Spring 2021

Developed stock market integration: New evidence from the pre- and post-financial crisis of 2007-2009

Carol Bruce Tagoe

Developed stock market integration: New evidence from the pre- and post-financial crisis of 2007-2009

Carol Bruce-Tagoe, MBA
cobrucetagoe@eiu.edu

Ingyu Chiou, Ph.D.
ichiou@eiu.edu

School of Business
Lumpkin College of Business and Technology
Eastern Illinois University
600 Lincoln Avenue
Charleston, IL 61920
U.S.A.

Abstract:

This paper studies the interdependence between the U.S. and four other developed stock markets in Canada, Japan, Sweden, and the UK. Specifically, we investigate how the 2007-2009 financial crisis influenced the dynamics of stock market integration among five developed countries by analyzing the short-run and long-run effects of the crisis over two sample periods: pre-crisis and post-crisis. We employ the Johansen co-integration test to verify cointegration and the Vector Error Correction Model (VECM) to examine the short-run and long-run relationships among five national stock markets. The results of co-integration tests confirm the presence of co-integration in both sample periods. The short-run VECM results indicate a significant influence of the U.S. market on four other markets in both periods, suggesting that little diversification benefits exist in the short-run. The pre-crisis long-run results demonstrate significant cointegrating relationships between the U.S. market and each of three markets (in Canada, Japan, and Sweden). The insignificant cointegrating relationship between the UK and U.S. markets in the pre-crisis period, however, becomes significant in the post-crisis period. In contrast, the Japanese stock market, which was initially cointegrated with the U.S. market in the pre-crisis period, loses its cointegrating relationship with the U.S. market in the post-crisis period. Overall, our findings confirm that major national equity markets are, to varying degrees, interdependent in both the short-run and long-run. We also find that a negative shock such as a financial crisis may significantly change the co-movements among national stock markets. Because of using recent data and studying the effects before and after the latest financial crisis, our research provides new evidence on financial market integration, thus making incremental contributions to the existing literature.

Keywords: Stock market integration; Financial crisis; Johansen cointegration analysis; Developed markets

1. Introduction

The 2007-2009 financial crisis, also known as the global financial crisis, is considered as the worst economic disaster since the U.S. Great Depression of the 1930s (Tong & Wei, 2008). According to the U.S. National Bureau of Economic Research (NBER), the recent U.S. recession began in December 2007 and ended in June 2009 (a total of about 19 months). The NBER defines a recession as a significant decline in economic activity, spreading across the economy. This decline, which normally lasts more than a few months, is visible in real GDP, real income, employment, industrial production, wholesaling, and retail sales (NBER, 2019).

The U.S. recession started in 2007 as a result of a crisis in the subprime mortgage market, which later spread into a full-blown international banking crisis with the collapse of Lehman Brothers (an investment bank) in September 2008. The great recession saw home prices fall, on average, approximately 30 percent by mid-2009 from their mid-2006 peak, while the S&P 500 Index fell about 57% by March 2009 from its October 2007 peak. The net worth of U.S. households and nonprofit organizations also fell from a peak of approximately $69 trillion in 2007 to a trough of $55 trillion in 2009 (Rich, 2013). Although the financial crisis originated from the U.S., its impacts were felt in many other countries around the world. For example, the European debt crisis took place afterwards.

Examining the effects of the U.S. financial crisis on other countries may tell us how national financial markets are interrelated. Stock markets in two countries could move together as a result of strong economic and financial ties between these countries. Majid and Kassim (2009) suggest that countries with similar macroeconomic policies could end up having highly correlated stock markets. Also, Lehkonen (2015) finds that integration is mostly affected by the institutional environment, financial openness, and global financial uncertainty, with these determinants varying slightly between emerging and developed markets. The 2007-2009 global financial crisis provides an opportunity to investigate how a financial crisis in one country affects other nations and their stock markets.

This study extends the existing literature in market integration by exploring the degrees of linkages between the U.S and other major developed stock markets with index prices denominated in one common currency, the U.S. dollar. Specifically, this paper differs from a lot of previous papers by analyzing the short-run and long-run linkage relationships between these stock markets before and after the 2007-2009 financial crisis. The results of our research offer suggestions to investors, who want to diversify their portfolio holdings in major national markets. A good understanding of the degree of co-movements among stock markets in both the short-run and long-run enables an investor to make informed decisions when creating a well-diversified portfolio.

