# Quantitative measurement of contagion effects during a Global Financial Crisis: Evidence from selected countries

by
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## Abstract

This paper investigates the existence and extent of contagion effects among international stock markets during the Global Financial Crisis (GFC), and if these financial contagion effects exist, it explores the differences of contagion effects in different sub-periods of pre, during, and post Global Financial Crisis. In a financial definition, the "domino effect" among international stock markets has been referred to as contagion, which draws much academic attention nowadays. Investigating contagion effects among stock markets helps us to study the inner relationship among global stock markets and to further prevent the devastating impact of similar catastrophes such as the Global Financial Crisis.

### 1.0 Introduction

This paper mainly aims to address whether the contagion effects among international stock markets exist in the US Subprime Mortgage crisis, and if the financial contagion existed, what are the differences of contagion effects in each of the sub-periods.

Masson (1998) concludes there are three types of contagion, including monsoonal effect, spillover effect and pure contagion. Monsoonal effect emphasises the attack which can affect the macro economy of all countries. It can be measured by the change of macro-economic variables. This paper takes CPI, Current account to GDP, Domestic Credit to GDP, Interest Rate, Money Supply to Total Foreign Reserve ($M_2$ $to$ Reserve) and Real Effective Exchange

Rate (REER) into consideration. The spillover effect explains how the crisis of one country can attack other countries, and generally there are two ways for a country to affect another: financial spillover and trade spillover. Since this paper sets stock index return as a dependent variable, only the trade spillover effect will be analysed. Moreover, the trade spillover effect is measured by a coefficient called $Trade_i$, which estimates the trade linkage between a specific country i and the "ground zero." Lastly, pure contagion always happens in analogous countries. If one country is in crisis, the intention of avoiding losses causes investors to stop investing in countries which are economically, politically or geophysically similar to the "ground zero" country. Thus, these behaviours cause other analogous countries to undergo financial crisis as well. This paper uses distances from a specific country to the USA on an economic-political coordinate axis and geographical coordinate axis to evaluate the effects of economic-political similarity and the effects of geographical similarity.

This paper applies the Vector Auto-regression model and DCC-MVGARCH model to estimate correlations among ten countries, including the USA, Canada, the UK, Germany, Japan, Korea, China, India, Australia and New Zealand. In order to obtain more accurate results, this paper takes four periods into consideration, including the pre-crisis period 2006, local breakout period 2007, international breakout period 2008 and after-crisis period 2009. Then, it uses weighted panel regression to conduct a further discussion on contagion channels of the subprime mortgage crisis. In order to check the validity of findings, this paper employs T-test and Z-test to test the existence of financial contagion. T-test is used to find out differences of mean, and Z-test is utilised to check differences of median.

Results indicate that both the VAR model and DCC-MVGARCH model suggest that correlation coefficients among stock markets in a pre-crisis period are low but increase dramatically during crisis. It supports the findings of Pesarau and Pick (2007), Arshanapalli and Doukas (1993), Reinhart and Calvo (1996) and Ang and Bekaert (2002). This low correlation also can be regarded as the measurement of financial contagion. Thus, it proves the contagion effects indeed exist in the US Subprime Mortgage crisis.

Then, from the Granger causality test and Impulse response function, it can be found that when the financial crisis is severe, the contagion effects are obvious, while when the economy recovers, the influential power of financial contagion would be lower. It may due to the feed back effects. The US subprime crisis derives from the USA. It not only has bad impacts on the US economy but also spreads to more countries and causes international

financial crisis. In return, the devastating crisis spreads back from other countries to the USA. The vicious circle accelerates effects of financial contagion and the global economic recession.

Thirdly, the DCC-MVGARCH model suggests that in the US Subprime Mortgage crisis, some developed countries like the UK act as intermediaries. Through them, the financial crisis can be transmitted to more countries. It proves that both linear contagion and cross contagion can be found in the US subprime mortgage crisis. This result is consistent with the finding of Longstaff (2010) that in the US Subprime Mortgage crisis, financial contagion spreads across markets. It also supports Chenguel (2014), who demonstrates the existence of contagion effects between developed and emergent markets.

Lastly, the panel weighted regression tests explain that the monsoonal effect, spillover effect and pure contagion existed in the US subprime mortgage crisis. It shows that overall global economy, trade linkage and economic-political similarities are transmission channels of financial contagion. This result is consistent with Glick and Rose (1999) and Kaminsky and Reinhart (2000). It is also partly in agreement with Eichengreen, Rose and Wyplosz (1996), who think trade linkage is more important than the political-economic environment in transferring financial crisis. However, this result is inconsistent with Hemandez and Valdes (2001), since they suggest that trade is not as important as the nature of the financial crisis and measurement method in transmitting crisis. These differences may be due to the sample size, since this paper only employs 10 countries as research targets. Besides that, it is only possible to collect annual trade data from the IMF, and the low frequency of data may lead to biases.

