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LINKAGES BETWEEN THE U.S. AND ASIA-PACIFIC EXCHANGE TRADED FUNDS (ETF) MARKETS: EVIDENCE FROM THE 2007–2008 GLOBAL FINANCIAL CRISIS

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ABSTRACT

This paper examines co-integration and spillover effects between U.S. and Asia-Pacific stock markets using nine Exchange Traded Funds (ETFs) over the period from 7 January 2004 to 30 September 2010, with sub-samples of before and after the 2007–2008 global financial crisis. The nine ETFs include: SPDR, TOPIX, KODEX200 (KODEX), Tracker Fund of Hong Kong (TraHK), Polaris Taiwan Top 50 Tracker Fund (TT), SPDR S&P/ASX 200 Fund (STW), StreetTRACKS Straits Times Index Fund (STI), SmartFONZ (FNZ), and China 50 ETF. The co-integration analysis shows that there is a co-integration relationship between SPDR and TraHK, STW, STI, and FNZ before and after the global financial crisis. However, TOPIX shows little co-integration relationship with SPDR. In the case of KODEX and TT, no co-integration relationship is found before the crisis; however, it is found after the crisis. Before the crisis, SPDR co-integrated with China 50, but after the crisis the co-integration relationship weakened. The Granger causality tests indicate that, although U.S. stock markets lead Asia-Pacific stock markets, Asia-Pacific stock markets do not exert the same influence. GARCH tests show that there are significant spillover effects between the U.S. and Asia-Pacific stock markets. This paper confirms the fact that, since the 2007–2008 global financial crisis, the degree of co-integration and spillover effects has generally grown stronger.

Keywords: Exchange traded funds, global financial crisis, co-integration, Granger causality tests, spillover effects

INTRODUCTION

The financial crisis caused by the U.S. subprime mortgage breakdown in 2007 has spread into other financial markets across the world. The recent global financial crisis raises some questions about the co-integration relationship between global financial markets. The returns and volatility across international equity markets have long been important issues with respect to international portfolio diversification (Arshanapalli & Doukas, 1993; Hardouvelis, Malliaropilos, & Preistly, 2006; Dooley & Hutchison, 2009). Most studies employ stock equity indices, such as S&P 500, DJIA, and Nikkei 225, to analyse an international stock market linkage.

Exchange Traded Funds (ETFs) are index funds that are listed on an exchange. Investors can buy or sell ETF shares as individual stocks. Like index funds, ETFs have lower expenses and more tax advantages than mutual funds (Gastineau, 2002). In addition, because ETFs can be sold short, ETFs are more effective than open- and closed-end index funds for diversification strategies (Miffre, 2006). Because ETFs are traded during trading hours, no information asymmetry and/or price inefficiency has been reported (Tse & Martinez, 2007; Kayali, 2007). ETFs also appear to be a cheaper vehicle for building a diversified index portfolio, compared with investing in individual stocks directly (Rosenberg, Weintraub, & Hyman, 2008).[1]

Even though there are many studies that examine the magnitude and extent of a linkage between financial markets across the world, these studies mainly focus on stock market indices. When investors diversify their portfolio internationally, they cannot directly invest in a stock market index. Instead, they have to put their money in index funds or mutual funds that track a stock market index. However, because the price of the index or mutual fund is not available to investors during trading hours, there could be information asymmetry and/or inefficiency in the pricing of the funds.

A few studies analyse the international equity market integration using ETFs (Olienyk, Schwebach, & Zumwalt, 1999; Durand & Scott, 2003; Lucey, Barari, & Voronkova, 2005; Barari, Lucey, & Voronkova, 2006; Gutierrez, Martinez, & Tse, 2007). However, these studies use iShares MSCI Index Funds.[2] Even though these iShares MSCI Index Funds track the foreign market equity index, they are actually traded in the U.S.[3] Zhong and Yang (2005) suggest that iShares may not provide significant diversification gains because their movements are closely related to the U.S. market.

This paper examines the relationship between ETFs across the U.S., Japan, Korea, Hong Kong, Taiwan, Singapore, Australia, New Zealand and China from January 2004 to September 2010 using co-integration and volatility analysis. Because the Asia-Pacific region has an economic link with the U.S. economy, Asia-Pacific countries have long been viewed as vulnerable to the effects of U.S. economic fluctuations.

This paper intends to contribute to existing literature on the stock market linkages across the countries included in the study in four ways. First, this paper adds empirical evidence on the co-movement in returns between U.S. and leading Asia-Pacific stock markets using a sample of ETFs. The sample of ETFs includes SPDR, TOPIX, KODEX 200 (KODEX), Tracker Fund of Hong Kong (TraHK), Polaris Taiwan Top 50 Tracker Fund (TT), StreetTRACKS Straits Times Index Fund, SPDR S&P/ASX (STW), SmartFONZ (FNZ), and China 50 ETF, which are all traded in their own countries.

Second, this paper investigates the effect of the global financial crisis on relationships between the world equity markets by comparing co-integration before and after the 2007 U.S. subprime crisis. Third, this paper also examines the co-integration relationship between China and the Asia-Pacific stock markets as China's influence on the Asia-Pacific region, as well as the world, has been increasing. Fourth, the spillover effects of volatility between the U.S. and Asia-Pacific stock markets are reported.

