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Contagion in International Stock Markets during the Sub Prime Mortgage Crisis

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ABSTRACT: The sub prime mortgages crises took place in July, 2007 in US which causes the large scare in the global financial markets, and the international stock and foreign market suffer heavy shock. Using twenty international stock indexes, this study examines whether any contagion effect occurred across international markets after the sub-prime financial mortgage crisis in US. Using the heteroscedasticity biases based on correlation coefficients to examine the existence of the contagion effect, this study shows that stock markets of some countries (namely Hong Kong, Taiwan, Australia and New Zealand) did suffer from the contagion effect.

Keywords: Contagion effect; Sub prime mortgage; Correlation coefficients; Stock markets, Financial crises
JEL Classification: F21, F32, G15

1. INTRODUCTION

The last two decades, bear witness to major financial disruptions roughly every three years, such as the US stock market crash in 1987, the savings and loan collapse and credit crunch in the early 1990s, the 1994 Mexican peso devaluation, the Asian financial crises in 1997, the Russian default and Long Term Capital Management implosion in 1998, the Brazilian devaluation in 1999, the bursting of the technological bubble in 2000, the 2002 post-Enron deflationary pressures in the credit markets, and the 2007 sub-prime mortgages crises in US. These crises caused heavy shock in the financial market of those countries, and potentially these events had influenced reverberating across the financial markets of different countries.

The sub-prime mortgage financial crisis of 2007 was a sharp rise in home foreclosures which accelerated in the United States in the fall of 2006 and triggered a global financial crisis between 2007 and 2008. The crisis began with the bursting of the US housing bubble and high default rates on "subprime". The share of sub-prime mortgages to total originations increased from 9% in 1996 to 20% in 2006. Further, loan incentives including interest repayment terms and low initial teaser rates (which later reset to higher, floating rates) encouraged borrowers believing they would be able to refinance at more favorable terms later. While US housing prices continued to increase from 1996 to 2006, refinancing was available. However, once housing prices started to decrease slowly from 2006 to 2007. In many states of the US, refinancing became more difficult. Defaults and foreclosure activity increased dramatically. By October 2007, 16% of sub-prime loans with adjustable rate mortgages (ARM) were 90-days into default or in foreclosure proceedings, roughly triple the interest rate of 2005. Sub-prime ARMs only represent 6.8% of the loans outstanding in the US, yet they represent 43.0% of the foreclosures started during the third quarter of 2007. Major banks and other financial institutions around the world have reported losses of approximately US $379 billion by May in 2008. The sub-prime mortgage financial crisis in 2007 caused heavy damage to businesses and the economy in the US. The US stock market declined significantly from the crisis, the also causes the large scare in the global financial markets, and the international stock market suffer heavy shock. Therefore, the main purpose of this study is to examine whether any contagion effect occurred among financial markets after the sub-prime mortgages crisis.

This paper, adopts the definition of contagion write introduced by Forbes and Rigobon (2002). It is defined as a significant increase in market co-movement after a shock for one country. According to

this definition, contagion does not occur if two markets show a high degree of co-movement during both stability and crisis periods. According to the previous findings, during international financial crises, financial markets are characterized by largely decreasing in asset prices, increasing in market volatility, and hence co-movements in asset price among markets. The sizes of these co-movements have led many economists to raise the question of whether crises periods are interpreted as different regimes in the international transmission of financial shock. Many studies have written about the propagation mechanisms of these crises. In particular, they have focused on the questions whether the relationships between markets in tranquil periods are different from those in crisis periods.

The funds of the world can freely flow through international trades in the economic globalization periods. Forbes (2002) finds that international trade linkages allow country-specific crises to spread over financial markets around the world. Bordo et al. (2001) show that global crises become more frequent since 1973 and they find that one reason for the increased frequency of crises is an increase in capital mobility. Internationally, capital market liberalization facilitates a greater flow of funds to emerging markets around the world. The wide-ranging financial deregulation makes much easier for banks and domestic corporations to tap into foreign capital to finance domestic investments. Such an evolution helps agents to reduce the risk of their assets by spreading their portfolios more widely, and creates new markets for domestic investments, which is no more bounded by national saving. Nevertheless, the also induces a rapid rise in financial flows, which lead to a higher risk of financial instability. Therefore, when large international crisis occurs, the international financial markets often influence each other.

The remainder of this paper is organized as follows. Section 2 presents the related literature on contagion effects. Section 3 describes the data and methodology. Section 4 then discusses the empirical results. Finally, section 5 summarizes the findings and presents conclusions.

2. THE RELATED LITERATURE ON CONTAGION EFFECTS

2.1 Contagion definitions

Not all economists confer about how to measure contagion effects. The World Bank classification uses three definitions of contagion[1]: First, broad definition: contagion is identified with the general process of shock transmission across countries. This definition is supposed to work during both tranquil and crisis periods, and contagion is associated not only with negative shocks, but also with positive spillover effects. Second, restrictive definition: contagion involves the propagation of shocks between two countries in excess of what should be expected based on the fundamentals and considering the co-movements triggered by common shocks. If this definition of contagion is adopted, it is necessary to be aware of what constitutes the underlying fundamentals. Otherwise, it is impossible to effectively appraise whether excess co-movements have occurred and whether contagion is displayed. Third, very restrictive definition: contagion should be interpreted as the change in the transmission mechanisms that takes place during a period of turmoil, and it can be inferred based on a significant increase in the cross-market correlation. As we have said, this is the third definition that will be used in this paper.