## 2.0 Literature Review

Since the public recognises the destructive force of financial crises, much work has been done on the formation mechanism theories of a financial crisis. The first theory in this area is proposed by Fisher (1933). He uses debt deflation to explain the formation mechanism of a financial crisis: it causes recessions and depressions in economic cycles. In order to liquidate debt and deposit currency, the public are willing to trade commodities with low prices. The decrease of commodity prices leads to a further fall of business value and raises the probability of bankruptcy. Then, companies tend to lower expenses and downsize their production capacity. As a result, the output of social profits will be lower and the

unemployment rate will be higher. After this, there will be a decrease in the nominal interest rates and growth in the real interest rate. All these lead the public to lose confidence in the economy and to further create a financial crisis.

Krugman (1979) raises the “first generation” currency crisis model. Based on the study of some small countries’ economies, he finds that due to incomplete macro-economic policies and fixed exchange rate systems, rational investors are able to forecast the changes of exchange rates. In order to avoid depreciation of domestic currency and get more profits from international financial markets, rational investors would short liquidate assets and long foreign currencies. Thus, their rational behaviours would pose an attack on the fixed exchange rate system and reduce total foreign reserves of the domestic country. For the purpose of preserving foreign reserves and limiting appreciation of the domestic currency, the government has to modify the existing fixed exchange rate system. Then, the crisis would take place. However, in his study, the non-linear analysis method cannot determine the exact crisis time of the fixed exchange rate system. In 1984, Flood and Garber employed another analysis method and completed the “first generation” currency crisis model.

Since the first generation currency crisis model does not analyse contagious currency crisis, it requires deeper insight into currency crisis. At the same time, the breakout of the European currency crisis in 1992 and the Mexico financial crisis in 1994 provide empirical evidence for further studies of currency crisis theories. Therefore, Obstfeld (1996) developed the “second generation” currency crisis model. He defines the new currency crisis model as a self-fulfilling currency crisis model. In this model, although the economic degradation is controlled, the public expectation of depreciation of the domestic currency is still able to cause financial crisis. Thus, the financial crisis is the result of public expectation of depression. As a main market participant, the government would analyse costs and public willingness to decide whether it is necessary to maintain a fixed exchange rate system. Different government strategies may lead to different public expectations and these expectations would further have diverse results.

In 1997, the Asian financial crisis took place. It pushed forward the development of the “third generation” currency crisis model. Without studying macro-economic policies and exchange rate systems, this model focuses on explaining the function of financial intermediaries and asset price changes on crisis formation mechanisms. Much empirical research contributes to

the “third generation” currency crisis model. McKinnon and Pill (1997) compare the Asian financial crisis with crises in Mexico and Chile and find that over-borrowing leads to crisis. Besides that, Radelet and Sachs (2000) investigated the Eastern Asian financial crisis in 1997, and their findings suggest that weaknesses of economy, policy missteps and accidents are responsible for financial panic, and the financial panic finally evolved into financial crisis. Chang and Velasco (2000) provide insight into the bank system and develop the banking crisis model.

### 2.1. Contagion mechanism theories of financial crisis

As contagion is the most important aspect of financial crisis, more research has been done on contagion mechanisms. For example, Allen and Gale (2000) give micro-economic foundations for financial contagion. They regard financial contagion as a kind of equilibrium phenomenon. In other words, when investors use bank loans rather than their own funds to invest in foreign liquidity stocks, the local bank requires overseas banks to provide insurance against the regional liquidity stocks. When the bank crisis takes place in one country, through the inter-linkage of international banks, the bank crisis would spread to other countries.

Instead of blaming international banks, King and Wadhwani (1990) explain the financial contagion results from rational expectations. Specifically, if investors were rational enough, they would be able to predict the movements of stock prices. Their investment activities have a huge influence on both local and international stock markets. When stock prices decrease in one country, rational investors would feel short similar stocks in other countries. As a result, the financial crisis in one country can be transmitted to other countries.

Unlike other researchers, Moser (2003) focuses on literature analysis. He summarises and compares recent empirical research on international financial contagion. His findings support the existence of diverse contagion mechanisms. He argues that both causes and results of different financial crises vary from each other. Despite this, researchers or governments should take differences of contagion mechanisms into consideration. Only after this would the analyses of financial contagion be exact and persuasive.

Masson (1998) suggests three contagion mechanisms in his work, including pure contagion, monsoonal effects and spillover effects. These three mechanisms refer to three contagion channels in financial crisis. Pure contagion explains the phenomenon that a crisis spreads

through countries' fundamentals, such as the similarities of countries. When one country has more similarities with another country, the probability of financial contagion between them would be higher. However, the monsoonal effects describe the external shocks on macro-economic indices of all countries. In addition to that, the spillover effects emphasise how a crisis can spread from one country to another. Both trade linkage and financial linkage cause spillover effects. More frequent cooperation and competition account for a higher spillover effect.