The remainder of the paper is organised as follows: First, a review of previous studies on ETFs; then we briefly describes the data; next we presents the empirical results; and lastly we summarise the paper.

PREVIOUS LITERATURE

Many researchers have examined the linkage between stock markets across countries using stock market indices (Barari et al., 2006), swap spreads (In, 2007; Ji & In, 2010), and real estate market indices (Zhu & Liow, 2007; Bardhan, Edelstein, & Tsang, 2008). Research concerning ETF performance is limited. Because this study mainly focuses on ETFs, this paper briefly reviews the studies focused on the relationship of ETFs between countries.

Olienyk et al. (1999) find that Granger causality and co-integration exists between 17 WEBS (World Equity Benchmark Securities) and SPDR, indicating a linkage between ETFs across countries. Pennathur, Delcoure and Anderson (2002) study the performance and diversification of iShares and closed-end country funds from April 1996 to December 1999. They find that iShares have a great deal of exposure to the U.S. market. Thus, both iShares and closed-end country funds show limited potential for diversification.

Durand and Scott (2003) examine how U.S. investors that invest in the Australian market through iShares Australia responded to changes in the U.S. market returns on a daily basis during the sample period of March 1996 to July 2000. They find that U.S.-based investors who are investing in the Australian market have a tendency to overreact to contemporaneous and lagged returns in the U.S. equity market, the U.S.-Australian dollar exchange rate, and past iShares Australian returns. Yavas, Rezayat and Bilici (2004) examine the joint impact of any two markets on a third market with weekly closing prices for iShares Russell 3000, iShares Japan and iShares S&P Europe 350. They provide evidence that the interdependencies among the three markets are significant, and their results indicate that iShares can still be a good international diversification tool.

Phengpis and Swanson (2004) examine U.S. investors who achieve significant international diversification gains, using a step-by-step approach in which they examine long-run information (e.g., co-integration relations) and short-run information (e.g., return correlations or individual asset performance) in the selection and allocation process. They find that actual diversification gains have been overstated primarily when gains are based on national indices as opposed to iShares. They also argue that investing in emerging and developing markets does not provide benefits of the magnitude found in earlier studies that cover earlier time periods. Zhong and Yang (2005) find that iShares are significantly affected by the U.S. market, and therefore potential diversification gains are weakened. Moreover, the U.S. market appears to be the key permanent factor while the home country market is a transitory factor. Their results indicate that significant co-integration among the majority of iShares reduced the benefits from international diversification.

Barari et al. (2006) use daily iShares to investigate diversification opportunities across G7 countries for U.S.-based investors for the sample period of March 1996 to January 2005. The multivariate recursive co-integration results show that, since 2001, both long-run and short-run relationships have been increasing. In addition, the time-varying conditional correlation analysis shows increased conditional correlations during the sample period. Darrat and Zhong (2002) find co-movement between the returns, volatility and liquidity of SDPR and iShares Japan Index Fund (EWJ) using 15-minute interval data. The returns, volatility and depth of SPDR lead the changes in returns, volatility and depth of iShares Japan Index Fund. However, they also report that the daily returns are not serially correlated, suggesting no evidence of spillover across funds in either direction with regard to daily data.

Tse and Martinez (2007) analyse the price discovery process and information transmission of 24 international iShares funds. Their findings show that the 24 international iShares prices have a high correlation with U.S. iShares. Gutierrez, Martinez and Tse (2007) analyse the return and volatility of Asian iShares traded in the U.S. during the period from January 2002 to December 2006, using the daily prices of iShares Hong Kong, iShares Japan, iShares Malaysia, iShares Singapore, iShares South Korea and iShares Taiwan. They report that ETF volatilities show significant bi-directional Granger causality between the U.S. and six Asian markets. Their findings also show that Asian markets play an important role in determining Asian ETF returns and, at the same time, returns for those funds are highly correlated with U.S. market returns.

DATA

This paper analyses the daily returns of SPDR, TOPIX, KODEX 200, Tracker Fund of Hong Kong, Polaris Taiwan Top 50 Tracker Fund, SPDR S&P/ASX 200 Fund, StreetTRACKS Straits Times Index Fund, SmartFONZ, and China 50 ETF. Sample periods for each ETF are different due to each ETF's inception date. Table 1 shows the sample period, country, underlying index, and inception date of each ETF. The sample period of 2 January 2004–30 September 2010 is chosen to avoid the aftershock of 11 September 2001.

Table 1
Summary of sample

ETF	Sample period	Country	Underlying index	Inception date
SPDR S&P 500 ETF	2/1/2004–30/9/2010	U.S.	S&P 500 index	29/01/1993
TOPIX	2/1/2004–30/9/2010	Japan	TOPIX index	11/07/2001
KODEX 200	2/1/2004–30/9/2010	Korea	KOSPI 200 index	14/10/2002
Tracker Fund of Hong Kong	2/1/2004–30/9/2010	Hong Kong	Hang Seng index	22/11/1999
Polaris Taiwan Top 50 Tracker Fund	31/8/2004–30/9/2010	Taiwan	TSEC Taiwan 50 index	30/06/2003
SPDR S&P ASX200 Fund	1/9/2004–30/9/2010	Australia	S&P/ASX 200 index	27/08/2001
StreetTRACKS Straits Times Index Fund	1/9/2004–30/9/2010	Singapore	Straits Times index	17/04/2002
SmartFONZ	13/12/2004–30/9/2010	New Zealand	NZSX 50 Portfolio index	10/12/2004
China 50 ETF	24/2/2005–30/9/2010	China	SSE 50 index	23/02/2005

