000
South Korea	48.8	0.42%	$897.4	4.8%	$18,389
Taiwan	23.0	0.61%	$353.9	4.4%	$15,387
Thailand	64.6	0.68%	$196.6	4.8%	$3,043
Region Total	1,973.1	0.73%**	$10,346.7	5.1%**	$5,244
World	6,525.2	1.14%	$46,660.0	5.1%	$7,151
Region as a % of World	30.2%		22.2%		73.3%

* Data source: http://www.cia.gov/cia/publications/factbook/index.html; Figures are all 2006 estimates.
** Weighted average.

TRADE RELATIONS BETWEEN THE PACIFIC-BASIN COUNTRIES

The trade statistics of the twelve Pacific-Basin countries are shown in Table 2. Among the twelve countries, China has the largest amounts of exports and imports ($974 billion and $777.9 billion, respectively). New Zealand has the smallest amounts of exports and imports ($23.7 billion and $25.2 billion, respectively). China, Hong Kong, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand have a trade surplus. Australia, New Zealand, and the Philippines have a trade deficit. Hong Kong, Indonesia, and China have the largest trade surplus as a percentage of exports (46.1%, 24%, and 20.1%, respectively). South Korea, Taiwan, and Thailand have the smallest trade surplus as a percentage of exports (5.1%, 4.5%, and 3.4%, respectively). The Philippines has the largest and New Zealand has the smallest trade deficit as a percentage of exports (-9.3% and -6.3%, respectively).

The U.S. is among the top three export partners of all Pacific-Basin countries except Australia. It is the most important export partner of China, Japan, Malaysia, the Philippines, and Thailand; the second most important export partner of Hong Kong,

Table 2. The Exports and Imports of the Pacific-Basin Countries

Stock Market	Exports (Bill. of U.S. $)	Imports (Bill. of U.S. $)	Deficit or Surplus (% of Exports)	Major Export Partners**	Major Import Partners***
Australia	117.0	127.7	- 9.1	Japan (20.3%) China (11.5%) S. Korea (7.9%)	U.S. (13.9%) China (13.7%) Japan (11.0%)
China	974.0	777.9	20.1	U.S. (21.4%) Hong Kong (16.3%) Japan (11.0%)	Japan (15.2%) S. Korea (11.6%) Taiwan (11.2%)
Hong Kong	611.6****	329.8	46.1	China (45.0%) U.S. (16.1%) Japan (5.3%)	China (45.0%) Japan (11.0%) Taiwan (7.2%)
Indonesia	102.3	77.7	24.0	Japan (21.1%) U.S. (11.5%) Singapore (9.2%)	Singapore (16.4%) Japan (12.0%) China (10.1%)
Japan	590.3	524.1	11.2	U.S. (22.9%) China (13.4%) S. Korea (7.8%)	China (21.0%) U.S. (12.7%) S. Arabia (5.5%)
Malaysia	158.7	127.3	19.8	U.S. (19.7%) Singapore (15.6%) Japan (9.3%)	Japan (14.6%) U.S. (13.0%) Singapore (11.8%)
New Zealand	23.7	25.2	- 6.3	Australia (21.4%) U.S. (14.1%) Japan (10.6%)	Australia (20.9%) U.S. (11.0%) Japan (11.0%)
Philippines	47.2	51.6	- 9.3	U.S. (18.0%) Japan (17.5%) China (9.9%)	U.S. (19.2%) Japan (17.0%) Singapore (7.9%)
Singapore	283.6	246.1	13.2	Malaysia (14.7%) U.S. (11.5%) Indonesia (10.7%)	Malaysia (14.4%) U.S. (12.4%) China (10.8%)
South Korea	326.0	309.3	5.1	China (21.8%) U.S. (14.6%) Japan (8.5%)	Japan (18.5%) China (14.8%) U.S. (11.8%)
Taiwan	215.0	205.3	4.5	China (22.5%) Hong Kong (15.7%) U.S. (15.0%)	Japan (23.0%) China (11.9%) U.S. (10.9%)
Thailand	123.5	119.3	3.4	U.S. (15.4%) Japan (13.6%) China (8.3%)	Japan (22.0%) China (9.4%) U.S. (7.4%)

* Data source: http://www.cia.gov/cia/publications/factbook/index.html; Figures are all 2006 estimates.
** The figure in parentheses is a percentage of total exports.
*** The figure in parentheses is a percentage of total imports.
**** Including re-exports.

Indonesia, New Zealand, Singapore, and South Korea; and the third most important export partner of Taiwan. Japan is also one of the top three export partners of most Pacific-Basin countries except Singapore and Taiwan. It is the most important export partner of Australia and Indonesia; the second most important export partner of the Philippines and Thailand; and the third most important export partner of China, Hong Kong, Malaysia, New Zealand, and South Korea.