The remainder of this paper is structured as follows: Section 2 discusses the relevant literature on market integration. Section 3 describes our data while section 4 focuses on methodology. Section 5 presents the empirical results and tests the robustness of our models. Section 6 summarizes major findings and discusses the implications of our study.

2. Literature Review

The advancement of information technology plays an essential role in lowering the cost of cross-border information flows, leading to more integrated capital markets. According to Arshanapalli and Doukas (1993), the relaxation of controls on capital movements and foreign exchange transactions, improvements in computer and communication technology, and expansion in the multinational operations of major corporations are among the factors that have resulted in the increasing flow of international investment. Investors, who are interested in efficiently allocating their assets across borders to diversify their portfolios to mitigate unsystematic risk and potentially increase returns, usually have an interest in the co-variation between two national stock markets. Therefore, the importance of studying the linkages between national stock markets has increased.

Investment theory suggests that investing in two markets, which are not positively and perfectly correlated, can help reduce the risk. In equilibrium, it may be difficult to make abnormal profits in the long-run through international portfolio diversification, but it is possible to make abnormal profits in the short-run. Although globalization can help investors achieve portfolio diversification, its positive effect, however, is reduced when it ends up increasing the correlations among national stock markets (Bouri and Yahchouchi, 2014). When investing globally, risks are spread around the world, benefiting investors in general. Hence, global financial market integration is supposed to lead to greater financial stability. Stiglitz (2010) argues that the financial crisis has cast doubt on the above conclusion. He suggests that greater financial integration tends to increase the risk of adverse contagion in the event of a large negative shock. As a result, full market integration may be less desirable than previously thought.

Most previous studies on stock market linkages do not cover the 2007-2009 financial crisis or tend to focus on the period before the 2008 recession in the U.S. Hamao, Masulis, and Ng (2002) study the short-run interdependence of prices and price volatility across three major international stock markets (London, New York and Tokyo). They find evidence of price volatility spillovers from New York to Tokyo, London to Tokyo, and New York to London. They, however, observe no price volatility spillover effects in other directions for the pre-October 1987 period. In investigating the volatility transmission of stock returns across Asia, Europe, and North America, Chiou (2011) finds strong evidence that the three stock markets are significantly interdependent, with the tie between London and New York being the strongest.

In a study on the linkages among stock prices in major national stock exchanges, using daily closing data from January 1980 through May 1990, Arshanapalli and Doukas (1993) find that the degree of international co-movements in stock price indices has changed significantly since the U.S. stock market crash in October 1987, with the Nikkei 225 Index being the only exception. Specifically, for the pre-crash period, the authors find that the stock markets in France, Germany, and UK are little related to the U.S. stock market. For the post-crash period, their results, however, show that the three major European stock markets are strongly linked to (or, co-integrated with) the U.S. stock market. Yamani (2013) investigates the impacts of the 1987 stock market crash and September 11, 2001 attack on the integration of equity markets by using data from G5 countries over the period 1986-2007. The results show that the equity

markets of these developed countries become less integrated after the stock market crash in October 1987, but more integrated after the September 11 attack in 2001. Overall, the results from the above studies show increasing integration over time among the stock markets in developed countries.

More recently, a few studies look into how the 2007-2009 U.S. financial crisis affected the linkages of selected stock markets before and during the crisis periods. Majid and Kassim (2009) employ the standard time series technique and vector autoregressive (VAR) framework to examine the effects of the 2007 U.S. sub-prime mortgage crisis on Indonesia and Malaysia by comparing the co-movements of their stock markets in the pre-crisis period and during the crisis period. Their results support the general view that stock markets tend to show a greater degree of integration during the crisis period than during the pre-crisis period. A greater degree of integration usually implies fewer diversification benefits from investing in those markets. Lehkonen (2015) studies the dynamics of stock market integration and its consequences during the 2007-2009 financial crisis for twenty-three developed markets and sixty emerging markets. The paper finds that integration increased slightly for emerging markets during the crisis, but decreased for developed countries. The author further argues that the high degree of integration propagated the crisis across the global financial markets in the beginning of the crisis, but it had little effect during the crisis.