For the U.S. stock market, the SPDR S&P 500 ETF Trust, which tracks the S&P 500 index and was the first ETF in the world stock market, is examined. For the Japanese stock market, TOPIX ETF is examined. KODEX, which tracks the KOSPI 200 index is selected for the Korean stock market. TraHK (Tracker Fund of Hong Kong), which is designed to closely correspond to the performance of the Hang Seng index, is investigated for the Hong Kong stock market. The Tracker Fund of Hong Kong was launched on 12 November 1999 as part of the government's efforts to dispose the portfolios that had been acquired during the 1997 Asian financial crisis. The underlying index of the Polaris Taiwan Top 50 Tracker Fund is the TSEC Taiwan 50 index. The SPDR S&P ASX200 Fund, which was introduced on 27 August 2001, tracks the S&P/ASX 200 index. The StreetTRACKS Straits Times Index Fund has the Straits Times index as its underlying index. SmartFONZ, the ETF for the New Zealand stock market, tracks the NZSX 50 Portfolio index. The China 50 ETF, which was listed on the Shanghai Stock Exchange on 23 February 2005, tracks the SSE 50 index.

SPDR daily closing prices are collected on finance.yahoo.com. The daily KODEX closing prices are available on Samsung Investments website. The daily prices of TOPIX are obtained from Nomura Asset Management's website. The daily closing prices of the Tracker Fund of Hong Kong are available from the Tracker Fund of Hong Kong's website. The daily closing prices of the Polaris Taiwan Top 50 Tracker Fund, SPDR S&P/ASX 200 Fund, StreetTRACKS Straits Times Index Fund, SmartFONZ, and China 50 ETF are obtained from the Bloomberg website.

To examine the daily returns of the ETFs, closing prices are transformed via a natural log. For example, the closing price of KODEX is transformed as follows: LKODEX = log(KODEX). To take into account the difference in trading hours between the Asia-Pacific and U.S. stock markets, this paper matches trading dates in the Asia-Pacific markets {t} to trading dates in the U.S. market {t–1}. Thus, SPDR is transformed as log (SPDR{1}).

EMPIRICAL RESULTS

Unit Root Test

To test whether time series are stationary or not, two methodologies are used: (i) the Augmented Dickey Fuller (ADF) procedure and (ii) the Phillips-Perron (PP) test. The unit root tests are performed for the nine ETFs to determine whether they are stationary on both the level and first difference. Table 2 reports the results of the unit root tests for the nine ETFs.

Column 2 of Table 2 shows that the null hypothesis (that the time series are not stationary) cannot be rejected for all variables on the level. In Column 3, however, the null hypothesis can be rejected because the ADF statistics for the first difference of all variables are larger than the critical values. In Columns 3 and 4 of Table 2, the Phillips-Perron (PP) test provides the same results. The results show that all variables are not stationary on the level, but they are stationary after the first difference.[4]

Table 2
Unit Root Tests for SPDR, TOPIX, KODEX, TraHK, TT, STW, STI, FNZ, and China 50

	ADF		PP	
	Level	First Difference	Level	First Difference
SPDR	–1.4697	–16.5045**	–1.8812	–44.2247**
TOPIX	–0.3917	–15.7534**	–0.5872	–39.1797**
KODEX	–1.2348	–16.6860**	–0.7470	–41.0831**
TraHK	–1.7082	–16.4852**	–1.2604	–41.9220**
TT	–2.3067	–17.1436**	–1.8526	–38.9813**
STW	–1.5504	–17.5867**	–1.7235	–41.8074**
STI	0.0362	–14.9695**	–0.9671	–41.0133**
FNZ	–0.6777	–17.8266**	–1.5872	–47.0058**
China 50	–1.4804	–15.0192**	–1.2217	–37.3920**

Note: Lags = 4. The lag length is based on AIC (Akaike Information Criterion). Critical value: DF test: 1% = –3.438, 5% = –2.864, PP test: 1% = –3.438, 5% = –2.864. ***, ** indicates significance at 1%, 5% level. For reference, KODEX: KODEX 200, TraHK: Tracker Fund of Hong Kong, TT: Polaris Taiwan Top 50 Tracker Fund, STW: SPDR S&P/ASX, STI: StreetTRACKS Straits Times Index Fund, FNZ: SmartFONZ, and China 50: China 50 ETF.

Co-integration Analysis

It is possible for two or more non-stationary data generating processes to share a long-term interdependent relationship. Thus, the linear combination of two or more non-stationary series would be stationary. Such series are said to be co-integrated (Brooks, 2008). If the two series are co-integrated, the deviation from long-term equilibrium is corrected over a period of time through short-term adjustments. In the Johansen methodology, two test statistics (trace and maximum eigenvalue) are used, as follows:

$$\lambda_{\max}(r, r+1) = -\mathrm{T} \times \ln(1-\lambda_{r+1}) \quad (2)$$

$$\lambda_{\text{trace}}(r) = -\mathrm{T} \times \sum_{i=r+1}^{n} \ln(1-\lambda_i) \quad (3)$$

where λ_{the} is the eigenvalue derived from the π matrix and r is the rank of the matrix.