Japan is one of the top three import partners of all Pacific-Basin countries except Singapore. It is the most important import partner of China, Malaysia, South Korea, Taiwan, and Thailand; the second most important import partner of Hong Kong, Indonesia, and the Philippines; and the third most important import partner of Australia and New Zealand. The U.S. is also one of the top three import partners of most Pacific-Basin countries except China, Hong Kong, and Indonesia. It is the most important import partner of Australia and the Philippines; the second most important import partner of Japan, Malaysia, New Zealand, and Singapore; and the third most important import partner of South Korea, Taiwan, and Thailand.

China is also an important trade partner in the region. It is one of the three most important export partners of Australia, Hong Kong, Japan, the Philippines, South Korea, Taiwan, and Thailand, and one of the three most important import partners of Australia, Hong Kong, Indonesia, Japan, Singapore, South Korea, Taiwan, and Thailand.

DATA AND METHODOLOGY

The study includes the Australian, Chinese, Hong Kong, Indonesian, Japanese, Malaysian, New Zealand, Philippine, Singaporean, South Korean, Taiwanese, and Thai stock markets. The Morgan Stanley Capital International (MSCI) weekly U.S.-dollar stock market indexes are used for the analysis. The index data are drawn from the Datastream database. The weekly index returns are computed as the natural log difference in the indexes, ln $(I_{i,t}/I_{i,t-1})$.

The principal components analysis (PCA) technique is used to study the co-movements of the twelve Pacific-Basin stock markets during the June 1995-May 2005 period. The stock markets are grouped into statistically significant principal components in terms of the similarities of their index return movements.

The rolling correlation analysis technique is used to study the time-varying correlation coefficients between the markets. Long-term trends are studied to determine if the diversification benefit is increasing or decreasing over time.

The Granger causality test is used to determine whether the weekly index returns of the twelve Pacific-Basin stock markets fallow a random walk (i.e., if the markets are weak-form efficient) and to study the lead/lag relations between the markets (i.e., to determine if the past returns of a market can be used to predict the future returns of the other markets).

PRINCIPAL COMPONENTS ANALYSIS

In this segment of the paper, we use the principal components analysis (PCA) technique to study the contemporaneous co-movements of the Pacific-Basin stock markets. The weekly index returns of all twelve stock markets for the June 1995-May 2005 period are used as inputs in the PCA computer program to group the stock markets in terms of the similarities of their movements. The Varimax rotation is employed to maximize the factor loadings of the stock markets in each principal component with similar movement patterns. Using Kaiser's rule, the statistically significant principal components with eigen values greater than unity are retained for analysis. A detailed discussion of the PCA technique can be found in Mardia et al. (1979) and Marascuilo and Levin (1983).

The analysis yields the two statistically significant principal components presented in Table 3. The stock markets with high factor loadings in the same principal component move closely together (i.e., they are closely correlated), and therefore, they provide less portfolio diversification benefit to global investors. The stock markets with high factor loadings in different principal components are less correlated, and therefore, they can provide greater portfolio diversification benefit to global investors.

The Australian, New Zealand, Japanese, Hong Kong, South Korean, Taiwanese, and Chinese stock markets have high factor loadings in the first principal component. It indicates that these stock markets are closely correlated and that portfolio diversification with these stock markets would result in a limited diversification benefit. The Indonesian, Philippine, Malaysian, Thai, and Singaporean stock markets have high factor loadings in the second principal component. It indicates that these stock markets are closely correlated and that portfolio diversification with these stock markets would provide a limited diversification benefit. To maximize portfolio diversification benefit, investors of the stock markets with high factor loadings in the first principal component should diversify into the stock markets with high factor loadings in the second principal component and vice versa.

Table 3. Principal Components Analysis of Stock Market Index Returns: June 1995-May 2005

Stock Markets	Principal Component #1	Principal Component #2
Australia	**0.769**	*0.193*
New Zealand	**0.648**	*0.129*
Japan	**0.639**	*0.148*
Hong Kong	**0.634**	*0.418*
South Korea	**0.630**	*0.134*
Taiwan	**0.609**	*0.233*
China	**0.508**	*0.410*
Indonesia	*0.084*	**0.765**
Philippines	*0.169*	**0.738**
Malaysia	*0.195*	**0.696**
Thailand	*0.401*	**0.634**
Singapore	*0.515*	**0.604**

In PCA, all variables (stock markets) are likely to have some correlation with all the other variables. Therefore, each stock market would have some factor loading in each principal component. In Table 3, the higher factor loading of each stock market is shown in bold and the lower factor loading in the other principal component is shown with regular font in italics.