Our paper is different from previous research in at least three aspects. First, we study how the U.S. stock market is linked to other developed stock markets, using more recent data that span over the period 1995-2018. Second, while some recent studies focus on the periods before and during the 2007-2009 financial crisis, our paper examines the periods before and after the crisis and explores the extent to which the recent crisis has impacted the market linkages both in the short-run and long-run. Finally, our methodologies include the Augmented Dickey-Fuller (ADF) test, the maximum likelihood approach, the Vector Error Correction Model (VECM), and so on.

3. Data and key statistics

The sample of this study covers the stock markets in five developed countries: London (main index: FTSE 100 Index), New York (main index: S&P 500 Index), Stockholm (main index: OMX Stockholm 30 Index), Tokyo (main index: Nikkei 225 Index), and Toronto (main index: S&P/TSX Composite Index) stock markets, respectively. We obtained daily price data from Bloomberg for all five stock market indices with the prices quoted in U.S. dollars to allow for comparable analysis and interpretations. The data set comprises of the daily prices of each stock market index from January 1995 to December 2018. The entire sample consists of 6,258 observations.

To investigate the linkage effects of the financial crisis on major stock markets before and after the crisis, we divide the dataset into 2 sub-samples: the pre-crisis period (January 1995 to November 2007) and the post-crisis period (July 2009 to December 2018). Hence, we exclude the period December 2007-June 2009. As a result, the pre-crisis and post-crisis periods consist of 3,367 and 2,479 observations, respectively. Having two sub-periods allows us to check

whether or not the cross-market linkages between the stock markets have changed after the financial crisis.

As in many time series studies in economics and finance, which transform the price level data into the log-form data, we take the natural log of each data variable. Using the natural log of a variable has at least two advantages. First, the log variable can deal with the issue of having positive skewness with a long right tail. Second, the log transformation can ease the problem of having a non-stationery mean and variance of a time series variable.

To provide an overview of the linkage relationships between the U.S. and four developed markets, we first calculate the correlation matrix, using the log-difference return data. Table 1 reports the correlation results for the pre-crisis period (January 1995 to November 2007).

Table 1 Pre-crisis period: Correlation matrix; N = 3,367 observations

	U.S.	Canada	Japan	Sweden	UK
U.S.	1.0000				
Canada	0.6261	1.0000			
Japan	0.0544	0.1668	1.0000		
Sweden	0.3549	0.4582	0.2358	1.0000	
UK	0.3764	0.4609	0.2014	0.6632	1.0000

As observed in Table 1, the U.S. market is positively correlated with each of four markets in the pre-crisis period. The U.S.-Canada pair has the highest correlation coefficient (0.6261), followed by the U.S.-UK pair (0.3764) and the U.S.-Sweden pair (0.3549). The Japanese market, however, shows a weak correlation (0.0544) with the U.S. market, suggesting that greater diversification benefits may result when a portfolio consists of stocks from these two countries.

Table 2 reports the correlation matrix for the post-crisis period (July 2009 to December 2018). The results show that all four developed stock markets are positively correlated with the U.S. stock market. The order of correlation coefficients is similar to that of the pre-crisis period. The U.S.-Canada pair has the highest correlation coefficient (0.7268), followed by the U.S.-UK pair (0.6038) and the U.S.-Sweden pair (0.5909). Again, the correlation between the Japanese and U.S. markets is the lowest with a correlation coefficient of 0.0455.

Table 2 Post-crisis period: Correlation matrix; N = 2,479 observations

	U.S.	Canada	Japan	Sweden	UK
U.S.	1.0000				
Canada	0.7268	1.0000			
Japan	0.0455	0.1272	1.0000		
Sweden	0.5909	0.6471	0.1413	1.0000	
UK	0.6038	0.6880	0.1798	0.8140	1.0000

When comparing the results in both pre-crisis and post-crisis periods, we find that, except the Japanese market, all other markets have increased, to varying degrees, their correlations with

the U.S. market. For example, the correlation coefficient between the Canadian and U.S. markets increases from 0.6261 to 0.7268. Also, for a U.S. investor to gain more diversification benefits, the Japanese market is the best choice among the four developed stock markets.

Although the correlation coefficient is helpful in establishing the linear relationship between two variables, it does not account for time variation (Paramati, Roca, & Gupta, 2016). We, therefore, undertake a more rigorous analysis in the next section.