$\lambda_{\max}$ conducts separate tests on each eigenvalue in which the null hypothesis is that the number of co-integrating vectors is r, against an alternative r + 1. λ_{trace} is a joint test where the null hypothesis is that the number of co-integrating vectors is less than or equal to *r*, against an alternative that is more than *r* (Johansen, 1988; Johansen & Juselius, 1990). To perform Johansen's co-integration analysis, the appropriate lag length is selected using the Akaike Information Criteria (AIC) test. This paper uses a restricted trend co-integration model that specifies a model with linear trends in the variables.[5]

This paper examines the effect of the recent global financial crisis on the co-movements of world equity markets. To analyse such impact, this paper divides the full sample into two sub-periods – before and after 11 October 2007, when both the S&P 500 index and the Dow Jones Industrial Average hit their highest points.[6] It is a common understanding that the deterioration of the U.S. subprime mortgage quality led to the global financial crisis, which caused fall of Bear Stearns, Merrill Lynch and Lehman Brothers in 2008.[7]

Table 3 provides the results of bivariate co-integration tests for SPDR, TOPIX, KODEX, TraHK, TT, STW, STI, FNZ and China 50 for the full sample period. The results indicate that there is no co-integrating vector between SPDR and TOPIX. The potential explanation is that the Japanese economy suffered even before the global crisis, whereas the U.S. economy experienced growth. Lucey et al. (2005) report a weak co-integration relationship between G7 iShares and SPDR.

The findings also show that, before the global financial crisis, there is no co-integrating vector between SPDR and KODEX or TT. However, after the global financial crisis, SPDR is found to be co-integrated with both KODEX and TT. This evidence indicates that because of the global financial crisis, co-movement between the U.S. and both the Korean and Taiwanese stock markets became stronger.

TraHK, STW, STI and FNZ are strongly co-integrated with SPDR before and after the global financial crisis. This evidence implies that the Hong Kong, Australia, Singapore and New Zealand stock markets have long been affected by the U.S. stock market. The results appear to suggest that in addition to domestic factors, the economic growth of Hong Kong, Australia, Singapore and New Zealand could be driven by foreign factors (e.g., foreign capital inflows, exchange mechanisms, foreign direct investments, etc.). These results are consistent with the previous studies that found a co-integration relationship between international stock indices (Arshanapalli & Doukas, 1993; Hardouvelis et al., 2006).

Table 3
Bivariate Co-integration Tests for SPDR, TOPIX, KODEX, TraHK, TT, STW, STI, FNZ, China 50 before and after the financial crisis (1 January 2004–11 October 2007 and 12 October 2007–30 September 2010)

Variables		Full sample		Before financial crisis		After financial crisis	
		λtrace	*λmax*	*λtrace*	*λmax*	*λtrace*	*λmax*
SPDR-TOPIX	$r = 0$	11.73	11.73	16.55	16.54	21.51	21.48
	$r < 1$	4.50	4.50	2.04	2.04	3.54	3.54
SPDR-KODEX	$r = 0$	25.26**	25.24**	21.75	21.73	30.39***	30.36***
	$r < 1$	2.10	2.10	8.75	8.75	4.84	4.84
SPDR-TraHK	$r = 0$	29.70**	29.68**	24.71**	24.69**	35.30***	35.26***
	$r < 1$	2.07	2.07	9.15	9.14	3.35	3.35
SPDR-TT	$r = 0$	37.19***	37.16***	20.84	20.82	29.41**	29.37**
	$r < 1$	3.66	3.66	9.25	9.24	3.73	3.72
SPDR-STW	$r = 0$	36.63***	36.59***	24.36***	24.24**	38.27***	38.22***
	$r < 1$	3.66	3.66	9.38	8.93	4.49	4.48
SPDR-STI	$r = 0$	65.03***	64.99***	34.79***	34.74**	50.10***	50.04***
	$r < 1$	1.46	1.46	5.93	5.93	5.54	5.54
SPDR-FNZ	$r = 0$	34.20***	34.18***	23.97**	23.75**	46.31***	46.26***
	$r < 1$	4.25	4.25	10.40	9.55	5.50	5.50
SPDR-China 50	$r = 0$	10.22	10.21	32.33***	32.28***	16.98	16.96
	$r < 1$	3.64	3.64	9.98	9.98	5.26	5.26

Note: All variables are lag = 1, but for STW lag = 3 and for FNZ lag = 4. The lag length is based on SC (Schwarz Criterion). The trace tests and maximum eigenvalue are obtained from the Johansen Full Information Likelihood co-integration regressions. The critical values are taken from simulation in RATs. ***, ** indicates significance at 1%, 5% level.

The evidence also shows that the China 50 ETF is strongly co-integrated with SPDR before the crisis. However, their co-integrating relationship becomes weaker after the global financial crisis, which suggests that the U.S. and Chinese stock markets show divergence. After the global financial crisis, the Chinese government tried to get its economy back on track with a stimulus policy. As a result, China got its economy on the path to recovery faster than the U.S.[8]

As the Chinese economy has grown rapidly, China has increasingly influenced the world economy (especially that of the Asia-Pacific area), and its importance to global investors has also increased. It is argued that emerging markets have a tendency to be de-coupled from the U.S. Tian (2008) finds that the interrelationship between two mainland Chinese stock markets (Shanghai and Shenzhen) and Hong Kong, Singapore and Taiwan grew stronger. This paper also examines the co-integration relationship between China and the rest of the Asia-Pacific stock markets.