For example, of the nine stock markets with higher factor loadings in the first principal component, the Hong Kong and Chinese stock markets also have high factor loadings in the second principal component (0.418 and 0.410, respectively). It indicates that the Hong Kong and Chinese stock markets are also highly correlated with the stock markets with high factor loadings in the second principal component. Therefore, Hong Kong and Chinese investors would realize limited portfolio diversification benefit by investing in the stock markets with high factor loadings in the second principal component. On the other hand, the Australian, New Zealand, Japanese, South Korean, and Taiwanese stock markets have high factor loadings in the first principal component but very low factor loadings in the second principal component (0.193, 0.129, 0.148, 0.134, and 0.233, respectively). It indicates that these stock markets have low correlation with the stock markets with high factor loadings in the second principal component. Therefore, compared with Hong Kong and Chinese investors, Australian, New Zealand, Japanese, South Korean, and Taiwanese investors would realize greater portfolio diversification

benefit by investing in the stock markets with high factor loadings in the second principal component.

Two of the stock markets with high factor loadings in the second principal component, the Thai and Singaporean stock markets, also have quite high factor loadings in the first principal component (0.401 and 0.515, respectively). It indicates that the Thai and Singaporean stock markets are also highly correlated with the stock markets with high factor loadings in the first principal component. Therefore, Thai and Singaporean investors would realize limited portfolio diversification benefit by investing in the stock markets with high factor loadings in the first principal component. On the other hand, the Indonesian, Philippine, and Malaysian stock markets have high factor loadings in the second principal component but very low factor loadings in the first principal component (0.084, 0.169, and 0.195, respectively). It indicates that these stock markets have very low correlation with the stock markets with high factor loadings in the first principal component. Therefore, compared with Thai and Singaporean investors, Indonesian, Philippine, and Malaysian investors would realize greater portfolio diversification benefit by investing in the stock markets with higher factor loadings in the first principal component.

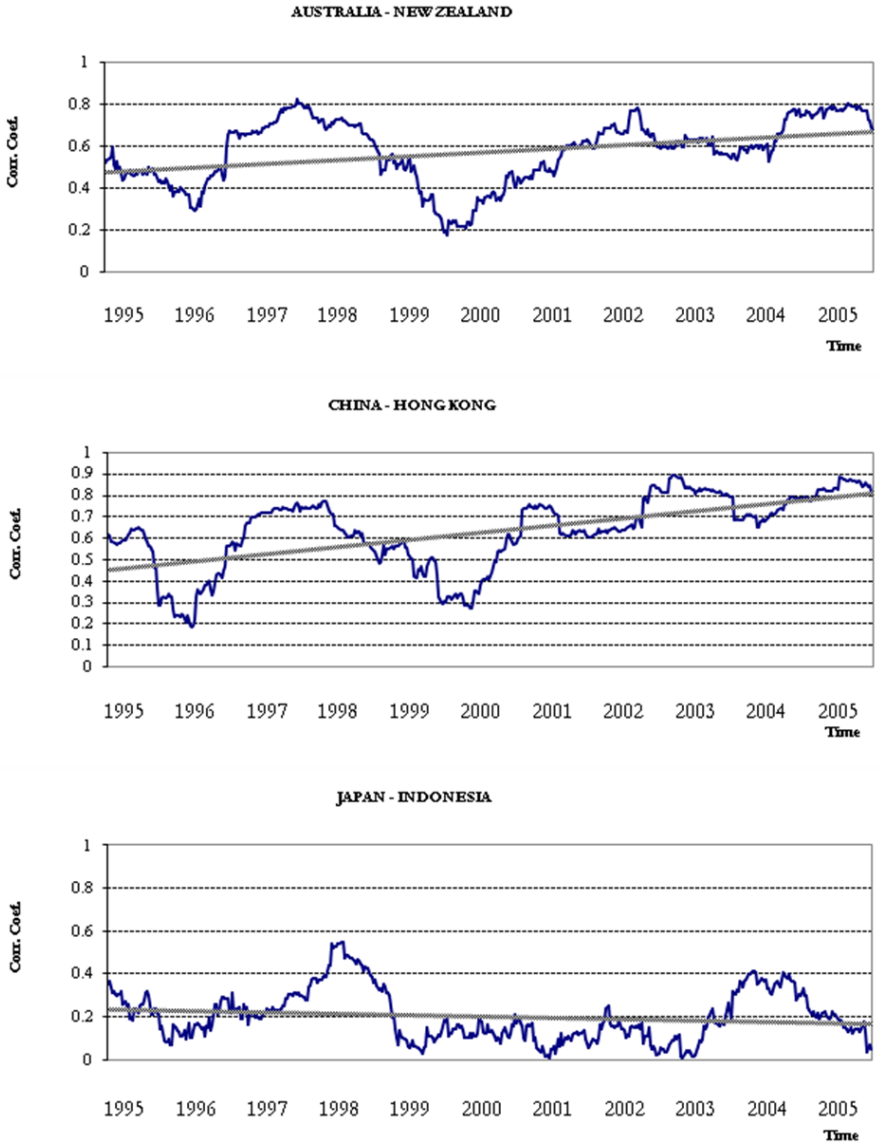
To our knowledge, this is the first principal components analysis (PCA) study on the Pacific-Basin stock markets. Therefore, empirical findings from previous studies are not available for comparison with our PCA findings in the study.