2.2 The relative literature on contagion

Forbes and Rigobon (2002) define contagion as a significant increase in market co-movement after a shock to one country. According to this definition, if two markets display a high degree of co-movement during periods of stability, even if the markets continue to be highly correlated following a shock to one market, this may not constitute contagion. According to the definitions used in this study, contagion only exists if cross-market co-movement increases significantly after the shock being considered. If co-movement does not increase significantly, then continued high level of market correlation suggests strong linkages between the two economies that exist in all countries in the world. This study uses the term "interdependence" to describe this situation.[2]

Forbes and Rigobon (2002) define contagion as a significant increase in market co-movement after a shock occurred in one country. According to this definition, if two markets display a high degree of co-movement during periods of stability, even if the markets continue to be highly correlated following a shock occurred in one market, this may not constitute contagion. According to the

[1] Source: www1.worldbank.org

[2] Please see Forbers and Rigobon (2002).

definitions used in this study, contagion only exists if cross-market co-movement increases significantly after the shock being considered. If co-movement does not increase significantly, then continued high level of market correlation suggests strong linkages between the two economies that usually exist in most countries of the world. This study uses the term "interdependence" to describe this situation.

Current studies on contagion offer many methods to measure the propagation of international shocks across countries. Some of the more widely used processes include cross-market correlation coefficients procedures (e.g., King and Wadhwani, 1990; Lee and Kim, 1993), volatility analysis assuming an ARCH and GARCH models (e.g., Hamao et al. 1990; King et al. 1994; Bekaert et al. 2005; Brailsford et al. 2006; Saleem, 2009) , techniques looking at changes in the cross-market co-integrating vectors (e.g., Longin and Solnik, 1995; Kanas, 1998; Yang and Bessler, 2008), and direct estimation of specific transmission mechanisms (e.g., Forbes, 2000; Ang and Bekaert, 2001).

For measure of contagion, previous empirical studies focus on the change of correlation coefficient between two markets during stability and turmoil periods. For example, King and Wadhwani (1990) examine the stock market correlations among the US, the U.K., and Japan and find that cross-market correlations were increased significantly after the US market crash in 1987. Lee and Kim (1993) extend similar analysis to twelve major markets and find evidence of contagion in global stock markets after US market crash in 1987. They show that cross-market correlations are increased for many emerging markets during the crisis. Baig and Goldfajn (1999) use a similar methodology to test for contagion in the Asian markets and find clear evidence of contagion in the currency and sovereign bond markets only.

Forbes and Rigobon (2002) use heteroscedasticity bias tests for contagion basing on correlation coefficients, and their empirical findings indicated little evidence of contagion between stock markets after the US stock market crash of 1987, Mexican peso devaluation of 1994, and the Asian crisis of 1997. Collins and Biekpe (2003) also use F-R (2002) method to test contagion and found that most of the African markets, with the exception of Egypt and South Africa, did not suffer from contagion during the crisis period, which resulted from the crash of the Hong Kong market in October 1997. Hon et al. (2004) also use this approach to test contagion in financial markets after the terrorist attack in the USA on September 11, 2001. Their results indicated that international stock markets, particularly in Europe, responded more closely to US stock market shocks for about three to six months after crisis. Caporale et al. (2005) use conditional correlation analysis to investigate contagion in the East Asian region during the 1997-1998 crisis periods. Their findings suggested there existed contagion in the East Asian region, and were consistent with crisis-contingent theories of asset market linkages. Corsetti et al. (2005) test contagion in financial markets using bivariate correlation analysis, and they found evidences of contagion for at least five countries during the Hong Kong stock market crisis of October 1997. Boyer et al. (2006) use two different methodologies to estimate correlations for testing the existence of contagion in the case of 1997 Asian crisis, and the results showed that there existed greater co-movements during high volatility periods, especially for accessible stock index returns, suggesting that crises spread through the asset holdings of international investors rather than through changes in fundamentals. Gravelle et al. (2006) estimate correlation from a regime-switching model to test contagion after the Mexican crisis of 1994, and their empirical results rejected the null hypothesis of no shift-contagion for a number of currency returns, especially for European countries, and found little evidence of shift-contagion in Latin American bond markets. Lee et al. (2007) use the heteroscedasticity biases based on correlation coefficients to examine the existence of the contagion effect after the strong earthquake in South-East Asia of 2004, this study shows that no individual country stock market suffered from the contagion effect, but that the foreign exchange markets of some countries (namely India, Philippines and Hong Kong) did suffer from the contagion effect.