## 3. Data Collection

This paper collects data from three main sources: Datastream, The World Bank and the International Monetary Fund (IMF). It firstly gets daily price indices of S&P500 (USA), TSX60 (Canada), FTSE100 (UK), DAX60 (Germany), NIKKEI255 (Japan), KOSPI200 (Korea), SSE50 (China), CNX500 (India), ASX200 (Australia) and NZX50 (New Zealand). This paper selects ten countries, including the USA, the UK, Germany, Japan, Korea, China, India, Australia and New Zealand. These countries are the most representative countries of the Americas, Europe, Asia and Oceania. Studying them can explain the global influence of the US Mortgage Crisis and further reveal the international contagion channel of the crisis.

For this paper, the research target is the US Subprime mortgage crisis in 2008, which caused a international global financial crisis afterwards. In order to compare and analyse contagion effects among stock markets in the whole process of the financial crisis, the sample periods should include pre-crisis period, during crisis period (local breakout period and international breakout period) and after crisis period. Based on the above reasons, the whole period should be broken into four sub-periods, including pre-crisis period (2006), local breakout period (2007), international breakout period (2008) and after-crisis period (2009.).

### 3.1 Variable selection

Screening of variables are based on the following criteria:

1. Choosing daily stock price indices rather than monthly data: Daily data is more precise than monthly data. In modern financial markets, the exchange of information is very fast. The transmission of information will affect the financial contagion significantly. Thus, high-frequency trading data is required in this paper.

2. Selection of stock market in each country: Most of the target countries have more than one stock market. In order to simplify analysis, this paper only chose the most representative market in each country; for example, the choosing of the stock index of Shanghai stock exchange (SSE50) rather than index of the Shenzhen stock exchange, since the Shanghai stock exchange is the largest stock market in China. Most blue chips are traded in this stock market. Thus, SSE50 is more representative than other stock indices in Chinese stock markets. The reason to choose S&P500 rather than the Dow-Jones Average Index is that S&P500 consists of more companies than DJIA. Thus, the study of S&P500 is more appropriate for this paper.

3. Using the daily return of stock price indices as variable: the calculated formula is that

$$R_t = (P_t - P_{t-1})/P_{t-1}$$

$R_t$ is the daily return of stock indices; $P_t$ is the closing price of stock indices for day t; $P_{t-1}$is the closing price of stock indices for day t-1.

However, different countries have different holidays. During holidays, stock markets will not trade. Thus, it will lead to a problem that at the same time, there is a Non-Match Error of trading data. There are two methods to deal with this problem. The first one involves using moving average to replace missing data. The second one involves deleting missing data. In order to simplify calculation, this paper uses the second method to process missing data. After treating data, the sample size for each country is 1065.

In terms of macro-economic variables, this paper uses monthly data. More specifically, Inflation rate, Current account to GDP and Interest Rate are obtained from Datastream. Domestic Credit, Money Supply to Total Foreign Reserve ($M_2$ $to$ Reserve) and Real Effective Exchange Rate (REER) came from The World Bank. Moreover, the trading data is from the IMF (2011). Based on the discussion of Glick and Rose (1999), a country which is first attacked in a financial crisis can be regarded as “first victim” or “ground zero.” In the subprime mortgage crisis, the USA is believed to be “ground zero.” $Trade_i$ measures the trade linkage between a specific country i and the “ground zero,” which can be calculated as follows (Glick & Rose, 1999):

$$Trade_i \equiv \sum_k \{[\frac{x_{0k} + x_{ik}}{x_0 + x_i}] * [1 - |\frac{x_{ik} - x_{0k}}{x_{ik} + x_{0k}}|)]\}$$

Here, $x_{ik}$ is the aggregate bilateral export from country i to country k, and $x_i$ is the total aggregate bilateral export from country i, while $x_{0k}$ is the aggregate bilateral export from ground zero to country k and $x_0$ is the total aggregate bilateral export from ground zero. For the purpose of simplifying calculation, in this paper, country k denotes emerging countries and developed countries. Larger $Trade_i$ implies greater trade completion between ground zero and country i.

Then, the economic and political data are received from the global economic freedom index of The Heritage Foundation and Wall Street Journal and the geographical data comes from CSGnetwork. Specifically, the economic freedom index consists of property rights, freedom from corruption, fiscal freedom, government spending, business freedom, labour freedom, monetary freedom, trade freedom, investment freedom and financial freedom. Among all of them, property rights, freedom from corruption and government spending are regarded as political indices, while fiscal freedom, business freedom, labour freedom, monetary freedom, trade freedom, investment freedom and financial freedom are believed to be economic indices. This paper sets average economic indices as X and average political indices as Y to establish an economic-political coordinate axis. In terms of geographical data, this paper regards latitude as X and longitude as Y to set a geographical coordinate axis. Each country has its specific location on these coordinate axes.