TIME-VARYING CORRELATION

For the global investor, the expected portfolio diversification benefit of investing in different countries depends on the expected correlation between the stock markets of those countries. Recent studies demonstrate that the correlation between global stock markets is quite volatile over time (Solnik et al. 1996, Meric et al. 2002). In Figure 1, the time-varying correlation graphs are presented between the Australian and New Zealand, Chinese and Hong Kong, and Japanese and Indonesian stock markets.

Yearly rolling correlation coefficients between the weekly index returns of pairs of stock markets are computed by rolling the sample period forward one week at a time starting with the first year. Specifically, the latest weekly return observation is added while the earliest weekly return observation is deleted. The linear trend line fitted to each graph shows the long-run correlation trend between the two stock markets.

Figure 1. Time-Varying Correlation Coefficients: June 1995-May 2005



The Australian and New Zealand stock markets are in the same principal component (see Table 3). Therefore, they are highly correlated and investing in these stock markets can provide limited portfolio diversification benefit to global investors. The upward slope of the trend line (see Figure 1) indicates that the correlation between the two markets is

increasing and that the portfolio diversification benefit of investing in these stock markets is decreasing.

The graph shows that the correlation between the Australian and New Zealand stock markets is quite volatile. The correlation coefficient becomes as high as 0.8 during the 1997-1998 global emerging markets crisis and falls to as low as 0.2 during the 1999 global bull market. It increases sharply during the 2000-2002 global bear market and it remains at a high level after the September 11, 2001, terrorist attacks in the U.S. and the commencement of the Iraqi war in 2003.

The Chinese and Hong Kong stock markets are also in the same principal component (see Table 3). Therefore, they are highly correlated and investing in these stock markets can provide limited portfolio diversification benefit to global investors. The upward slope of the trend line (see Figure 1) indicates that the correlation between the two markets is increasing and that the portfolio diversification benefit of investing in these stock markets is decreasing.

The graph shows that the correlation between the Chinese and Hong Kong stock markets is also quite volatile. The fluctuation pattern of the rolling correlation coefficient indicates that the correlation between the Chinese and Hong Kong stock markets is also affected by global events. The correlation coefficient becomes as high as 0.8 during the 1997-1998 global emerging markets crisis and falls to as low as 0.25 during the 1999 global bull market. It increases sharply during the 2000-2002 global bear market and remains at a high level after the September 11, 2001, terrorist attacks in the U.S. and the commencement of the Iraqi war in 2003.

The PCA results indicate that investors can maximize their portfolio diversification benefit by investing in stock markets with high factor loadings in different principal components. For example, the Japanese stock market has a high factor loading in the first principal component (0.639) and a low factor loading in the second principal component (0.148) (see Table 3). Therefore, a Japanese investor can maximize portfolio diversification benefit by investing in a stock market with a high factor loading in the second principal component and a low factor loading in the first principal component. The Indonesian stock market is such a stock market with a high factor loading of 0.765 in the second principal and a very low factor loading of 0.084 in the first principal component.

The graph in Figure 1 shows that there is a low correlation between the Japanese and Indonesian stock markets. The correlation trend line has a slight downward slope. The average correlation coefficient between the two markets was about 0.22 in 1995. It went

down to about 0.18 in 2005. The fluctuation pattern of the correlation coefficient indicates that the correlation between the Japanese and Indonesian stock markets is also affected by some global events. The correlation coefficient between the two stock markets increased sharply when the emerging markets crisis started in 1997, and when the Iraqi war started in 2003.

The time-varying correlation analysis technique has become popular in recent years (see, e.g., Solnik et al. 1996, Meric et al. 2002). To our knowledge, ours is the first study that studies time-varying correlation patterns between Pacific-Basin stock markets. Due to this fact, we are not able to compare our results in this study with the findings of previous studies. Nevertheless, some general observations can be made which give support to empirical findings in some previous studies.

Hamao et al. (1990) and Malliaris and Urrutia (1992) document significantly increased correlation among national equity market movements during periods of global financial crisis. During the 1997-1998 global emerging markets crisis, we observe a sharp increase in the correlation between markets in all three graphs in Figure 1. Previous studies by Meric at al. (2000, 2001b) and Tuluca and Zwick (2001) also find that the world's stock markets moved closely together and the correlation between them increased considerably during the 1997-1998 emerging markets crisis. An examination of the returns data indicates that the correlation between the markets increased sharply at the peak of the crisis when stock returns fell sharply in all world markets at the end of 1997 and at the beginning of 1998. However, the correlation between all markets decreased sharply when the effects of the crisis gradually dissipated in 1998.