4. Methodology

The empirical framework of this study involves a few tests. First, we use the Augmented Dickey-Fuller (ADF) test to examine each time series for stationarity or the presence of a unit root. Second, we test cointegration among the stock markets, using the maximum likelihood approach of Johansen and Juselius (1990). Finally, we employ the Vector Error Correction Model (VECM) to estimate the equilibrium cointegration relationships and the speed of adjustments back to the equilibrium in the event of a shock.

4.1 Test for Stationarity

A time series is said to be non-stationary if its mean and variance are time-varying. A unit root test is normally conducted to determine whether or not a time series is stationary. Non-stationary time series data can result in spurious regressions with high R-squared values and little correlation between variables. Before running a VECM/VAR (Vector Auto Regression) system, there is a need for all variables to be integrated in the order of 1, i.e., I(1). We employ the Augmented Dickey-Fuller (ADF) test, suggested by Said and Dickey (1984), which assesses whether or not a unit root is present in a time series. The ADF test is preferred over the standard Dickey-Fuller (DF) test because the ADF test can be used even when a serial correlation exists in a time series. The general ADF test model is stated as:

$$\Delta y_t = \alpha + \mu T + \rho y_{t-1} + \Sigma_{i=1 \text{ to } k} \gamma_i \Delta y_{t-i} + \varepsilon_i$$

Where $\mathbf{y}_t$ is a time series variable and Δ is the difference operator. The null hypothesis of the ADF test is the presence of a unit root ($\rho = 0$) or non-stationarity in a time series variable (i.e., a stock market index). The time series variable is stationary if ρ is negative and significantly different from zero. We conduct the ADF test for each of all stock market indices.

4.2 Test for Cointegration

After implementing the unit root tests and making sure that all time series are integrated in the same order (I(1) in this case), we conduct a cointegration test on all stock market indices. This method was developed by Johansen and Juselius (1990) to assess long-run relationships between variables. The method applies a maximum likelihood procedure to determine the presence of cointegrating vectors in a set of non-stationary time series. The null hypothesis is that there is no cointegration between the national stock index series. The presence of cointegration suggests that although all the time series are individually nonstationary, I(1), their

linear combination is stationary, I(0). We can, therefore, infer that our time series sample will not drift apart in the long-term and any short-term drift will be reverted to the equilibrium level.

Johansen (1991) adopts the Trace Test and Maximum Eigenvalue test statistic to ascertain the number of cointegration equations in a model. The Trace Test evaluates the null hypothesis of no cointegration versus the alternative hypothesis of cointegration. Under the eigenvalue test, the null hypothesis is *r* cointegrating vectors against the alternative hypothesis of (r + 1) cointegrating vectors.

4.3 Vector Error Correction Model

After cointegration is established between time series variables, we proceed to explore the long-run relationships between these national stock markets as well as the short-run error corrections. A vector error correction model (VECM) is used to detect the long-run relationships that may exist among the variables. The advantage of this model is that all variables are treated as endogenous and tests relating to the long-run parameters are possible. By running the VECM, we can estimate the error-correction equations. The Johansen error correction model is stated as follows:

$$\Delta X_t = \mu + \Sigma_{i=1 \text{ to } k-1} \Gamma_i \Delta X_{t-i} + \Pi_i X_{t-1} + \varepsilon_t$$

Where

Δ = the first difference operator
I = identity matrix, whose rank determines the number of distinct cointegrating vectors
X_i = (n x 1) vector of all the non-stationary indices in our study
Γ_i = (n x n) matrix of coefficients, which represents short run dynamics
Π = (n x r) matrix of r cointegrating vectors, so that $0 < r < n$. This is what represents the long-run cointegrating relationship between the variables.
ε_t = multivariate random error

5. Results and discussions

5.1 Stationarity test

Before conducting the Augmented Dickey-Fuller (ADF) test, the appropriate trend lag to make the time series stationary is investigated, using the following information criteria: Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC).

In Table 3, the results of the ADF tests indicate the presence of a unit root in the log-level form for all market indices in the whole sample (pre-crisis period and post-crisis period). After taking the first difference, all five stock market indices, however, become stationary in both sub-periods. The null hypothesis of a unit root in the first difference is thus rejected, suggesting that each index series becomes stationary individually when it is integrated of order one, I(1).