Table 4 shows bivariate co-integration tests of the Asia-Pacific ETFs and the China 50 ETF. For China 50 and TOPIX, KODEX, TraHK and STI, co-integration relationships are not found for both the full sample and the sub-samples. In the case of TT, STW and FNZ, a co-integration relationship is found before the crisis. However, this relationship no longer exists after the crisis.

The evidence implies that the Chinese stock markets did not seem to influence the rest of the Asian stock markets over the sample period even though Chinese influences have been expected to increase (The Wall Street Journal, 2009, December). These results suggest potential gains from diversification with investments in Chinese ETFs.

Table 4
Bivariate Co-integration Tests for TOPIX, KODEX, TraHK, TT, STW, STI, FNZ, and China 50 before and after the financial crisis (1 September 2004–11 October 2007 and 12 October 2007–30 September 2010)

Variables		Full sample		Before financial crisis		After financial crisis	
		λtrace	*λmax*	*λtrace*	*λmax*	*λtrace*	*λmax*
China 50-TOPIX	$r = 0$	10.22	10.21	22.99*	22.96*	13.92	13.90
	$r < 1$	3.63	3.64	11.27	11.26	5.82	5.82
China 50-KODEX	$r = 0$	6.75	6.74	17.40	17.38	14.45	14.44
	$r < 1$	1.77	1.77	5.24	5.24	5.17	5.17
China 50-Trahk	$r = 0$	5.96	5.96	21.64	21.61	12.57	12.55
	$r < 1$	1.23	1.23	8.57	8.57	4.04	4.94
China 50-TT	$r = 0$	5.82	5.82	30.55***	30.51***	12.96	12.94
	$r < 1$	1.71	1.71	11.70	11.69	5.50	5.50
China 50-STW	$r = 0$	8.33	8.32	28.53**	28.49**	12.54	12.53
	$r < 1$	1.93	1.93	9.71	9.71	4.13	4.13
China 50-STI	$r = 0$	2.04	2.04	21.78	21.75	14.95	14.93
	$r < 1$	0.33	0.33	7.01	7.00	4.30	4.30
China 50-FNZ	$r = 0$	14.26	14.26	39.87***	39.81***	15.29	15.27
	$r < 1$	3.13	3.13	12.28	12.27	3.47	3.47

Note: Lag = 1. The lag length is based on SC (Schwarz Criterion). The trace tests and maximum eigenvalue are obtained from the Johansen Full Information Likelihood co-integration regressions. The critical values are taken from simulation in RATs. ***, ** indicates significance at 1%, 5% level.

Granger Causality Tests

A bi-directional Granger causality test is used to examine the short-term relationship between the U.S. and Asia-Pacific stock markets. Granger causality tests determine whether *X* variables are explained by the lagged *Y* variables and vice versa. Bi-directional Granger causality tests can avoid the interactions among the variables in the equation. The Granger causality test equation can be written as follows:

$$X_t = \delta_0 + \sum_{1=1}^{k} a_i X_{t-i} + \sum_{j=1}^{l} b_j Y_{t-j} + \varepsilon_t \quad (4)$$

$$Y_t = \gamma_0 + \sum_{i=1}^{m} c_i Y_{t-i} + \sum_{j=1}^{n} d_j X_{t-j} + \varepsilon_t \quad (5)$$

Table 5 presents the bi-directional Granger causality tests. In Table 5, it is evident that SPDR has a unilateral causal relationship on Asia-Pacific ETFs and that no Asia-Pacific ETFs cause SPDR. These findings are consistent with the research of Gutierrez, Martinez and Tse (2008) that found significant bi-directional Granger causality between the U.S. and six Asian markets.

These results suggest that, in the short-term, Asian stock markets are affected by the performance of the U.S. market (The New York Times, 11 September 2009). These findings are not consistent with the de-coupling argument in which Asian markets have been diverging from the U.S. stock market over the years (The Wall Street Journal, 14 September 2009).

Interestingly, after the global financial crisis, there is a bi-directional causality between the U.S. and China. This finding might imply that China's financial influence has increased since 12 October 2007. It is also noted that while a co-integration relationship between SPDR and China is found, it is only before the crisis in Table 5. Granger causality is found in the full sample and after the crisis. The plausible explanation of this result is that after the crisis, the Chinese and U.S. stock markets are diverging based on the severity of the recession and the speed of economic recovery.

Table 5
Bi-directional Granger causality Tests for SPDR, TOPIX, KODEX, TraHK, TT, STW, STI, FNZ, China 50 before and after the financial crisis (2 January 2004–11 October 2007 and 12 October 2007–30 September 2010)

	Full sample	Before crisis	After crisis
SPDR → TOPIX	288.46***	84.91***	157.60***
TOPIX → SPDR	2.10	0.55	0.92
SPDR → KODEX	107.06***	58.45***	55.99***
KODEX → SPDR	0.41	0.30	0.65
SPDR → TraHK	156.67***	78.64***	71.71***
TraHK → SPDR	2.02	6.28	2.20
SPDR → TT	118.01***	71.00***	60.24***
TT → SPDR	1.04	2.00	4.48
SPDR → STW	322.35***	155.27***	157.41***
STW → SPDR	0.71	4.22	1.63
SPDR → STI	106.89***	79.11***	53.55***
STI → SPDR	0.98	1.35	4.25
SPDR → FNZ	66.52***	13.02***	74.80***
FNZ → SPDR	4.34	0.17	1.19
SPDR → China 50	21.74***	6.61	17.99***
China 50 → SPDR	1.06	1.36	2.88**

Note: F-statistics are reported in the table. The critical values are taken from simulation in RATs. ***, ** indicates significance at 1%, 5% level.