Yang and Bessler (2008) This study investigates financial contagion among seven international stock markets around the October 19, 1987 crash, and the results clearly show that the crash originated in the US market and that an upward movement in the Japanese market after the crash helped the recovery in the US market, which has not yet been empirically documented in the literature. Khan and Park (2009) this paper presents empirical evidence of herding contagion in the stock markets during the 1997 Asian financial crisis, above and beyond macroeconomic fundamental driven comovements, and the paper finds strong evidence of herding contagion. Ahlgren and Antell (2010) this paper proposes to use cobreaking to model comovements between stock markets during the

terrorist attack crises in the USA on September 11, 2001 and to test for contagion. The paper finds evidence of short-term linkages during times of crisis but not contagion. These short-term linkages have important implications for investors, risk managers and regulators. Saleem (2009) this study considers the linkage of the Russian equity market to the world market, examining the international transmission of the Russia's 1998 financial crisis, They find evidence of direct linkage between the Russian equity market with regards to returns and volatility, while the weakness of the linkage suggests that the Russian equity market was only partially integrated into the world market. At the time of the crisis, evidence of contagion is clear. Longstaff (2010) the study empirical investigation into the pricing of subprime asset-backed collateralized debt obligations (CDOs) and their contagion effects on other markets. The paper finds strong evidence of contagion in the financial markets. The results support the hypothesis that financial contagion was propagated primarily through liquidity and risk-premium channels, rather than through a correlated-information channel. Kim et al. (2010) the study empirical the turmoil of 2007–2009, troubles in a small segment of the US mortgage market escalated into a crisis of global proportions. The paper find that valuation losses on CDS contracts for these Asian borrowers arose in part from movements in global and region-specific risk pricing factors as well as from revisions to expected losses from defaults. Yilmaz (2010) this article examines the extent of contagion and interdependence across the East Asian equity markets since early 1990s and compares the ongoing crisis with earlier episodes. They show that there is substantial difference between the behavior of the East Asian return and volatility spillover indices over time. While the return spillover index reveals increased integration among the East Asian equity markets, the volatility spillover index experiences significant bursts during major market crises, including the East Asian crisis. Fidrmuc and Korhonen (2010) the paper analyze the transmission of global financial crisis to business cycles in China and India. They find wide differences for different frequencies of cyclical development. More specifically, at business cycle frequencies, dynamic correlations are typically low or negative, but they are also influenced most by the global financial crisis. Finally, they find a significant link between trade ties and dynamic correlations of GDP growth rates in emerging Asian countries and OECD countries.

3. DATA AND METHODOLOGY

3.1. Data

This study investigates the correlations between the returns of the US daily stock index returns and 20 other international stock indexes returns. Taking the US equity markets as the base criterion, this study investigates whether co-movements among national stock markets are significantly strengthened after sub-prime mortgages crisis. The sample period is divided into two sections: the 12-month pre-crisis period (July 23, 2006 to July 22, 2007) and the 6-month post-crisis period (July 23, 2007, to January 22, 2008). The stable period is defined as the pre-crisis period, and the turmoil period is defined as the post-crisis period. To ensure robustness of the findings, the turmoil period is divided into three sections: the 1-month post-crisis period (July 23, 2007, to August 22, 2007) is defined as the short-term turmoil period, the 3-month post-crisis period (July 23, 2007, to October 22, 2007) is defined as the middle-term turmoil period, and the 6-month post-crisis period (July 23, 2007, to January 22, 2008) is defined as the long-term turmoil period. The data used in this study are taken from the 'international stock index of the Taiwan Economic Journal (TEJ) Database.

Table 1 presents GDP and stock market capitalization. As Table 1 shows that US is number one in the all sample countries rank of GDP and stock market capitalization. The evidence indicates that US has the great influence to the world economy.

Table 2 present daily returns on international stock indexes returns from July 23, 2006 to January 22, 2008. As Table 2 shows. That during the stable period all of the average daily returns for the international stock markets are positive. During the short-term, middle-term and long-term turmoil periods, international stock market returns are all negative, respectively. Additionally, the average daily returns of china stock market are positive in the full periods.

Table 1. GDP and stock market capitalization

Region	Country	GDP			Stock Market Capitalization		
		Million US dollars	Sample Rank	Word Rank	1000 million US dollars	Sample Rank	Word Rank
North America	US	13,811,200	1	1	13,712	1	1
	Canada	1,326,376	7	9	984	5	5
	Mexico	893,364	10	14	144	17	23
South America	Argentina	262,331	14	31	n.a.	n.a.	n.a.
	Brazil	1,314,170	8	10	260	13	17
	Chile	163,915	18	43	86	19	29
Europe	France	2,526,288	6	6	1,280	4	4
	Germany	3,297,233	3	3	896	6	6
	U.K.	2,727,806	5	5	2,559	3	3
North-East Asia	Japan	4,376,705	2	2	3,232	2	2
	Korea	969,795	9	13	357	11	14
East Asia	China	3,280,053	4	4	285	12	15
	Hong Kong	206,706	16	37	551	9	11
	Taiwan	397,965	13	22	432	10	13
South-East Asia	Indonesia	432,817	12	21	56	20	32
	Malaysia	180,714	17	38	145	16	22
	Philippines	144,129	20	46	20	22	37
	Singapore	161,364	19	45	177	15	20
	Thailand	245,818	15	34	89	18	28
Australia	Australia	821,716	11	15	666	7	8
	New Zealand	129,372	21	52	30	21	34

Soure：The GDP data form World Bank on 2007.The stock market capitalization form Dow Jones Global Index Statistics, www.djindexes.com on 2006.

3.2. Methodology

The variety of empirical methods developed for the analysis of contagion has the aim of testing the stability of parameters in the sphere of a chosen econometric model. Forbes and Rigobon (2002) points out four different methodologies, which have been utilized to measure how shocks are transmitted internationally, they are cross-market correlation coefficients; ARCH and GARCH models; cointegration techniques; and direct estimation of specific transmission mechanisms (such as probit model). According to Forbes and Rigobon (2002), GARCH model can provide important evidence that volatility is transmitted across markets, but most of the time does not explicitly test for contagion as defined in this paper. The cointegration techniques does not specifically test for contagion, since cross-market relationships over such long periods can increase for a number of reasons, such as greater trade integration or higher capital mobility. Finally, direct estimation of specific transmission mechanisms (such as probit model) only measure specific cross-market transmission channels, but do not explicitly test contagion for its existence. Here used the correlation coefficient method to solve problems, and Forbes and Rigobon (2002) points out this method is the most direct one.