In the subprime mortgage crisis, the USA was the first victim. Thus, this paper calculates distances between the USA and other countries on the economic-political coordinate axis and geographical coordinate axis. The equations can be written as: $D(ep)_i = \ln(\sqrt{(x_{epi} - x_{ep0})^2 + (y_{epi} - y_{ep0})^2}$, $D(g)_i = \ln(\sqrt{(x_{gi} - x_{g0})^2 + (y_{gi} - y_{g0})^2}$

Here, $D(ep)_i$ and $D(g)_i$ represent the distances from s specific country i to "ground zero" on economic-political coordinate axis and geographical coordinate axis respectively. $x_{epi}$, $x_{ep0}$, $y_{epi}$ and $y_{ep0}$ are x and y values of country i and "ground zero" on the economic-political coordinate axis. $x_{gi}$, $x_{g0}$, $y_{gi}$ and $y_{g0}$ are x and y values of country i and "ground zero" on the geographical coordinate axis.

## Results

### 5.1 Static Correlation analysis

Static Correlation analysis checks whether there is an excess increase in the correlation coefficient in each sub-period, which is the measurement to identify contagion effects of a stock market. If there is an excess increase in correlation coefficients, it can be regarded as financial contagion. Otherwise, the phenomenon is called stock prices co-movement.

Looking at the whole period, with the degeneration of the financial crisis, correlation coefficients between stock markets increase dramatically. [1] For example, the correlation coefficient between the US stock market and German stock market rose from 0.5588 in 2006 to 0.696 in 2009. The correlation coefficient between the US stock market and Australian stock market increased from 0.0462 to 0.165 during the whole period. Although the correlation coefficient between the US stock market and New Zealand stock market is low, it still has huge growth. All these phenomena prove that no matter where the stock market is and what regulations it has, it will be affected by other stock markets in a financial crisis. Based on the definition of the World Bank, if the correlation coefficient remains steady during the whole period, it can be viewed as co-movement of stock markets. However, if there is an excess increase in correlation coefficient, it can be treated as contagion. Thus, through the correlation analysis, it proves that the contagion existed.

However, the correlation analysis only measures linear relationships among stock markets. Since the stock indices are time-varying, the correlation coefficient among stock markets is changing all the time. Thus, it is necessary to construct a Vector Auto-regression to investigate the time-varying characteristics of stock correlation and to further explain the time-varying relationships among stock markets.

### 5.2 VAR model

#### 5.2.1 ADF test

Table 5 shows the results of the ADF test. In both sub-periods and the whole period, all test statistics are statistically significant at 0.01 and the null hypothesis is rejected. It illustrates that all stock indices during each period are stable. Thus, without establishing a difference

[1] Correlation tables are available upon request from the authors

equation, the Vector auto-regression can be constructed.

Table 5 ADF test statistics

| | USA | CANADA | UK | GERMANY | JAPAN | KOREA | CHINA | INDIA | AUSTRALIA | NZ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | -13.3239*** | -16.3234*** | -18.6443*** | -17.3818*** | -16.8999*** | -16.5381*** | -14.42423*** | -13.5375*** | -17.7436*** | -13.5962*** |
| 2007 | -19.0159*** | -18.3166*** | -17.7319*** | -16.0931*** | -15.9987*** | -15.7803*** | -16.84415*** | -15.1676*** | -17.5801*** | -15.6240*** |
| 2008 | -15.0320*** | -14.3314*** | -11.9389*** | -17.2305*** | -15.9445*** | -16.1672*** | -16.97096*** | -15.0249*** | -11.5461*** | -13.0901*** |
| 2009 | -18.1012*** | -17.2622*** | -17.0095*** | -16.4849*** | -17.3127*** | -16.4264*** | -15.73529*** | -15.8271*** | -16.5803*** | -14.8184*** |
| 2006-2009 | -27.4535*** | -26.4779*** | -16.1926*** | -33.8030*** | -32.7193*** | -32.3646*** | -32.61580*** | -30.0449*** | -34.0010*** | -24.3243*** |

* significant at 10% **significant at 5% ***significant at 1%

## 5.2. Granger causality test

Table 10 concludes the two-way causalities of countries in the whole period. It can be clearly seen that with the worsening of the financial crisis, more countries have causality relationships with other countries and the cross-country infection effects become more obvious. Causality relationships existed in all sub-periods, but they are more visible when the global financial crisis happened.

Table 10 Two-way causality relationship

| | sub-period 1 | sub-period 2 | sub-period 3 | sub-period 4 |
|---|---|---|---|---|
| USA | Canada India Australia NZ | India Australia | Canada UK Germany Korea Australia NZ | Germany Japan NZ |
| Canada | USA | NZ | USA UK Germany Japan India | India |
| UK | China | Japan Korea India | USA Canada India | |
| Germany | China | Japan | USA Canada | USA NZ |
| Japan | | UK Germany Korea | Canada Korea | USA |
| Korea | | UK Japan | USA Japan Australia NZ | |
| China | UK Germany | | | |
| India | USA | USA UK | Canada UK | Canada Australia |
| Australia | USA | USA | USA Korea | India |
| NZ | USA | Canada | Korea | USA Germany |

As the USA is the origin of the subprime mortgage crisis, this paper sorts all causality relationships between the US stock market and other stock markets during each sub-period. The results are shown in Table 11. Then, based on Table 11, this paper conducts an impulse response function to explore the further response effects of stock markets to the US shock.