Volatility Spillover Effects

This paper also examines the spillover effects between the U.S. and Asia-Pacific stock markets. A multivariate GARCH model is employed to see whether there is volatility transmission between the U.S. and Asia-Pacific stock markets. Different multivariate GARCH formulations have been suggested in existing literature.[9] This paper uses the BEKK model to analyse the volatility spillover effect between SPDR and Asia-Pacific ETFs (Wang & Wang, 2010). In the BEKK model proposed by Engle and Kroner (1995), positivity is easily imposed with a parameterisation for *H*, a variance matrix.

The conditional variance of the bivariate GARCH (1,1) model can be expressed as follows:

$$R_{i,t} = \mu_i + \varepsilon_{i,t} \tag{6}$$

where $R_{i,t}$ is the continuously compounded percentage return series on ETF_i between t and $t-1$.

μ_i is the long-term drift coefficient and $\varepsilon_{the,t}$ is the error term for the return on ETF_i at time t. The standard BEKK parameterisation for the bivariate GARCH (1,1) model can be written as:

$$H_t = C^l C + A^l \varepsilon_{t-1}\varepsilon_{t-1}^l A + B^l H_{t-1} B \tag{7}$$

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,4} \end{bmatrix} = \begin{bmatrix} c_{11} & \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\,\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\,\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{8}$$

where H_t is a 2 × 2 matrix of conditional variance-covariance at time t and C is a 2 × 2 lower triangle matrix with three parameters. A is a 2 × 2 square matrix of parameters and measures the extent to which conditional variances are correlated with past squared errors. B is a 2 × 2 squared matrix of parameters and shows the extent to which current levels of conditional variances are related to past conditional variances.

The coefficients a_{12} and a_{21} represent the effect of the past shocks, or ARCH effects, of one country on the future volatility of another country. the coefficients b_{12} and b_{21} capture the presence of the transmission of volatility, or GARCH effects, between the U.S. and Asia-Pacific stock markets.

Table 6 shows spillover effects, both ARCH and GARCH effects, between the U.S. and Asia-Pacific stock markets before and after the 2007–2008 global financial crisis.

Table 6(A) shows evidence of bi-directional past shock spillover between SPDR and all Asia-Pacific ETFs except for FNZ and China 50. theThe past shock of the China 50 affects the volatility of SPDR. In Table 6(B), a strong bi-directional past shock spillover between SPDR and TOPIX, KODEX, STW, STI is found before the global financial crisis. However, in the case of TraHK, TT, FNZ, and China 50, uni-directional past shock spillover effects are found. The results indicate strong past shock spillover effects of SPDR on TraHK and TT. Interestingly, there are shock spillover effects from FNZ and China 50 on SPDR. In Table 6(C), the evidence provides a strong bi-directional shock spillover effect between SPDR and Asia-Pacific ETFs (except for FNZ) after 12 October 2007. Overall, shock spillover effects between the U.S. and Asia-Pacific ETFs are documented, and it seems that these spillover effects have been increasing since 12 October 2007.

For the full sample, Table 6(A) also provides a strong bi-directional volatility spillover effect between SPDR and Asia-Pacific ETFs, except for FNZ and China 50. Before the global financial crisis, TOPIX, STW, STI and China 50 show significant bi-directional volatility spillover effects with SPDR, while KODEX, TraHK, TT and FNZ do not. The results report evidence of a volatility spillover from TraHK and TT to SPDR. After the global financial crisis, there is evidence of strong bi-directional volatility spillover effects between SPDR and Asia-Pacific ETFs, except for China 50. The results report a volatility spillover effect from SPDR to China 50. These results are consistent with the results of Singh, Kumar and Pandey (2010) in which they find returns and spillover effects between equity indices and that there is a greater regional influence among Asian stock markets.

Table 6
Parameter estimates for variance-covariance equations of bivariate MGARCH(1.1) for SPDR, TOPIX, KODEX, TraHK, TT, STW, STI, FNZ, China 50 before and after the financial crisis (2 January 2004–11 October 2007 and 12 October 2007–30 September 2010)