In Figure 1, correlation between the Australian and New Zealand stock markets and between the Chinese and Hong Kong stock markets decreases during the 1999 global bull market and increases during the 2000-2002 global bear market. These observations are in line with Meric et al.'s (2002, 2007) findings that correlation between the world's stock markets tend to decrease in bull markets and tend to increase in bear markets. The September 11, 2001, terrorist attacks in the U.S. also appear to have contributed to the high correlation between the Australian and New Zealand stock markets and between the Chinese and Hong Kong stock markets. Previous studies by Hon et al. (2004) and Meric and Meric (2004) also find that correlation and contagion increased significantly in the world's financial markets after September 11, 2001.

Correlation between the Japanese and Indonesian stock markets is generally very low and does not appear to be affected significantly by the 1999 global bull market, the 2000-2002 global bear market, and the September 11, 2001, events. Correlation between the two markets appears to be affected considerably by the emerging markets crisis of 1997-1998 and by the commencement of the Iraq war in 2003. However, the effects of these events appear to be temporary. After a sharp initial increase, the correlation coefficient between the two markets decreases below 0.2 when the initial impact of the events gradually dissipates.

GRANGER CAUSALITY TESTS

An independent variable *X* Granger-causes changes in dependent variable *Y*, if *Y* can be better forecasted with past values of *X* and *Y*, than just with past values of *Y* alone (Granger 1969). The causality in the Granger sense does not imply a cause and effect relationship, but one of predictability. In several recent studies, the Granger causality technique is used to determine if some national stock market index returns can be used to predict the future index returns of other national stock markets (see, e.g., Ratner and Leal 1996, Meric et al. 2002).

In this segment of the paper, we use the VAR methodology and the Granger causality test to study the linkages between the twelve Pacific-Basin stock markets during the June 1995-May 2005 period. A detailed description of the VAR methodology and the Granger causality test is available in Enders (1995). The optimal lag-length (Sims 1980) is three weeks in the VAR system used in the analysis and, to conserve space, t-statistics for the individual lags are not given. The results of the Granger causality test for the joint hypothesis of zero coefficients on all three lags for each stock market are presented in Table 4.

The PCA methodology studies the contemporaneous co-movements of the stock markets. However, there may be significant lead/lag relations between the stock markets. The Granger causality technique can be a useful tool in determining the significant lead/lag relations between the stock markets. To maximize the portfolio diversification benefit, the stock markets with high contemporaneous correlation (as determined by the PCA technique) and those with significant lead/lag linkages (as determined by the Granger causality test) should be avoided.

Table 4. Granger Causality Tests: June 1995-May 2005

Dependent Variable	Independent Variable - F Statistic											
	AUS	CHI	HON	IND	JAP	KOR	MAL	NEW	PHI	SIN	TAI	THA
AUS	0.3	1.1	0.9	0.5	0.3	0.7	1.1	1.4	0.1	0.5	0.2	0.5
CHI	2.4	1.7	0.3	0.8	1.4	1.9	0.9	2.1	0.5	1.5	0.4	4.6*
HON	0.8	1.3	0.1	1.5	0.4	1.7	3.0**	1.6	1.6	0.7	1.0	3.9*
IND	1.2	0.1	0.1	1.5	0.4	1.7	3.0**	1.6	1.6	0.7	1.0	3.9*
JAP	0.3	2.7**	2.8**	2.0	4.3*	1.3	2.4	1.8	2.9**	1.4	0.3	2.1
KOR	1.7	0.3	0.2	7.0*	1.7	12.4*	2.3	3.3**	1.6	0.2	1.6	1.1
MAL	0.5	2.0	3.0**	6.4*	1.5	5.2*	2.0	1.4	3.0**	2.7**	0.8	2.7**
NEW	0.7	0.9	1.5	0.4	0.3	2.1	3.8*	4.2*	0.3	0.8	0.8	2.1
PHI	0.9	0.5	1.0	0.5	0.7	1.3	1.5	2.2	1.6	2.6**	1.6	2.4
SIN	1.5	2.7**	3.2**	3.2**	3.4**	2.8**	1.4	0.5	2.0	3.3**	2.6**	4.6*
TAI	0.9	0.9	0.8	0.5	0.3	0.1	0.5	3.4**	3.0**	1.0	0.4	3.2**
THA	1.0	3.2**	0.9	1.7	0.3	4.9*	0.2	0.4	0.6	1.4	0.9	0.4

* Significant at the 1% level.
** Significant at the 5% level.

Australia

The statistics in Table 4 indicate that the Australian stock market is the only Pacific-Basin stock market with no significant lead/lag linkages with the other stock markets. Neither the past returns of another Pacific-Basin stock market can predict the future returns of the Australian stock market nor the past returns of the Australian stock market can predict the future returns of another Pacific-Basin stock market.