Table 11 USA causality relationship

| | sub-period 1 | sub-period 2 | sub-period 3 | sub-period 4 |
|---|---|---|---|---|
| one-way | Canada UK Germany Japan Korea India Australia NZ | UK Germany Japan Korea China India Australia NZ | Canada UK Germany Japan Korea China India Australia NZ | UK Germany Japan Korea China India Australia NZ |

| | | | | |
|---|---|---|---|---|
| two-way | Canada India Australia NZ | India Australia | Canada UK Germany Korea Australia NZ | Germany Japan NZ |

5.3 Impulse response function

The impulse response function describes the reaction of one stock market in response to the US shock. This method is used to compare the response times and response levels of countries in each sub-period. Longer response and stronger response levels refer to higher response of countries.

According to Table 12, with the economic recession, the US stock market has stronger impulse force to influence other stock markets. In sub-period 3, the US stock market had the largest impulse force. This result supports the finding of the correlation analysis and Granger causality test. Sub-period 3 is regarded as the global financial tsunami, in which most international stock markets are affected, and the contagion effect in this period is strongest.

Table 12 The conclusion of impulse response function

| Period | Impulse length | Value rage |
|---|---|---|
| sub-period 1 | less than 8 days | `-0.002～0.008 |
| sub-period 2 | less than 9 days | `-0.004～0.01 |
| sub-period 3 | less than 11 days | `-0.01～0.025 |
| sub-period 4 | less than 8 days | `-0.004～0.016 |

**5.3 DCC-MVGARCH analysis**

5.3.5 DCC-MVGARCH correlation

As introduced in the methodology section, the DCC-MVGARCH model is constructed by two processes. Firstly, two univariate GARCH(1,1) models are established to obtain variances. Based on the ARCH test, all stock indices are believed to have autoregressive conditional heteroscedastic (ARCH) effects. Thus, GARCH(1,1) can be constructed; then, a multivariate model is constructed, which can be used to estimate DCC parameters and dynamic conditional correlations between stock indices.

Table 14 presents estimations of GARCH(1,1) parameters and DCC parameters. $b_1$ $b_2$ are the parameters of the GARCH(1,1) model: $h_t = b_0 + b_1 e_{t-1}^2 + b_2 h_{t-1}^2$ Specifically, $b_1$ is the first (lag 1) ARCH parameter, which measures the forecast volatility level. In addition to that,

$b_2$ is the first (lag 1) GARCH parameter. If $b_2$ is close to 1, the movements of the conditional variance are continuing for a long time. All GARCH(1,1) parameters are statistically significant at 0.01. In terms of stock indices, the India stock index has the highest level of forecast volatility and the US stock index is most persistent.

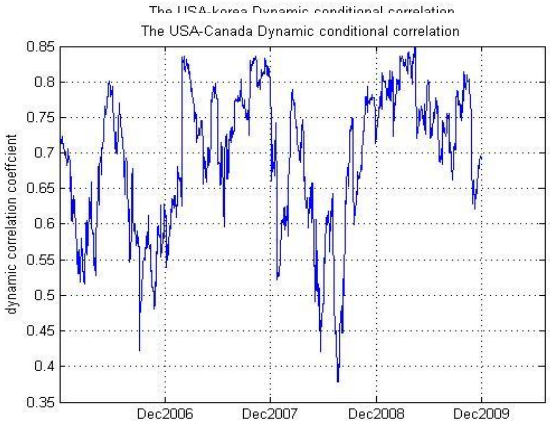
The DCC parameters have similar meanings to GARCH(1,1) parameters. In the subprime mortgage crisis, the ground zero country was the USA, which was first attacked by financial crisis. Thus, this test investigates dynamic conditional correlations between the USA and other countries. From Table 14, Japan, Korea, Australia and New Zealand have insignificant α. Low α implies the effects of the previous period's standardised residual on dynamic conditional correlation is small. Thus, the volatility of these countries is not spiky. Most countries have significant β. Higher β shows a higher degree of persistency of volatility. Thus, the conditional variance of the UK stock index is most persistent when it is attacked by the US subprime mortgage crisis. Looking at all DCC parameters, α+β measures the effects of US shock on pair-wise dynamic conditional correlations. Thus, from the DCC parameters, it can be inferred that the US shock has limited influence on the dynamic conditional correlations of Japan-USA, Korea-USA, Australia-USA and New Zealand-USA.