Table 3: ADF unit root tests on time series with a trend

Country	Variable	Pre-Crisis		Post-Crisis	
		Levels	First diff.	Levels	First diff.
U.S.	LnUS	-2.343	-42.643 ***	-3.936	-35.204***
Canada	LnCAD	-1.412	-31.771 ***	-3.763	-28.742 ***
Japan	LnJPN	-1.456	-43.230 ***	-3.508	-30.437***
Sweden	LnSWD	-1.77	-41.920 ***	-3.714	-36.328***
UK	LnUK	-1.608	-29.603 ***	-3.546	-35.526***

*** indicate $p < 0.01$; ** indicate $p < 0.05$; * indicates $p < 0.1$

5.2 Cointegration Test

Since all the stock index series are integrated of order one, I(1), the precondition for cointegration is established. The appropriate lag length for the independent variable in both the Johansen cointegration test and VECM (vector error correction model) can be determined by the VAR (vector autoregression) lag order selection criteria such as the SBIC (Schwarz's Bayesian information criterion) and HQIC (Hannan and Quinn information criterion). After selecting the lag length for the independent variable, we can proceed to estimate the Johansen cointegration equation.

In Table 4, the trace and maximum eigenvalue statistics for the pre-crisis period indicate the existence of one cointegrating equation at the 5% level of significance between the U.S. and four developed stock markets.

Table 4 Pre-crisis period: Cointegration test

Maximum Rank	Eigenvalue	Trace Statistic	5% Critical Value
0		70.5630	68.52
1	0.01114	32.8753*	47.21
2	0.00586	13.0907	29.68
3	0.00244	4.8654	15.41
4	0.00140	0.1381	3.76
5	0.00004		
# of observations	3365	Lags	2

Asterisk (*) – establishes presence of cointegration

In Table 5, the trace and maximum eigenvalue statistics for the post-crisis period indicate the existence of one cointegrating equation at the 5% level of significance between the U.S. and developed stock markets. The results of the two cointegration tests, therefore, confirm that there is a cointegrating relationship among five stock market indices over the two sample periods.

Table 5 Post-crisis period: Cointegration test

Maximum Rank	Eigenvalue	Trace Statistic	5% Critical Value

0		70.7802	68.52
1	0.01004	45.8061*	47.21
2	0.00934	22.5785	29.68
3	0.00645	6.5602	15.41
4	0.00235	0.7420	3.76
5	0.00030		
# of observations	2476	Lags	3

Asterisk (*) – establishes the presence of cointegration

5.3 VECM (Vector Error Correction Model) results

After establishing the presence of cointegration between the U.S. and developed markets, we proceed to estimate the VECM (Vector Error Correction Model), which captures both the short-run and long-run dynamics. The VECM treats all variables as endogenous. Because the U.S. market is the major variable of interest, we focus on the influence of the LnUS variable (independent variable in log) on all the dependent variables in the columns of Tables 6 and 8. This helps establish the presence of a significant short-run relationship between the U.S. and other national stock markets. For the VECM to show long-term convergence after a shock, the coefficient of the speed adjustment needs to be negative and significant. We choose to normalize the U.S. variable since that is our focus. Due to the normalization process, the signs are reversed to enable proper interpretations of the long-run relationship.

Table 6 reports the short-run results. It shows that the Toronto (LnCAD), Tokyo (LnJPN), Stockholm (LnSWD), and London (LnUK) stock markets are significantly (at the 1% level of significance) influenced by the U.S. stock market in the short-run during the pre-crisis period (see the row of LnUS(t-1), lagged variable). The strong and positive relationships suggest that diversification benefits may not be achieved in the short-run between the U.S. and all other developed markets.

We also observe in Table 6 that none of the speed-adjusting coefficients (see the row of the speed djusting coefficient) appears to be both negative and significant. This result implies that in the event of a shock, all four developed markets will continue to move away from their long-run relationships with the U.S. market.