The Granger causality test results imply that the Australian stock market is a good prospect for portfolio diversification in the region with no lead/lag relations with the other stock markets. The PCA results in Table 3 indicate that Australian investors would obtain the greatest portfolio diversification benefit by investing in the Indonesian, Philippine, and Malaysian stock markets.

China

The Thai stock market is the only Pacific-Basin stock market whose past stock returns lead (can be used to predict) the future returns of the Chinese stock market at the one-percent significance level. The past returns of the Chinese stock market can also predict (lead) the future returns of the Thai, Japanese, and Singaporean stock markets at the five-percent significance level.

The PCA results in Table 3 indicate that the other Pacific-Basin stock markets are not good portfolio diversification prospects for Chinese investors because the Chinese stock

market is highly correlated with the stock markets in both principal components. In addition, the Granger causality test results in Table 4 indicate that the Chinese stock market also has significant lead/lag linkages with three other Pacific-Basin stock markets.

Hong Kong

Past returns of the Thai and Malaysian stock markets can predict (lead) future returns of the Hong Kong stock market at the one-percent and five-percent significance levels, respectively. Past returns of the Hong Kong stock market can predict (lead) future returns of the Singaporean, Malaysian, and Japanese stock markets at the five-percent significance level.

As in the case of the Chinese stock market, the PCA and Granger causality test results indicate that the other Pacific-Basin stock markets are not beneficial diversification prospects for Hong Kong investors. The Hong Kong stock market has high contemporaneous correlation with all the other stock markets in the region and it has significant lead/lag relations with four other Pacific-Basin stock markets.

Indonesia

As in the case of the Hong Kong stock market, past returns of the Thai and Malaysian stock markets can also predict (lead) future returns of the Indonesian stock market at the one-percent and five-percent significance levels, respectively. Past returns of the Indonesian stock market can predict (lead) future returns of the South Korean and Malaysian stock markets at the one-percent significance level and the Singaporean stock market at the five-percent significant level.

If we combine the PCA and Granger causality test results, Indonesian investors would have the greatest portfolio diversification benefit by investing in the Australian, New Zealand, Japanese, South Korean, and Taiwanese stock markets.

Japan

Past returns of the Philippine, Hong Kong, and Chinese stock markets can predict (lead) future returns of the Japanese stock market at the five-percent significance level. Past returns of the Japanese stock market can predict (lead) future returns of the Singaporean stock market at the five-percent significance level.

The PCA and Granger causality test results indicate that Japanese investors would obtain

the greatest portfolio diversification benefit by investing in the Indonesian and Malaysian stock markets.

South Korea

Past returns of the Indonesian and New Zealand stock markets can predict (lead) future returns of the South Korean stock market at the one-percent and five-percent significance levels, respectively. Past returns of the South Korean stock market can predict (lead) future returns of the Malaysian and Thai stock markets at the one-percent significance level and the Singaporean stock market at the five-percent significant level.

The PCA and Granger causality test results indicate that South Korean investors would achieve the greatest portfolio diversification benefit by investing in the Philippine stock market with a low correlation and no significant lead/lag linkages.

Malaysia

Future returns of the Malaysian stock market are led by (can be predicted by) past returns of the Indonesian and South Korean stock markets at the one-percent significance level and by the Hong Kong, Philippine, Singaporean, and Thai stock markets at the five-percent significance level. Past returns of the Malaysian stock market can predict (lead) future returns of the New Zealand stock market at the one-percent significance level and the Hong Kong and Indonesian stock markets at the five-percent significant level.

The PCA and Granger causality test results indicate that Malaysian investors would obtain the best portfolio diversification benefit by investing in the Australian, Japanese, and Taiwanese stock markets.

New Zealand

Past returns of the Malaysian stock market can predict (lead) future returns of the Japanese stock market at the five-percent significance level. Past returns of the New Zealand stock market can predict (lead) future returns of the South Korean and Thai stock markets at the five-percent significance level.

If we combine the PCA and Granger causality test results, New Zealand investors would have the greatest portfolio diversification benefit by investing in the Indonesian and Philippine stock markets.

The Philippines

Past returns of the Singaporean stock market can predict (lead) future returns of the Philippine stock market at the five-percent significance level. Past returns of the Philippine stock market can predict (lead) future returns of the Malaysian, Thai, and Japanese stock markets at the five-percent significance level.

The PCA and Granger causality test results indicate that Philippine investors would obtain the best portfolio diversification benefit by investing in the Australian, New Zealand, South Korean, and Taiwanese stock markets.

Singapore

It appears that the Singaporean stock market has significant linkages with most other Pacific-Basin stock markets. Future returns of the Singaporean stock market are led by (can be predicted by) past returns of the Thai stock market at the one-percent significance level and by the Japanese, Hong Kong, Indonesian, South Korean, Chinese, and Taiwanese stock markets at the five-percent significance level. Past returns of the Singaporean stock market can predict (lead) future returns of the Malaysian and Philippine stock markets at the five-percent significance level.