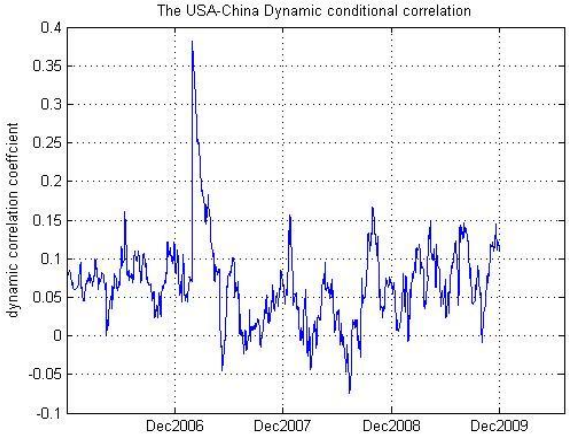
Table 14 GARCH(1,1) Parameters and DCC parameters

| | | | Ground Zero Country USA | |
|---|---|---|---|---|
| parameter | b1 | b2 | α | B |
| USA | 0.0871*** | 0.9056*** | - | - |
| Canada | 0.08734*** | 0.8999*** | 0.0396*** | 0.942*** |
| UK | 0.1218*** | 0.8763*** | 0.0081*** | 0.9886*** |
| Germany | 0.1149*** | 0.8748*** | 0.011*** | 0.9863*** |
| Japan | 0.1013*** | 0.8866*** | 0.00020148 | 0.3739*** |
| Korea | 0.0725*** | 0.9193*** | 0 | 0.0251 |
| China | 0.0768*** | 0.9175*** | 0.0151*** | 0.9396*** |
| India | 0.1477*** | 0.8530*** | 0.0056*** | 0.9876*** |
| Australia | 0.1168*** | 0.8698*** | 0 | 0.2791*** |
| New Zealand | 0.1121*** | 0.8547*** | 0 | 0.4446*** |

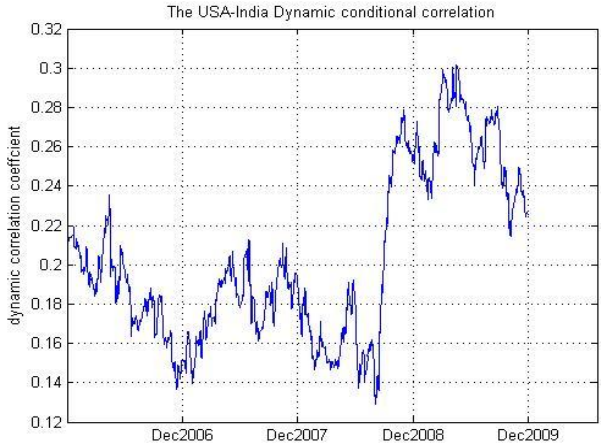
* significant at 10%, **significant at 5%, ***significant at 1%

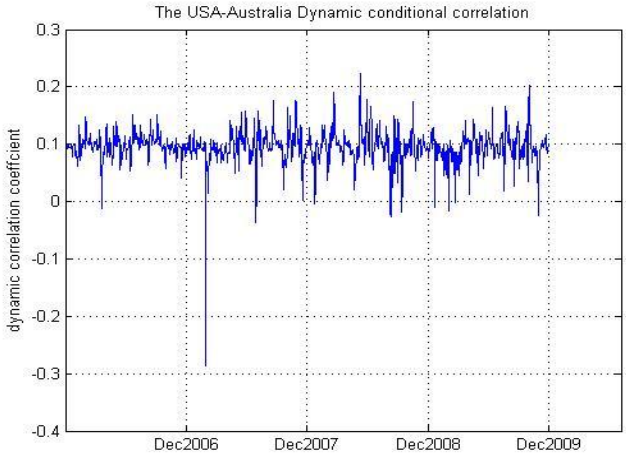
The results in Table 14 are supported by following figures of pair-wise dynamic correlations.