Table 6 Pre-crisis period: VECM short-run dynamics and error corrections

Columns 2-6: dependent variables in log

LnUS(t-1) = independent variable (lagged one period)

Variable	LnUS	LnCAD	LnJPN	LnSWD	LnUK
Speed adjusting coefficient	-0.00995***	-0.00403	-0.000792	0.0125***	0.0026
	(0.00284)	(0.00285)	(0.00393)	(0.0039)	(0.00274)
LnUS(t-1)	-0.014	0.154***	0.287***	0.515***	0.331***
	(0.0224)	(0.0225)	(0.031)	(0.0308)	(0.0216)
Observations	3,365	3,365	3,365	3,365	3,365

Standard errors in parentheses

*** indicate p < 0.01; ** indicate p < 0.05; * indicates p < 0.1

Table 7 reports the the long-run results for the pre-crisis period. Based on the normalization coefficient, the Toronto (LnCAD), Tokyo (LnJPN), and Stockholm (LnSWD) stock markets are significantly related to the U.S. market. Surprisingly, we do not observe a significant long-term relationship between the UK and U.S. stock markets. But this is consistent with the results of some previous papers.

Specifically, the Candian and Japanese stock markets are negatively cointegrated with the U.S. stock market because their normalization coefficients are positive. In contrast, the long-term relationship between the Sweden and U.S. markets is positive because of a negaive normalization coefficient (-0.9075).

Table 7 Pre-crisis period: VECM long-run relationships

A negaive normalization coefficient means a positive long-run relationship
A positive normalization coefficient means a negaive long-run relationship

Variables	LnUS	LnCAD	LnJPN	LnSWD	LnUK
Normalization Coefficient	1	0.3907***	0.3596***	-0.9075***	-0.2032
		(0.0618)	(0.0374)	(0.1134)	(0.1389)
Observations	3,365	3,365	3,365	3,365	3,365

Standard errors in parentheses
*** indicate p < 0.01; ** indicate p < 0.05; * indicates p < 0.1

Table 8 reports the short-run results for the post-crisis period, which are similar to those of the pre-crisis period reported in Table 6. As observed, there are strong relationships between the U.S. and other developed markets in a one-day period. If the LnUS(t-1) variable (lagged one period) increases by one unit today, the Ln(CAD) variable will increase by 0.142 unit the next day. In the case of LnUS(t-2) (lagged two periods), the Ln(CAD) variable in Day t is not affected by the LnUS(t-2) variable in Day t-2. This suggests that with the passing of time (2 days), the Canadian stock market becomes less responsive to the U.S, market, making it possible for some diversification gains.

Table 8 Post-crisis period: VECM short-run dynamics and error corrections

Columns 2-6: dependent variables in log
LnUS(t-1) = independent variable (lagged one period)
LnUS(t-2) = independent variable (lagged two periods)
Speed Adj Coeff = Speed adjusting coefficient

Variable	LnU.S.	LnCAD	LnJPN	LnSWD	LnUK
Speed Adj Coeff	-0.00123**	-0.00269***	0.0000731	-0.00214**	-0.00254***
	(0.000553)	(0.000641)	(0.000611)	(0.000864)	(0.000651)

LnUS(t-1)	0.0909***	0.142***	0.551***	0.358***	0.315***
	(0.031)	(0.0359)	(0.0342)	(0.0485)	(0.0365)
LnUS(t-2)	-0.0314	0.0602	0.213***	0.106**	0.0964**
	(0.0324)	(0.0376)	(0.0358)	(0.0507)	(0.0382)
# of observations	2,476	2,476	2,476	2,476	2,476

Standard errors in parentheses

*** indicate p < 0.01; ** indicate p < 0.05; * indicates p < 0.1

Table 8 also reports negative and significant coefficients of the speed adjustment for the Canadian, Sweden and UK markets. This suggests that any deviation from equilibriumin in these three markets will be reverted. Specifically, the speed adjusting coefficients of these three markets suggest that a short-run disequilibrium resulting from a shock is corrected toward the long-run cointegrating relationship at a speed of approximately 0.269%, 0.214% and 0.254% per day, respectively. In other words, in the event of a shock, 0.269%, 0.214% and 0.254% of the error or deviation is corrected daily towards the long-run equilibrium. The Japan stock market, however, continues to move away from its long-tun equilibrium relationship with the U.S. market.

Table 9 reports VECM (Vector Error Correction Model) long-run relationships for the post-crisis period. It is worth noting that the insignificant cointegrating relationship between the UK and U.S. markets in the pre-crisis period (in Table 7) becomes significant in the post-crisis period. Also, the Japanese stock market, which is cointegrated with the U.S. market in the pre-crisis period, shows no evidence of cointegration with the U.S. market in the post-crisis period. Finally, as in the pre-crisis period, the Canadian and Swedish markets maintain their long-run cointegration relationships with the U.S. market in the post-crisis period.