The traditional approach used to demonstrate the effects of large international crises is to evaluate whether the correlation among international asset returns have changed. However, one problem with this approach is that crises typically increase the volatility of asset returns, which may induce a false or spurious estimated increase in correlation. While the methodologies presented above carry some imperfections, the data often suffer from heteroscedasticity, endogeneity and omitted variable problems. Some authors have tried to solve these problems in a similar way, although they have reached different conclusions in terms of contagion. Forbes and Rigobon (2002) develop a correlation analysis that adjusted correlation coefficients only for heteroscedasticity under the assumption of no omitted variables.

Table 2. Summary Statistics of Daily Returns on International stock Indexes Returns from July 23, 2006 to January 22, 2008

Region	Country	stable period $R_{(12M,0)}$	short-term turmoil period $R_{(0,1M)}$	middle-term turmoil period $R_{(0,3M)}$	long-term turmoil period $R_{(0,6M)}$
North America	US	0.0928%	-0.1883%	-0.0257%	-0.1139%
	Canada	0.0942%	-0.3542%	-0.0546%	-0.1537%
	Mexico	0.1971%	-0.3603%	0.0133%	-0.1270%
South America	Argentina	0.1358%	-0.5392%	-0.0127%	-0.1935%
	Brazil	0.1989%	-0.4635%	0.1058%	-0.0052%
	Chile	0.2007%	-0.2016%	0.0391%	-0.2225%
Europe	France	0.0799%	-0.3172%	-0.0677%	-0.1585%
	Germany	0.1417%	-0.2028%	-0.0100%	-0.1199%
	U.K.	0.0509%	-0.2447%	-0.0185%	-0.1024%
North-East Asia	Japan	0.0702%	-0.5900%	-0.1907%	-0.3178%
	Korea	0.1892%	-0.5070%	-0.0471%	-0.1576%
East Asia	China	0.3961%	0.9128%	0.5649%	0.0849%
	Hong Kong	0.1475%	-0.1559%	0.3327%	-0.0295%
	Taiwan	0.1729%	-0.4975%	-0.0233%	-0.1710%
South-East Asia	Indonesia	0.2541%	-0.5755%	0.0819%	0.0928%
	Malaysia	0.1694%	-0.4020%	-0.0276%	-0.0087%
	Philippines	0.2165%	-0.6466%	-0.0110%	-0.0772%
	Singapore	0.1790%	-0.3191%	0.0116%	-0.1739%
	Thailand	0.1035%	-0.3621%	0.0279%	-0.1119%
Australia	Australia	0.1123%	-0.3035%	0.0493%	-0.1517%
	New Zealand	0.0859%	-0.2932%	0.0016%	-0.1409%

Note: New York DJ. Stock Index (US), Toronto 300 Stocks Index (Canada), Mexico IPC Index (Mexico), Argentina MERYAL Index (Argentina), Brazil BOYESPA Index (Brazil), Chile IGPA Index (Chile), France Paris CAC40 Index (France), Frankfurt-Commerzbk. Index (Germany), London-FTSE-100 Index (U.K.), Nikkei 225 Stock Index (Japan), South Korea-Stock Index (Korea), Shanghai Synthesis Stock Index (China), Hang Seng Index-Hong Kong (Hong Kong), TSE Weigh Stock Index (Taiwan), Indonesia JSX-Stock Index (Indonesia), Kuala Lumpur-Stock Index (Malaysia), Manila-Stock Index (Philippines), Strait Times Index-Singapore (Singapore), Bangkok Set Stock Index (Thailand), Sydney All Ordinaries Stock Index (Australia), Wellington NZSE-50 Index (New Zealand).

The empirical test on contagion in international financial markets adopts an adjustment to the conditional coefficient, as proposed by Forbes and Rigobon (2002). Forbes and Rigobon (2002) points out that there was a bias with conditional coefficient due to heteroscedasticity in market returns. An increase in market volatility biased the estimates of cross-market correlation coefficients.

Conditional correlation coefficients are measured as follows：

$$\rho = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \tag{1}$$

According to Forbes and Rigobon (2002) , the correlation coefficient is adjusted in the following way (see Appendix for proof) ：

$$\rho^* = \frac{\rho}{\sqrt{1+\delta\left[1-(\rho)^2\right]}} \tag{2}$$

where,

$$\delta = \frac{\sigma_{xx}^{h}}{\sigma_{xx}^{l}} - 1$$

which measures the change in high period volatility against the low period volatility.

To calculate the adjusted correlation coefficient, the turmoil period often used as the high volatility period and the stable period often used as the low volatility period. The following hypothesis is then tested

$$H_0 : \rho_t \le \rho_s$$

$$H_1 : \rho_t > \rho_s$$

ρ_t is the adjusted correlation coefficient during the turmoil period, and ρ_s is the adjusted correlation coefficient during the stable period. Compare the difference in correlations between stable and turmoil periods. Contagion is then measured by the significance of adjusted correlation coefficients in the turmoil period versus those of the stability period. If financial market contagion exists, co-movement during the turmoil period would be more obvious than that of the stable period. Where H_0 is the null hypothesis of no contagion and H_1 is the alternative hypothesis that contagion does indeed exist.