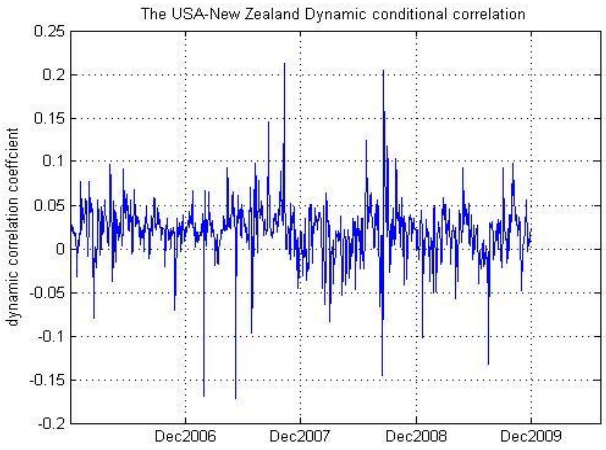


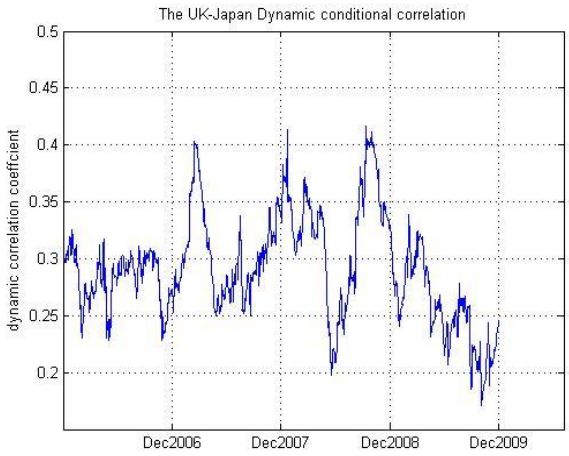
The dynamic conditional correlations of USA-Japan, USA-Korea, USA-Australia and USA-New Zealand fluctuate randomly. It shows that the subprime crisis cannot pose huge influence on the pair-wise correlation coefficients between them. However, from following figures, the movements of pair-wise correlations suggest the crisis in the USA is transmitted to Canada, the UK, Germany and India, which proves the existence of contagion effect. Meanwhile, it shows that with the worsening of the financial crisis, the correlation coefficients become higher.

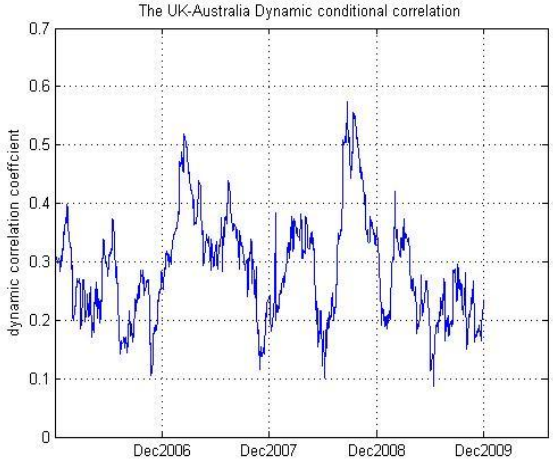


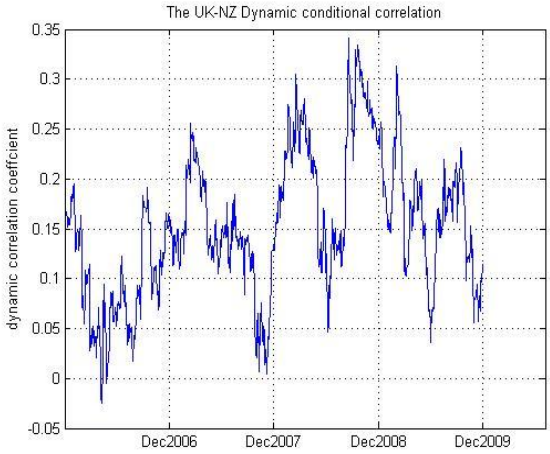




Although the dynamic conditional correlation coefficients of USA-Japan, USA-Korea, USA-Australia and USA-New Zealand move stochastically, based on static correlation analysis and the Granger causality test, the results suggest that the US subprime mortgage crisis indeed



spread to Japan, Korea, Australia and New Zealand. Thus, this paper does further tests on




DCC correlations on UK-Japan, UK-Australia, UK-New Zealand.

From the above figures, the crisis in the UK had a huge influence on dynamic conditional correlations of UK-Japan, UK-Australia, and UK-New Zealand. All correlations show that in the global financial tsunami period, the time-varying correlations reached their peak. When the global economy recovers, the correlation coefficients decrease. It is the same with the movements of correlations between USA-Canada, USA-UK, USA-Germany and USA-India, which proves the contagion effects of internationally. Although the dynamic conditional correlation coefficients of USA-Japan, USA-Australia and USA-New Zealand do not have excess increases, it cannot say the US subprime mortgage crisis has no influence on Japan, Australia and New Zealand. Since the contagion effects between UK-Japan, UK-Australia, UK-New Zealand are proven, through the stock markets of UK, the US subprime mortgage crisis was transmitted to Japan, Australia and New Zealand. Not only the UK, but also Canada and Germany all acted as intermediaries of the US subprime mortgage crisis. The crisis can spread from the USA to target countries directly. It also can be transmitted to more countries through the UK, Canada and Germany. Thus, both linear contagion and cross contagion existed in the subprime mortgage crisis.

## 5.2 Robustness check

In order to check the validity of findings, this paper employs T-test and Z-test to test the existence of financial contagion. T-test is used to find out differences of mean and Z-test is utilised to check differences of median. In May 2008, the subprime mortgage attacked most of international community and the worst time was believed to have started at that time. Thus,

this paper regarded May 20th, 2008 as the breakout point of international shock. The breakout point of the shock divides the whole sample period into pre shock period and after shock period. This paper calculates the means, medians, and standard deviations of dynamic conditional correlation coefficients for all the pair-wise countries in each period. Then it uses T-test and Z-test to find out whether means and medians of each pair-wise country remain stable in different periods. The null hypothesis of T-test is that means of two periods are the same and the null hypothesis of Z-test is that medians of two periods are the same. If P values of T-test and Z-test are smaller than 0.05, the null hypotheses should be rejected, which explains that contagion effects can be found.