Table 9 Post-crisis period: VECM long-run relationships

Columns 2-6: dependent variables in log

A negaive normalization coefficient means a positive long-run relationship

A positive normalization coefficient means a negaive long-run relationship

Variables	LnUS	LnCAD	LnJPN	LnSWD	LnUK
Normalization Coefficient	1	1.8021*	-0.3702	-4.8361***	6.6283***
	.	(0.9988)	(0.5078)	(1.5186)	(1.9431)
Observations	2,476	2,476	2,476	2,476	2,476

Standard errors in parentheses

*** indicate p < 0.01; ** indicate p < 0.05; * indicates p < 0.1

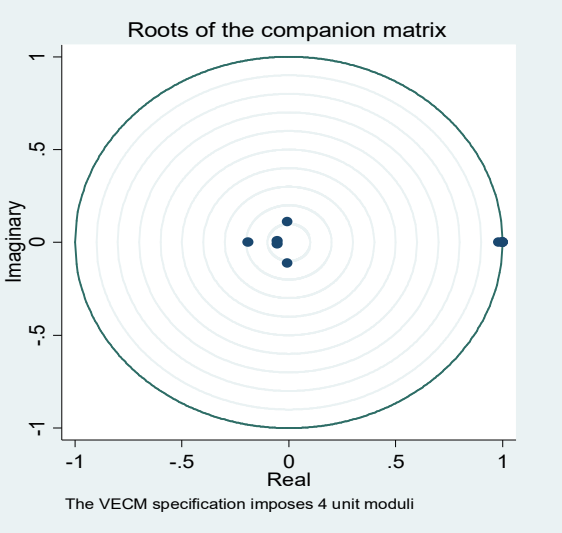
The results in Table 9 also have inplications for portfolio management. First, adding Canadian and UK stocks to a portfolio may reap substantial diversification gains in the long-run because these two markets have positive normalization coefficients and are negatively cointegrated with the U.S. market. Second, a portfolio of Japanese and U.S. stocks may yeild some diversification gains due to little or no cointegration between these two stock markets.

Finally, holding a portfolio of Swedish and U.S. stocks may accrue little diversification benefits due to the strong and positive cointegrattion between the Swedish and U.S. markets.

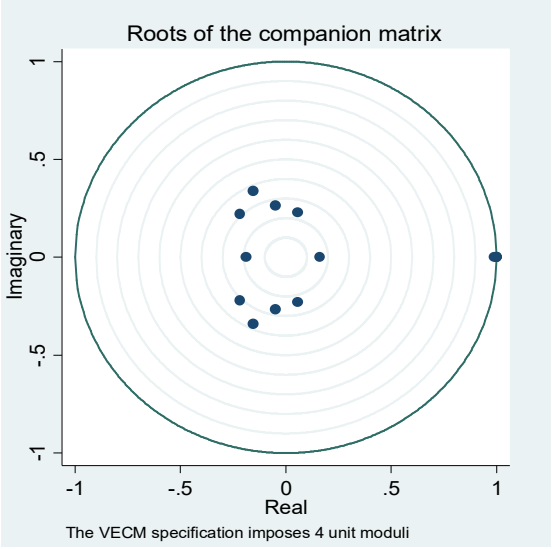
5.4 Stability Test

To check whether or not our models are dynamically stable, we plot the eigenvalues of the VECM coefficient matrix for each of two sample periods, as shown in Graphs 1 and 2. In both the pre-crisis and post-crisis periods, the moduli of the eigenvalues are within the unit cirlce. These results indicate that both VECM models are dynamically stable.

Graph 1 (Pre-crisis: VECM stability graph)



Graph 2 (Post-crisis: VECM stability graph)



6. Summary and conclusions

The 2007-2009 financial crisis, which originated from the U.S. due to its troubled mortgage market, affected many national stock markets. To better understand how the U.S. market affects other national markets in both the short-run and long-run, this paper employs the theory of cointegration to investigate the impact of the financial crisis on the dynamic interactions between the U.S. and four developed national stock markets in Canada, Japan, Sweden, and UK. We compiled daily stock market index prices in U.S. dollars to avoid the complication of dealing with the foreign exchange rate risk. To compare the linkage effects before and after the financail crisis, the dataset is divided into two samples: the pre-crisis period (January 1995 to November 2007) and the post-crisis period (July 2009 to December 2018), respectively.