A: Full Sample

	a_{11}	a_{12}	a_{21}	a_{22}	b_{11}	b_{12}	b_{21}	b_{22}
SPDR-TOPIX	0.2409 (9.41)***	–0.3500 (–8.70)***	0.1310 (6.84)***	0.1563 (5.03)***	0.8874 (56.70)***	0.6107 (27.34)***	–0.4089 (–27.14)***	0.6943 (34.24)***
SPDR-KODEX	0.3215 (14.35)***	–0.2434 (–5.23)***	0.0474 (3.11)***	0.2096 (9.14)***	0.9028 (61.07)***	0.6058 (27.68)***	–0.3228 (–27.69)***	0.7390 (35.07)***
SPDR-TraHK	0.2094 (8.27)***	–0.3101 (–5.79)***	0.0549 (3.31)***	0.2449 (11.935)***	0.9888 (120.67)***	0.3740 (21.15)***	–0.1756 (–18.08)***	0.8494 (52.22)***
SPDR-TT	0.2465 (7.57)***	–0.4065 (–6.45)***	0.1349 (4.83)***	0.1183 (3.24)***	0.8429 (48.14)***	0.7027 (22.47)***	–0.4450 (–26.38)***	0.6343 (25.40)***
SPDR-STW	0.2022 (7.82)***	–0.3832 (–11.26)***	0.1872 (6.99)***	0.2231 (9.59)***	0.8289 (33.83)***	0.5970 (22.48)**	–0.5348 (–20.71)***	0.6390 (22.47)***
SPDR-STI	0.2268 (8.92)***	–0.2341 (–6.70)***	0.2446 (9.70)***	0.2293 (8.78)***	0.9282 (75.18)***	0.3740 (18.55)***	–0.3730 (–21.03)***	0.7832 (42.86)***
SPDR-FNZ	0.2763 (11.96)***	–0.0049 (–0.25)	0.0070 (0.61)	0.1871 (11.13)***	0.9578 (134.27)***	–0.0013 (–0.24)	–0.0011 (–0.41)	0.9801 (292.73)***
SPDR-China 50	0.2979 (12.54)***	0.0011 (0.05)	0.0659 (5.26)***	0.1822 (11.42)***	0.9507 (135.49)***	0.2062 (2.51)***	–0.0377 (–1.72)	0.9878 (–273.13)**

(*continued*)

Table 6 (*continued*)

B: Before the global financial crisis

	a_{11}	a_{12}	a_{21}	a_{22}	b_{11}	b_{12}	b_{21}	b_{22}
SPDR-TOPIX	–0.0127 (–0.26)	0.4507 (7.28)***	0.1033 (4.01)***	0.2537 (6.24)***	0.9693 (60.34)***	0.2286 (5.51)***	–0.1216 (–5.11)***	0.8212 (29.06)***
SPDR-KODEX	0.1373 (3.12)**	0.6252 (5.69)***	–0.0426 (–3.11)***	0.2384 (6.28)***	0.9549 (56.11)***	–0.1726 (–1.76)	0.0173 (1.03)	0.8581 (24.31)***
SPDR-TraHK	–0.0877 (–1.09)	0.4438 (6.09)***	–0.0111 (–0.44)	0.2542 (7.65)***	0.8880 (12.79)***	0.0643 (0.75)	0.1163 (2.88)***	0.8102 (15.83)***
SPDR-TT	–0.0064 (–0.13)	0.9331 (11.35)***	0.0557 (1.59)	–0.0652 (–1.34)	0.9339 (32.71)***	–0.0475 (–0.55)	0.1889 (4.33)***	0.3854 (3.84)***
SPDR-STW	0.0111 (0.27)	–0.4346 (–8.09)***	–0.1893 (–3.89)***	0.2830 (5.24)***	0.6785 (13.53)***	–0.5973 (–12.03)***	0.4314 (8.32)***	0.7206 (16.94)***
SPDR-STI	–0.1237 (–2.44)**	0.7831 (12.05)***	0.1476 (4.22)***	–0.0812 (–1.74)	0.6197 (6.24)***	0.6906 (6.74)***	0.3420 (4.71)***	0.2254 (1.80)
SPDR-FNZ	–0.1926 (–6.68)***	0.0220 (0.20)	–0.0473 (-2.70)***	0.3908 (6.30)	0.9536 (60.31)***	0.0218 (0.26)	0.0104 (0.83)	0.8461 (13.71)***
SPDR-China 50	–0.1806 (6.34)***	0.0437 (0.73)	–0.0251 (–2.25)***	0.2757 (8.74)***	0.9734 (126.28)***	–0.0526 (–2.58)***	0.0171 (4.96)***	0.9568 (100.06)***

C: After the global financial crisis

	a_{11}	a_{12}	a_{21}	a_{22}	b_{11}	b_{12}	b_{21}	b_{22}
SPDR-TOPIX	0.2585 (5.06)***	–0.4657 (–7.27)***	0.2655 (6.68)***	0.2080 (4.96)***	0.8792 (17.58)***	0.5167 (9.83)***	–0.4257 (–8.23)***	0.5607 (8.36)***
SPDR-KODEX	0.1589 (3.18)***	–0.3188 (–5.19)***	0.2883 (8.06)***	0.1229 (2.70)***	0.9440 (54.49)***	0.1286 (5.05)***	–0.0545 (–2.36)**	0.8829 (25.59)***
SPDR-TraHK	0.1642 (3.51)***	–0.3305 (–6.06)***	0.2034 (6.08)***	0.2602 (5.95)***	0.9184 (38.35)***	0.6806 (10.73)***	–0.4217 (–12.04)***	0.6276 (14.65)***
SPDR-TT	0.1746 (5.89)***	–0.1117 (–2.76)***	0.2634 (9.46)***	0.0827 (2.04)**	0.8998 (35.42)***	0.5024 (19.11)***	–0.4469 (–18.36)***	0.7704 (29.45)***
SPDR-STW	0.2858 (7.55)***	–0.3793 (–5.22)***	0.1508 (3.73)***	0.1996 (5.18)***	0.8254 (21.28)***	0.5532 (15.39)***	–0.5548 (–16.29)***	0.6208 (12.85)***
SPDR-STI	0.2477 (7.99)***	–0.1510 (–3.91)***	0.2418 (5.37)***	0.3112 (7.50)***	0.9500 (42.58)***	0.3201 (16.58)***	–0.4276 (–16.28)***	0.7705 (30.98)***
SPDR-FNZ	0.2519 (6.30)***	–0.2780 (–6.57)***	0.0271 (0.45)	0.4600 (7.64)***	0.9100 (43.39)***	0.0610 (2.61)***	–0.3588 (–6.24)***	0.4829 (6.85)***
SPDR-China 50	0.2543 (5.94)***	–0.3028 (–3.70)***	0.1240 (7.47)***	0.0653 (0.63)	0.9504 (58.08)***	0.2785 (2.92)***	0.0106 (0.13)	–0.6278 (–5.44)***