Table 15 Robustness test of contagion effects

| Target country | Pre-shock | | | | After-shock | | | | T test | Z test |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | Median | Std DEV | N | Mean | Median | Std DEV | P values | P values |
| USA-Canada | 622 | 0.6813 | 0.6906 | 0.0921 | 422 | 0.7050 | 0.7396 | 0.1089 | 0.0000 | 0.0001 |
| USA-UK | 622 | 0.5407 | 0.5460 | 0.0251 | 422 | 0.5656 | 0.5582 | 0.0621 | 0.0000 | 0.0000 |
| USA-Germany | 622 | 0.5664 | 0.5722 | 0.0604 | 422 | 0.6296 | 0.6331 | 0.0735 | 0.0000 | 0.0000 |
| USA-Japan | 622 | 0.0864 | 0.0863 | 0.0274 | 422 | 0.0882 | 0.0895 | 0.0321 | 0.1742 | 0.1756 |
| USA-Korea | 622 | 0.1505 | 0.1497 | 0.0268 | 422 | 0.1463 | 0.1464 | 0.0327 | 0.0148 | 0.0146 |
| USA-China | 622 | 0.0683 | 0.0656 | 0.0599 | 422 | 0.0649 | 0.0645 | 0.0465 | 0.1486 | 0.1485 |
| USA-India | 622 | 0.1798 | 0.1817 | 0.0200 | 422 | 0.2373 | 0.2506 | 0.0450 | 0.0000 | 0.0000 |
| USA-Australia | 622 | 0.0963 | 0.0976 | 0.0279 | 422 | 0.0933 | 0.0950 | 0.0305 | 0.0551 | 0.0550 |
| USA-NZ | 622 | 0.0221 | 0.0223 | 0.0290 | 422 | 0.0172 | 0.0189 | 0.0327 | 0.0068 | 0.0066 |
| UK-Japan | 622 | 0.3004 | 0.2971 | 0.0352 | 422 | 0.2762 | 0.2637 | 0.0562 | 0.0000 | 0.0000 |
| UK-Australia | 622 | 0.2918 | 0.2993 | 0.0803 | 422 | 0.2794 | 0.2524 | 0.1048 | 0.0197 | 0.0195 |
| UK-NZ | 622 | 0.1328 | 0.1362 | 0.0668 | 422 | 0.1797 | 0.1756 | 0.0688 | 0.0000 | 0.0000 |

Table 15 provides results of T-test and Z-test. From these tests, most test statistics are significant at five percent levels. Only the correlations between the USA and Japan/China/Australia are not significant. It shows that the crisis was not transferred from the USA to these countries directly. Then this study also checks the correlation coefficient between the UK and Japan/Australia/New Zealand. The results show contagion happens in these markets. It supports the findings of the DCC-MVGARCH model. However, the financial crisis only had limited influence on the Chinese stock market, since the Chinese stock market has strict regulations to hinder foreign funds from participating in it. At first, the crisis only had a huge impact on the exports of China, but the government introduced a 4 trillion Yuan stimulus plan and cut interest rates immediately when the global financial tsunami broke out. Although the Chinese stock market became more fluctuant in US subprime mortgage crisis, the impact of the crisis on the Chinese stock market was small.

## Conclusion

In order to investigate contagion effects among international countries, this research selects the US subprime mortgage crisis as the study target, from 2006 to 2009. Firstly, the statistic correlation model, VAR model and DCC-MVGARCH model suggest that correlation coefficients among stock markets in the pre-crisis period are low but increase dramatically during crisis. Thus, it proves the contagion effects indeed exist in the US Subprime Mortgage crisis.

Then, from the Granger causality test and Impulse response function, it can be found that when the financial crisis is severe, the contagion effects are obvious. Meanwhile, when the economy recovers, the influential power of financial contagion would be lower. It may due to the feedback effects. The US subprime crisis derived from the USA. It not only had negative impacts on the US economy but also spread to more countries and caused international financial crisis. In return, the devastating crisis spread back from other countries to the USA. This vicious circle accelerates effects of financial contagion and the global economic recession.

Thirdly, DCC-MVGARCH model suggests that in the US Subprime Mortgage crisis, some developed countries, such as the UK, acted as intermediaries. Through them, the financial crisis was transmitted to more countries. It proves that both linear contagion and cross contagion can be found in the US subprime mortgage crisis. It also supports the existence of contagion effects between developed and emergent markets.

Lastly, the panel weighted regression tests explain that monsoonal effect, spillover effect and pure contagion existed in the US subprime mortgage crisis. It shows that overall global economy, trade linkage and economic-political similarities are transmission channels of financial contagion.