The major findings of this paper are as follows. First, the unit root tests indicate that all five stock market indices are not stationary in the whole sample (the pre-crisis and post-crisis periods combined). After taking the first difference, all five stock market indices, however, become stationary, suggesting that each index series is integrated of order one, I(1). Second, cointegration tests establish that five stock markets are cointegrated in each of two time periods.

Third, in the short-run, the U.S. market significantly affects four developed markets (in Canada, Japan, Sweden, and UK) in both sample periods. Fourth, in the event of a shock (e.g., a financial crisis), all four developed markets continue to move away from their long-run relationships with the U.S. market in the pre-crisis period. In constrast, only the Japanese market moves away from its long-run relationships with the U.S. market in the post-crisis period. Fifth, the Canadian and Swedish markets maintain their long-run cointegration relationships with the U.S. market in both time periods.

Our results also have some implications for international portfolio management. Because the correlation between two national stock markets plays a key role in portfolio risk, being able to accurately forecast the correlation measure is key to success for a portfolio manager. One possible challenge is that the correlation between two markets may change due to a shock. For example, we do not observe a significant long-term or cointegrating relationship between the UK and U.S. stock markets before the financial crisis. But the cointegrating relationship between these two markets becomes significant after the crisis. Overall, our findings confirm that major national equity markets are, to varying degrees, interdependent both in the short-run and long-run. We also find that a negative shock such as a financial crisis may significantly change the co-movements among national stock markets.

In summary, this paper uses more recent data to investigate the dynamic linkages among five developed stock markets before and after the 2007-2009 financial crisis. Our research provides new evidence on financial market integration, thus making incremental contributions to the existing literature.

References

Arshanapalli, Bala and John Doukas, 1993, International stock market linkages: Evidence from the pre- and post-October 1987 period, *Journal of Banking and Finance* 17, 193-208.

Bouri, Elie and Georges Yahchouchi, 2014, Do return and volatility traverse the Middle Eastern and North African (MENA) stock markets borders? *Journal of Economic Studies* 41(2), 317–344.

Chiou, Ingyu, 2011, The volatility transmission of stock returns across Asia, Europe, and North America, *Managerial Finance* 37(5), 442–450.

Hamao, Yasushi, Ronald Masulis, and Victor Ng, 2002, Correlations in Price Changes and Volatility across International Stock Markets, *Review of Financial Studies* 3(2), 281–307.

Johansen, Soren, 1991, Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models, *Econometrica* 59(6),1551-1580.

Johansen, Soren and Katurina Juselius, 1990, Maximum Likelihood Estimation and Inference on Cointegration-- With Applications To the Demand for Money, *Oxford Bulletin of Economics and Statistics* 52(2), 169–210.

Lehkonen, Heikki, 2015, Stock Market Integration and the Global Financial Crisis, *Review of Finance* 19(5), 2039–2094.

Majid, Shabri Abd M. and Salina Hj Kassim, 2009, Impact of the 2007 U.S. financial crisis on the emerging equity markets, *International Journal of Emerging Markets* 4(4), 341–357.

National Bureau of Economic Research (NBER), 2019, U.S. Business Cycle Expansions and Contractions. Retrieved May 19, 2019, from NBER: https://www.nber.org/cycles.html

Paramati, Sudharshan R., Eduardo Roca, and Rakesh Gupta, 2016, Economic integration and stock market dynamic linkages: evidence in the context of Australia and Asia, *Applied Economics* 48(44), 4210–4226.

Rich, Robert, 2013, The Great Recession. Retrieved from Federal Reserve Bank of Cleveland: https://www.federalreservehistory.org/essays/great_recession_of_200709.

Said, Said E. and David Dickey, 1984, Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order, *Biometrika* 71(3), 599-607.

Stiglitz, Joseph E., 2010, Risk and Global Economic Architecture: Why Full Financial Integration May Be Undesirable, *American Economic Review* 100(2), 388–392.

Tong, Hui and Shang-Jin Wei, 2008, Real Effects of the Subprime Mortgage Crisis. National Bureau of Economic Research (NBER) Working Paper Series, 14205.

Yamani, Ehab, 2013, Stock Market Crashes and Integration: Empirical Evidence from G5 Countries, *SSRN Electronic Journal*.