Notes: (): *t*-statistics, ***, **, denote significance at the 1%, 5% levels.

The evidence provided in Table 6 reports that the U.S. and Asia-Pacific ETFs are found to be extremely contagious in terms of shock and volatility for the full sample, even though the sign and magnitude of spillover across countries varies widely. These spillover effects seem to be driven by concerns fuelled by the fluctuations of the U.S. economy.

CONCLUSIONS

The globalisation of financial markets leads to stronger price transmission between international financial markets. Therefore, the understanding of the extent of linkages across the several types of financial markets is of importance for financial market participants. This paper analyses the co-integration between the U.S. and Asia-Pacific leading ETFs (including Korea, Japan, Hong Kong, Taiwan, Australia, Singapore, New Zealand and China) for the sample period of 2 January 2004 to 30 September 2010. This paper divides the full sample into two sub-samples, before and after the financial crisis, to investigate the effect of a global financial crisis on the Asia-Pacific stock markets.

The evidence shows that before the global financial crisis, ETFs in Korea and Taiwan have a weak co-integration relationship with the U.S. ETF. However, after the global financial crisis, co-integration between the U.S. and both Korea and Taiwan has been getting stronger. ETFs in Hong Kong, Australia, Singapore and New Zealand are found to have a strong co-integration relationship with the U.S. ETF before and after the global financial crisis. However, ETFs in Japan and China have a weak co-integration relationship with the U.S. ETF. The overall results in this paper indicate that, due to the global financial crisis, the interrelationship between U.S. and Asia-Pacific ETF markets has been getting stronger.

In addition, the Chinese ETF is found to have little effect on the rest of Asia-Pacific ETFs, contrary to the belief that China's financial clout has been greater. Granger causality results confirm that the U.S. ETF has an impact on Asia-Pacific ETFs in the short-term. Notably, after the global financial crisis, there is evidence of bi-directional causality between the U.S. and Chinese ETFs, which suggests China's presence in international stock markets is growing.

This paper also provides evidence of a strong spillover effect of shock and volatility between the U.S. and Asia-Pacific ETF markets – Japan, Korea, Hong Kong, Taiwan, Australia, Singapore, New Zealand and China.

The evidence found in this paper shows that the U.S. stock market continues to be a main driver of Asia-Pacific stock markets. These findings imply that, with co-integration and spillover effects from U.S. to Asia-Pacific ETFs, investors can obtain limited benefit from diversifying into ETFs across U.S. and Asia-Pacific ETF markets.

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NOTES

1. The first ETF, SPDR (Standard & Poor's Depository Receipts), or Spiders, tracks the S&P 500 index and was introduced on AMEX in 1993. Since then, ETFs in the worldwide stock market have increased rapidly in terms of the number and range of underlying indexes (Carrel, 2008).
2. iShares MSCI Index Funds were introduced initially as WEBS (World Equity Benchmark Securities) in 1996 and then renamed as iShares.
3. iShares were introduced in 1996 and are managed and marketed by Barclays Global Investors.
4. Even though the results of the unit root test for lag = 1, 2, 3, 4 are not reported in the paper, the unit root tests for lag = 1, 2, 3, 4 show all variables in the sample are non-stationary on the level, but stationary on the first difference.
5. As a check of the robustness of the restricted trend model, the other models (e.g., unrestricted model, restricted constant model, a model with no deterministic components) are tested. Though not reported, the results are the same as those of the restricted trend model.
6. On 11 October 2007, the Shanghai stock composite index also closed at its highest point, 6092.05.
7. The IMF Global Financial Stability Report (2008) explains the events that led to the U.S. subprime crisis.
8. To evaluate whether the co-integration rank determined by the standard Johansen's test is appropriate and whether the number of co-integration vectors increases over time, the recursive co-integration technique is employed (Johansen, 1988; Hansen & Johansen, 1999). The recursive trace analysis shows that there is at least more than one co-integration vector between SPDR and TraHK, STW, STI and FNZ. In the case of KODEX and TT, at least one co-integrating vector is found. Meanwhile, it is apparent that there are no co-integrating vectors between SPDR and TOPIX or China 50 ETF.
9. For an excellent survey of multivariate GARCH, see Bollerslev (1986), Bauwens, Laurent and Rombouts (2006).

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