The PCA results in Table 3 indicate that the Pacific-Basin stock markets with high factor loadings neither in the first principal component nor in the second principal are good diversification prospects for Singaporean investors. The Granger causality test results also indicate that the other Pacific-Basin stock markets are not good investment prospects for Singaporean investors as most of them have significant lead/lag linkages with the Singaporean stock market.

Taiwan

The past returns of the New Zealand, Thai, and Philippine stock markets can predict (lead) the future returns of the Taiwanese stock market at the five-percent significance level. The past returns of the Taiwanese stock market can predict (lead) the future returns of the Singaporean stock market at the five-percent significance level.

The PCA and Granger causality test results indicate that Taiwanese investors would obtain the best portfolio diversification benefit by investing in the Indonesian and Malaysian stock markets.

Thailand

Past returns of the South Korean and Chinese stock markets can predict (lead) future returns of the Thai stock market at the one-percent and five-percent significance levels, respectively. The South Korean stock market appears to have a significant influence on the Thailand-Malaysia-Singapore south-east Asia region. The influence of the Chinese stock market on the Thai and Singaporean stock markets is also significant.

The Thai stock market returns appear to have a significant leading role in the Pacific-Basin region. Past returns of the Thai stock market can predict (lead) future returns of the Chinese, Singaporean, Hong Kong and Indonesian stock markets at the one-percent significance level and the Taiwanese and Malaysian stock markets at the five-percent significance level. Empirical studies argue that the 1997-1998 emerging markets crisis started in Thailand (see, e.g., Meric et al. 2000). This fact may explain the leading role of the Thai stock market with data that includes the 1997-1998 emerging markets crisis period.

The PCA results in Table 3 indicate that the Pacific-Basin stock markets with high factor loadings neither in the first principal component nor in the second principal are good diversification prospects for Thai investors. The Granger causality test results in Table 4 also show that the other Pacific-Basin stock markets are not good investment prospects for Thai investors as most of them have significant lead/lag linkages with the Thai stock market.

Previous Studies on the Linkages of the Pacific-Basin Stock Markets

Lie and Pan (1997) study the linkages of the Hong Kong, Singapore, Taiwan, and Thai stock markets with the U.S. and Japanese stock markets. They conclude that the U.S. stock market is more influential than the Japanese market in transmitting returns and volatilities to the four Pacific-Basin stock markets. Ng (2002) studies the Singaporean stock market and he concludes that the Indonesian, Philippine, and Thai stock markets are becoming more closely linked with the Singaporean stock market over time. This finding is in line with our finding above for the Singaporean stock market. We also found that the Singaporean stock market is closely linked with the other Pacific-Basin stock markets and, therefore, portfolio diversification opportunities are limited to Singaporean investors with the other Pacific-Basin stock markets.

In an earlier study, Corhay et al. (1995) find the Pacific-Basin stock markets to be highly

integrated with limited diversification opportunities. They conclude that the regional aspects (Asian versus Pacific) play important roles in the degree of integration. Chang et al. (1994), however, find imperfect regional integration in the Pacific-Basin region and argue that diversification opportunities exist for investors.

Random Walk of Returns and Market Efficiency

In the diagonal cells of Table 4 from the upper left corner to the lower right corner, the dependent variable and the independent variable are the same stock market. Therefore, the test statistics in these cells can serve as a weak-form efficiency (random walk) test. According to the F statistics in these cells, the Australian, Chinese, Hong Kong, Indonesian, Malaysian, Philippine, Taiwanese, and Thai stock markets are weak-form efficient, i.e., the past returns of these stock markets cannot be used to predict their future returns. However, the Japanese, South Korean, and New Zealand stock markets are not weak-form efficient at the one-percent level and the Singaporean stock market is not weak-form efficient at the five-percent level, i.e., the past returns of each of these stock markets can be used to predict its future returns.

Stock market efficiency is one of the most popular research topics in finance. It is no surprise that there are also many previously conducted efficiency tests on the Pacific-Basin stock markets. In an earlier study covering the pre-October 1987 crash period, Chan and Tse (1994) find that the Japanese, Hong Kong, Singapore, and Australian stock markets do not generally follow random walk. In this study, with more recent data, we also find that the Japanese and Singaporean stock markets are not weak-form efficient. However, we find the Australian and Hong Kong stock markets to be weak-form efficient.