The utilize Fisher z transformations of correlation coefficient to test for pair-wise cross-country significance. Fisher z transformations convert standard coefficients to normally distributed z variables. Before testing, the ρ value must be transformed to a Zr value. The following hypothesis testing demonstrates：

$$H_0 : \rho_t \le \rho_s \Rightarrow H_0 : Z_{rt} \le Z_{rs}$$

$$H_1 : \rho_t > \rho_s \Rightarrow H_1 : Z_{rt} > Z_{rs}$$

where

$$Z_{rt} = \frac{1}{2}\ln(\frac{1+\rho_t}{1-\rho_t})$$

$$Z_{rs} = \frac{1}{2}\ln(\frac{1+\rho_s}{1-\rho_s})$$

$$Z = \frac{Z_{rt} - Z_{rs}}{\sqrt{\frac{1}{n_t - 3} + \frac{1}{n_s - 3}}}$$

where, n_t (n_s) are number of actual observe days during the turmoil (stable) period.

The critical value for the Fisher Z test at the one, five and ten percent level is 1.28, 1.65 and 1.96, respectively, so any test statistic greater than those critical values indicates contagion (C) , while any test statistic less than or equal to those critical values indicates no contagion (N).

4. EMPIRICAL RESULTS

4.1. Contagion effect after sub-prime crisis in the short-term turmoil period

Table 3 displays the conditional (unadjusted) and unconditional (adjusted) correlation coefficients for international stock indexes after sub-prime crisis. The cross-market correlations of stock index returns are compared with both stable period and short-term turmoil period during the sub prime mortgage crisis. As Table 3 shows, the cross-market conditional (unadjusted) correlations between US and most of the countries in the sample during the short-term turmoil period are larger than those during the stable period, with the exceptions of Chile, Germany, Philippines and Singapore. In addition, the volatilities of all of the stock index returns during the stable period exceeded those during the period of short-term turmoil. Contagion effects were observed for four stock markets (Canada, Taiwan, Australia and New Zealand), and those stock index returns experience significantly increases in unadjusted correlation of 1-month after the sub prime mortgage crisis.

As Table 3 shows, that the cross-market unconditional (adjusted) correlations between US and most of the countries in the sample during the short-term turmoil period are larger than those during the stable period, with the exceptions of Chile, Germany, Philippines and Singapore. After the correlation by adjustment, contagion effects were observed for six stock markets (Canada, Korea, Hong Kong, Taiwan, Australia and New Zealand), those stock index returns experience significantly increases in adjusted correlation of 1-month after the sub prime mortgage crisis. The test contagion effects by unconditional (adjusted) correlation more than two stock markets by conditional (unadjusted) correlation.

Table 3. The conditional (unadjusted) and unconditional (adjusted) correlation coefficients for international stock indexes after sub-prime crisis in the short-term turmoil period

Region	Country	**conditional (unadjusted) Correlation Coefficients**						**unconditional (adjusted) Correlation Coefficients**			
		Stable period		short-term Turmoil period				Stable period	short-term turmoil period		
		ρ	σ	ρ	σ	Z-test	Contagion	ρ*	ρ*	Z-test	Contagion
North America	Canada	0.5628	0.0075	0.7500	0.0132	1.443*	C	0.6703	0.8328	1.657**	C
	Mexico	0.6855	0.0106	0.7092	0.0184	0.198	N	0.7785	0.7983	0.224	N
South America	Argentina	0.5947	0.0119	0.6329	0.0252	0.263	N	0.7326	0.7655	0.322	N
	Brazil	0.7445	0.0135	0.8155	0.0232	0.785	N	0.8254	0.8794	0.858	N
	Chile	0.5104	0.0091	0.3919	0.0167	-0.641	N	0.6266	0.4998	-0.802	N
Europe	France	0.2721	0.0080	0.3968	0.0177	0.604	N	0.3877	0.5408	0.843	N
	Germany	0.3381	0.0086	0.3025	0.0136	-0.170	N	0.4117	0.3707	-0.208	N
	U.K.	0.3076	0.0068	0.4102	0.0203	0.507	N	0.4876	0.6136	0.781	N
North-East Asia	Japan	0.3986	0.0092	0.5511	0.0174	0.850	N	0.5130	0.6723	1.066	N
	Korea	0.4218	0.0091	0.6224	0.0274	1.199	N	0.6281	0.8097	1.666**	C
East Asia	China	0.0739	0.0197	0.3523	0.0203	1.263	N	0.0750	0.3570	1.281	N
	Hong Kong	0.4292	0.0101	0.6156	0.0225	1.112	N	0.5785	0.7591	1.434*	C
	Taiwan	0.2104	0.0088	0.6602	0.0238	2.489***	C	0.3337	0.8224	3.510***	C
South-East Asia	Indonesia	0.3912	0.0102	0.4622	0.0311	0.373	N	0.5960	0.6731	0.556	N
	Malaysia	0.4877	0.0083	0.6438	0.0183	0.995	N	0.6384	0.7807	1.253	N
	Philippines	0.5931	0.0133	0.5615	0.0307	-0.204	N	0.7457	0.7178	-0.258	N
	Singapore	0.5244	0.0097	0.4846	0.0244	-0.229	N	0.6988	0.6601	-0.309	N
	Thailand	0.2207	0.0154	0.3093	0.0217	0.410	N	0.2594	0.3602	0.479	N
Australia	Australia	0.4869	0.0076	0.8532	0.0187	3.161***	C	0.6583	0.9317	3.787***	C
	New Zealand	0.4054	0.0056	0.7105	0.0104	1.968**	C	0.5172	0.8089	2.368***	C

Note 1: This table shows the conditional (unadjusted) and unconditional (adjusted) cross-market correlation coefficients for US and 20 other stock indexes. The test statistics are derived from Fisher Z transformations. The stable period is defined as the 12-month pre-crisis period (July 23, 2006 to July 22, 2007). The short-term turmoil period is defined as the 1-month post-crisis period (July 23, 2007, to August 22, 2007). A "C" indicates that the test statistic is greater than the critical value, and contagion occurred. An "N" indicates that the test statistic was less than or equal to the critical value, and no contagion occurred.

Note 2:***Statistical significance at 1% level. **Statistical significance at 5% level. *Statistical significance at 10% level

4.2. Contagion effect after sub-prime crisis in the middle-term turmoil period

Table 4 displays the conditional (unadjusted) and unconditional (adjusted) correlation coefficients for international stock indexes after sub-prime crisis. The cross-market correlations of stock index returns are compared with both stable period and middle-term turmoil period during the sub prime mortgage crisis. As Table 4 shows the cross-market conditional (unadjusted) correlations between US and most of the countries in the sample during the middle-term turmoil period are larger than those during the stable period with the exceptions of Germany and Singapore. In addition, the volatilities of most of the stock index returns during the stable period exceeded those during the period of middle-term turmoil with the exceptions of China. Contagion effects were observed for seven stock markets (Canada, Japan, Hong Kong, Taiwan, Malaysia, Australia and New Zealand) , and those stock index returns experience significantly increases in unadjusted correlation of 3-month after the sub

prime mortgage crisis.

As Table 4 shows that the cross-market unconditional (adjusted) correlations between US and most of the countries in the sample during the middle-term turmoil period are larger than those during the stable period, with the exceptions of Germany and Singapore. After the correlation by adjustment, contagion effects were observed for nine stock markets (Canada, Argentina, Japan, Korea, Hong Kong, Taiwan, Malaysia, Australia and New Zealand) , and those stock index returns experience significantly increases in adjusted correlation of 3-month after the sub prime mortgage crisis. The test contagion effects by unconditional (adjusted) correlation more than two stock markets by conditional (unadjusted) correlation.

Table 4. The conditional (unadjusted) and unconditional (adjusted) correlation coefficients for international stock indexes after sub-prime crisis in the middle-term turmoil period

Region	Country	**conditional (unadjusted) Correlation Coefficients**						**unconditional (adjusted) Correlation Coefficients**			
		Stable period		middle-term Turmoil period				Stable period	middle-term turmoil period		
		ρ	σ	ρ	σ	Z-test	Contagion	ρ*	ρ*	Z-test	Contagion
North America	Canada	0.5628	0.0075	0.8038	0.0102	3.270***	C	0.6218	0.8443	3.517***	C
	Mexico	0.6855	0.0106	0.7376	0.0150	0.732	N	0.7459	0.7925	0.792	N
South America	Argentina	0.5947	0.0119	0.7009	0.0185	1.275	N	0.6780	0.7747	1.431*	C
	Brazil	0.7445	0.0135	0.8009	0.0206	0.973	N	0.8092	0.8555	1.049	N
	Chile	0.5104	0.0091	0.5122	0.0132	0.017	N	0.5815	0.5834	0.019	N
Europe	France	0.2721	0.0080	0.3207	0.0139	0.369	N	0.3493	0.4076	0.471	N
	Germany	0.3381	0.0086	0.2639	0.0105	-0.565	N	0.3690	0.2894	-0.618	N
	U.K.	0.3076	0.0068	0.3077	0.0151	0.001	N	0.4340	0.4341	0.001	N
North-East Asia	Japan	0.3986	0.0092	0.5454	0.0155	1.314*	C	0.4913	0.6453	1.587*	C
	Korea	0.4218	0.0091	0.5345	0.0201	1.014	N	0.5687	0.6849	1.333*	C
East Asia	China	0.0739	0.0197	0.2232	0.0182	1.059	N	0.0710	0.2317	1.141	N
	Hong Kong	0.4292	0.0101	0.6462	0.0197	2.145**	C	0.5530	0.7636	2.645***	C
	Taiwan	0.2104	0.0088	0.5453	0.0171	2.756***	C	0.2874	0.6718	3.588***	C
South-East Asia	Indonesia	0.3912	0.0102	0.4744	0.0219	0.710	N	0.5287	0.6197	0.943	N
	Malaysia	0.4877	0.0083	0.6625	0.0127	1.829**	C	0.5685	0.7381	2.084**	C
	Philippines	0.5931	0.0133	0.5943	0.0225	0.013	N	0.6918	0.6930	0.015	N
	Singapore	0.5244	0.0097	0.4221	0.0177	-0.915	N	0.6396	0.5324	-1.135	N
	Thailand	0.2207	0.0154	0.2671	0.0145	0.342	N	0.2145	0.2747	0.443	N
Australia	Australia	0.4869	0.0076	0.7086	0.0143	2.439***	C	0.6074	0.8092	2.908***	C
	New Zealand	0.4054	0.0056	0.6451	0.0079	2.331***	C	0.4660	0.7081	2.619***	C

Note1: This table shows the conditional (unadjusted) and unconditional (adjusted) cross-market correlation coefficients for US and 20 other stock indexes. The test statistics are derived from Fisher Z transformations. The stable period is defined as the 12-month pre-crisis period (July 23, 2006 to July 22, 2007). The middle-term turmoil period is defined as the 3-month post-crisis period (July 23, 2007, to October 22, 2007). A "C" indicates that the test statistic is greater than the critical value, and contagion occurred. An "N" indicates that the test statistic was less than or equal to the critical value, and no contagion occurred.