In a recent study, Lin (2006) also finds the Taiwanese stock market to be weak-form efficient. He attributes this fact to the recent reforms in the Taiwanese stock market to improve transparency. Hameed and Kusnadi (2002) find that the Pacific-Basin stock markets generally follow a random walk and that the factors that contribute to the momentum phenomenon in the U.S. stock market are not prevalent in the Pacific-Basin stock markets. With a different statistical methodology, Narayan (2005) finds the Australian and New Zealand stock markets both to be weak-form efficient. In this study, we also find the Australian stock market to be weak-form efficient, however, the New Zealand stock market not to be weak-form efficient.

SUMMARY AND CONCLUSIONS

In this paper, we have studied the co-movements of and the linkages between twelve Pacific-Basin stock markets during the June 1995-May 2005 period. The Morgan Stanley Capital International (MSCI) U.S.-dollar stock market indexes were used in the study. The data were drawn from the Datastream database. The weekly index returns used in the analysis were computed as the natural log difference in the weekly indexes, ln $(I_{i,t}/I_{i,t-1})$.

We used the principal components analysis (PCA) and Granger causality techniques to study the co-movements of and the linkages between the Pacific-Basin stock markets. In previous studies, the PCA technique is used to analyze contemporaneous market co-movements and the Granger causality technique is used to study the lead/lag linkages between markets. To our knowledge, ours is the first empirical study that combines the findings of the two techniques to derive conclusions regarding the potential portfolio diversification benefits of investing in different national stock markets. Although the PCA technique has been used in previous studies to analyze the contemporaneous co-movements of national stuck markets in different parts of the world, to our knowledge, ours is the first study that applies the PCA technique to the Pacific-Basin stock markets to study the portfolio diversification implications of investing in these stock markets.

We used the PCA technique to group the stock markets in terms of the similarities of their weekly index return movements. The analysis yielded two statistically significant principal components. The Australian, New Zealand, Japanese, Hong Kong, South Korean, Taiwanese, and Chinese stock markets have high factor loadings in the first principal component. It indicates that these stock markets are highly correlated and that portfolio diversification with these stock markets would result in a limited diversification benefit. The Indonesian, Philippine, Malaysian, Thai, and Singaporean stock markets have high factor loadings in the second principal component. It indicates that these stock markets are highly correlated and that portfolio diversification with these stock markets would provide a limited diversification benefit.

To maximize the portfolio diversification benefit, investors of the stock markets with high factor loadings in the first principal component and low factor loadings in the second principal component should diversify into stock markets with high factor loadings in the second principal component and low factor loadings in the first principal component. Investors of the stock markets with high factor loadings in the second principal component and low factor loadings in the first principal component should diversify into

stock markets with high factor loadings in the first principal component and low factor loadings in the second principal component.

Rolling correlation analysis was used to study the time-varying correlation between the stock markets in the same principal component and between the stock markets in different principal components. The analysis results show that the correlation coefficients tend to have a high level of volatility over time. The results indicate that volatility is caused by global events such as the 1997-1998 emerging markets crisis, the 1999 bull market, the 200-2002 bear market, and the September 11, 2001, terrorist attacks in the U.S. The findings of previous studies confirm our conclusions.

There is a high time-varying correlation between the stock markets with high factor loadings in the same principal component (e.g., between the Australian and New Zealand stock markets and between the Chinese and Hong Kong stock markets). The long-term trends of the correlation coefficients between these markets tend to have an upward slope indicating that the diversification benefit with these stock markets is decreasing over time. There is a low time-varying correlation between the stock markets with high factor loadings in different principal components if they have a low factor loading in the other principal component (e.g., the Japanese and Indonesian stock markets). Investing in these stock markets can provide a substantial diversification benefit for global investors.

The Granger causality technique can be a useful tool in determining the significant lead/lag relations between national stock markets. To maximize the portfolio diversification benefit, the stock markets with high contemporaneous correlation (as determined by the PCA technique) and those with significant lead/lag linkages (as determined by the Granger causality test) should be avoided.

Our Granger causality test results indicate that there are significant lead/lag linkages between the Pacific-Basin stock markets. The Australian stock market is the only Pacific-Basin stock market with no significant lead/lag linkages with the other Pacific-Basin stock markets. Previous studies also find close linkages between most Pacific-Basin stock markets, which reduce the portfolio diversification benefit of investing in the region's stock markets. In this study, we have identified pairs of stock markets with a low correlation and insignificant lead/lag linkages that can provide good portfolio diversification benefit to global investors.

The Granger causality test results indicate that the Australian, Chinese, Hong Kong, Indonesian, Malaysian, Philippine, Taiwanese, and Thai stock markets are weak-form efficient, i.e., the past weekly returns of these stock markets cannot be used to predict

their future weekly returns. However, the weekly returns of the Japanese, Singaporean, South Korean, and New Zealand stock markets do not follow a random walk, i.e., the past weekly returns of each of these stock markets can be used to predict its future weekly returns. Previous studies, which use different statistical methodologies and different data sets, also find that most Pacific-Basin stock markets are weak-form efficient.

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