Note2:***Statistical significance at 1% level. **Statistical significance at 5% level. *Statistical significance at 10% level

4.3. Contagion effect after sub-prime crisis in the long-term turmoil period

Table 5 displays the conditional (unadjusted) and unconditional (adjusted) correlation coefficients for international stock indexes after sub-prime crisis. The cross-market correlations of stock index returns are compared with both stable period and long-term turmoil period during the sub prime mortgage crisis. As Table 5 shows, the cross-market conditional (unadjusted) correlations between US and less of the countries in the sample during the long-term turmoil period are large than those during the stable period, only China, Hong Kong, Taiwan, Indonesia, Malaysia, Philippines, Australia and New Zealand). In addition, the volatilities of most of the stock index returns during the stable period exceeded those during the period of long-term turmoil with the exceptions of Thailand. Contagion effects were observed for four stock markets (China, Taiwan, Australia and New Zealand) ,

those stock index returns experience significantly increases in unadjusted correlation of 6-month after the sub prime mortgage crisis.

As Table 5 shows, the cross-market unconditional (adjusted) correlations between US and lease of the countries in the sample during the long-term turmoil period are larger than those during the stable period, such as China, Hong Kong, Taiwan, Indonesia, Malaysia, Philippines, Thailand, Australia and New Zealand. After the correlation by adjustment, contagion effects were observed for five stock markets (China, Hong Kong, Taiwan, Australia and New Zealand) , and those stock index returns experience significantly increases in adjusted correlation of 6-month after the sub prime mortgage crisis. The test contagion effects by unconditional (adjusted) correlation more than one stock markets by conditional (unadjusted) correlation.

To sum up, this study finds that some international stock markets (such as Hong Kong, Taiwan, Australia and New Zealand) suffer contagion after the US sub-prime mortgages crises in 2007

Table 5. The conditional (unadjusted) and unconditional (adjusted) correlation coefficients for international stock indexes after sub-prime crisis in the long-term turmoil period

Region	Country	**conditional (unadjusted) Correlation Coefficients**						**unconditional (adjusted) Correlation Coefficients**			
		Stable period		long-term Turmoil period				Stable period	long-term turmoil period		
		ρ	σ	ρ	σ	Z-test	Contagion	ρ*	ρ*	Z-test	Contagion
North America	Canada	0.5628	0.0075	0.3911	0.0190	-2.005	N	0.7349	0.5602	-2.742	N
	Mexico	0.6855	0.0106	0.0755	0.0174	-6.841	N	0.7699	0.0966	-8.268	N
South America	Argentina	0.5947	0.0119	0.1305	0.0170	-4.959	N	0.6624	0.1554	-5.735	N
	Brazil	0.7445	0.0135	0.0267	0.0213	-8.363	N	0.8139	0.0335	-9.896	N
	Chile	0.5104	0.0091	0.2600	0.0156	-2.662	N	0.6136	0.3325	-3.306	N
Europe	France	0.2721	0.0080	0.2225	0.0141	-0.473	N	0.3515	0.2900	-0.614	N
	Germany	0.3381	0.0086	0.1745	0.0118	-1.573	N	0.3879	0.2033	-1.820	N
	U.K.	0.3076	0.0068	0.1749	0.0150	-1.264	N	0.4328	0.2551	-1.814	N
North-East Asia	Japan	0.3986	0.0092	0.3669	0.0182	-0.333	N	0.5216	0.4851	-0.438	N
	Korea	0.4218	0.0091	0.3713	0.0189	-0.537	N	0.5569	0.4993	-0.715	N
East Asia	China	0.0739	0.0197	0.3825	0.0206	2.946***	C	0.0756	0.3898	3.009***	C
	Hong Kong	0.4292	0.0101	0.5348	0.0234	1.235	N	0.5861	0.6938	1.644*	C
	Taiwan	0.2104	0.0088	0.4846	0.0181	2.825***	C	0.2949	0.6221	3.801***	C
South-East Asia	Indonesia	0.3912	0.0102	0.3916	0.0209	0.004	N	0.5198	0.5203	0.006	N
	Malaysia	0.4877	0.0083	0.5484	0.0121	0.744	N	0.5592	0.6208	0.847	N
	Philippines	0.5931	0.0133	0.6168	0.0199	0.335	N	0.6694	0.6920	0.377	N
	Singapore	0.5244	0.0097	0.3976	0.0171	-1.447	N	0.6330	0.4987	-1.781	N
	Thailand	0.2207	0.0154	0.2187	0.0149	-0.019	N	0.2173	0.2222	0.046	N
Australia	Australia	0.4869	0.0076	0.6682	0.0144	2.467***	C	0.6088	0.7775	2.974***	C
	New Zealand	0.4054	0.0056	0.5579	0.0079	1.788**	C	0.4660	0.6240	2.028***	C

Note1: This table shows the conditional (unadjusted) and unconditional (adjusted) cross-market correlation coefficients for US and 20 other stock indexes. The test statistics are derived from Fisher Z transformations. The stable period is defined as the 12-month pre-crisis period (July 23, 2006 to July 22, 2007). The short-term turmoil period is defined as the 6-month post-crisis period (July 23, 2007, to January 22, 2008). A "C" indicates that the test statistic is greater than the critical value, and contagion occurred. An "N" indicates that the test statistic was less than or equal to the critical value, and no contagion occurred.

Note2:***Statistical significance at 1% level. **Statistical significance at 5% level. *Statistical significance at 10% level

5. CONCLUSION

This study examines whether the sub-prime mortgage financial crisis of 2007 influenced the stability of the correlation structure in international stock markets. Heteroscedasticity biases based on correlation coefficients are used to test for the contagion effect, across 20 economies. The results indicate that six (Canada, Korea, Hong Kong, Taiwan, Australia and New Zealand) , nine (Canada, Argentina, Japan, Korea, Hong Kong, Taiwan, Malaysia, Australia and New Zealand) and five (China, Hong Kong, Taiwan, Australia and New Zealand) international stock markets displayed contagion for

one, three and six months after the sub-prime mortgage financial crisis of 2007 in US respectively. Those countries of suffer from the contagion effect, which Hong Kong, Taiwan, Australia and New Zealand are most significant.

The sub-prime crisis also places downward pressure on economic growth because fewer or more expensive loans decrease investment by businesses and consumer spending. The financial crisis caused the US stock market declined significantly, also causes the Asia-Pacific region stock market suffer contagion effect. In an economic perspective, the learned that US market influence Asia-Pacific markets performance when these developing or emerging markets were hit by financial crises. One of important results is that contagion effects are more obviously in developing or emerging financial markets than those in developed ones. Our results are similar to previous researches by Collins and Biekpe (2003), Ito and Hashimoto (2005), and Gravelle et al. (2006).

The apparent high correlation coefficients during sub prime crisis periods implies that investors gain from diversification by holding less investment portfolio consisting of diverse stocks from these suffering contagion countries. In other words, if the increase in cross-market correlations during market crashes exists as a real effect and should consider asset allocation and portfolio composition. The benefits of portfolio diversification will be severely limited during periods with high volatility and increased cross-market correlation, when, in fact, international portfolio diversification is needed most.

The results have important implications. That is, when the international major crisis takes place, majority of all the developing or emerging markets are easily affected. And the contagion effect of financial crisis may result from funds of the world can freely flow through international trades in the economic globalization.

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Appendix

Proof of Bias in Conditional Correlation

Assume x and y are stochastic variables that represent returns on different stock markets, and these returns are related according to the equation:

$$y_t = \alpha + \beta x_t + \varepsilon_t \tag{A1}$$

where, $E(\varepsilon_t) = 0$, $E(\varepsilon_t^2) = c < \infty$ (where c is a constant), and $E(x_t \varepsilon_t) = 0$

Note that these assumptions assume that there is no endogeneity or omitted variable. Other than these assumptions, it is not necessary to make any further restrictions on the distribution of the residuals. The further divide the sample data into two portions so that the variance x_t is lower in the first group (l) and higher in the second group (h). Because $E(x_t \varepsilon_t) = 0$ by assumption, OLS estimates of equation (A1) are consistent and efficient for both groups, so that $\beta^h = \beta^l$.

Next, define

$$1 + \delta \equiv \frac{\sigma_{xx}^h}{\sigma_{xx}^l} \tag{A2}$$

Then, according to equation (A1), the variance of y is:

$$\sigma_{yy}^h = \beta^2 \sigma_{xx}^h + \sigma_{ee} = \beta^2 (1+\delta)\sigma_{xx}^l + \sigma_{ee} = \left(\beta^2 \sigma_{xx}^l + \sigma_{ee}\right) + \delta\beta^2 \sigma_{xx}^l = \sigma_{yy}^l + \delta\beta^2 \sigma_{xx}^l$$

$$= \sigma_{yy}^l \left(1 + \delta\beta^2 \frac{\sigma_{xx}^l}{\sigma_{yy}^l}\right) \tag{A3}$$

and when this is combined (A3) with

$$\rho = \frac{\sigma_{xy}}{\sigma_x \sigma_y} = \beta \frac{\sigma_x}{\sigma_y} \tag{A4}$$

then

$$\sigma_{yy}^h = \sigma_{yy}^l \left[1 + \delta \left(\rho^l\right)^2\right] \tag{A5}$$

Therefore,

$$\rho^h = \frac{\sigma_{xy}^h}{\sigma_x^h \sigma_y^h} = \frac{(1+\delta)\sigma_{xy}^l}{(1+\delta)^{1/2} \sigma_x^l \left[1 + \delta\left(\rho^l\right)^2\right]^{1/2} \sigma_y^l} = \rho^l \sqrt{\frac{1+\delta}{1+\delta\left(\rho^l\right)^2}} \tag{A6}$$

As a result, the correlation coefficient is clearly an increasing function ofö δ. (Forbers and Rigobon (2002).