

# **Correlation analysis based on Sub-prime Mortgage Crisis**

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## **1. Introduction**

With the deepening of economic globalization in today's world, it is likely that a financial extreme event will affect the whole financial market and break out the financial crisis. To study the contagious impact of external shocks on a country's financial system has become a major practical problem facing the world today. This article takes the sub-prime crisis in 2008 as an example,mainly uses copula function to study the impact of the crisis in the U.S. market on the Asian market by calculating correlation of loss ratio in these places.

## **2. Literature Review**

### **● Paper written in Chinese**

1. 尹新哲,基于 Copula 理论的金融资产传染效应研究,财经论丛 2012 年第 3 期
2. 赵学雷 艾永芳,基于 Copula-GARCH 的金融市场时变相关性分析,科学决策 2010 年第 6 期

### **● Paper written in English**

1. Juan Carlos Rodriguez, Measuring financial contagion: A copula approach, Journal of Empirical Finance, 14(2007) 401-423
2. Frees E W, Valdez E A, Understanding relationships using Copulas[ J]
3. Longin, F. and Solnik, B. (2001) Extreme correlation of international equity market, Journal of Finance, 56, 649-76
4. Yi-Hsuan Chen, Kehluh-Wang and Anthony H. Tu, 2011, Default correlation at the sovereign level: evidence from some Latin American markets. Applied Economics, 43, 1399-1411
5. Solnik, B., C. Bourcuelle, and Y. Le Fur, 1996, International market correlation and volatility, Financial Analyst Journal 52, 17-34

Author(Year)	Location	Period	Conclusion
Paper written in English			
Juan Carlos Rodriguez (2007)	East Asia	1993-1995 1996-1998	Overall dependence increases between stock market returns of countries in Asia and Latin America during the Asian and Mexican crisis, with tail dependence being more prevalent in times of financial turmoil
Frees E W, Valdez E A	-	-	Copulas offer financial analysts an intuitively appealing structure, first for investigating univariate distributions and second for specifying a dependence structure. Copulas connect finance with statistics.
Longin, F. and Solnik, B	U.S., U.K.	-	International correlation is much higher in periods of volatile markets (large absolute returns).
Yi-Hsuan Chen, Kehluh-Wang, Anthony H. Tu	Latin America	2001-2006	Before the crisis, there was no tail dependence between Argentina and other countries, making Gaussian copula the best

			fitting model for that period. However, during the crisis period, the Gumbel copula performs best for Brazil and Venezuela, but not for Mexico, reflecting the different credit risk relationship
Solnik, B., C. Bourcuelle, and Y. Le Fur	U. S., European countries	Early 1980s	The growth in international capital flows and market integration has raised the general level of correlation in the past 30 years
Paper written in Chinese			
尹新哲 (2012)	U.S.,Asian countries	2005-2009	The outbreak of the sub-prime crisis has changed the average yield level, volatility and related structure of each stock market.
赵学雷 艾永芳 (2010)	U.S.,China, European countries	2000-2010	Copula GARCH can be better used to study the correlation of financial markets

### Summary:

1. Location:most of researchers choose to investigate USA,China and other European countries:UK,Germany,France and so on.
2. Period:The period from 1980s to 2010s is studied.
3. Conclusion:tail dependence becomes more prevalent during financial crisis,and Copula is useful to measure the dependence.

### 3. Methodology

The contagion of financial markets has become a very important issue, especially after the financial crisis in 2008. The contagion of financial markets is the possibility that one national crisis has led to another national crisis. Nowadays, cooperative motion analysis and correlation coefficients are two important methods of contagion research.

Cooperative motion analysis can only test the existence of contagion while correlation coefficients can measure the degree of contagion. We therefore chose correlation coefficients in this paper.

Correlation coefficients mainly includes Pearson's  $\rho$ , Kendall's  $\tau$ , Spearman's  $\rho$  and all copula analysis. Pearson correlation only indicates the strength of linear relationship, and Kendall and Spearman measures are less sensitive to the dependence of tails. To get reliable results, we chose copula technique which can not only show nonlinear relationship, but also capture tail dependence.

In this study, we used different copulas to got robust results and find the best fitting dependence structure of their relationship. The chosen copulas were Gumbel and Clayton which are Archimedean copulas. Gumbel copula reflects the upper tail dependence while Clayton copula shows the lower one. The copula functions are described as followed.

(a) Gumbel copula

$$C_{\theta}^{Gum}(u, z) = f^{-1}[\varphi(u) + \varphi(z)] = \exp\left\{-[(-\ln u)^{\theta} + (-\ln z)^{\theta}]^{1/\theta}\right\}$$

Where  $\theta \in [1, \infty)$  measures the degree of dependence between  $u$  and  $z$ .  $\theta = 1$  means an independent relationship while  $\theta \rightarrow \infty$  indicates perfect dependence. Gumbel copula can only reflect the upper tail dependence. For continuously distributed random variables, the coefficient of upper tail dependence is given by:

$$\lambda_U = 2 - 2^{1/\theta}$$

(b) Clayton Copula

$$C^{Cla}(\varphi^{-1}(u), \varphi^{-1}(z)) = (u^{-\theta} + z^{-\theta} - 1)^{1/\theta}$$

Where  $\theta \in [0, \infty)$  measures the degree of dependence between u and z.

$\theta = 0$  means an independent relationship while  $\theta \rightarrow \infty$  indicates perfect dependence. Clayton copula can only reflect the upper tail dependence. For continuously distributed random variables, the coefficient of lower tail dependence is given by:

$$\lambda_L = 2^{-\frac{1}{\theta}}$$

## 4. Empirical Results

I choose to analyze the correlation of loss ratio between U.S. market and Thailand market before, during and after the sub-prime mortgage crisis. Data is downloaded from Yahoo Finance and Investing.com.

After calculating the loss ratio, we can use the loss ratio to define the simple period. From the book “Understanding Financial Crises 2007”, we know that very large values of loss ratio (possibly unrealistically large values), the contagion extends to most of the financial system. And in real life, when the loss ratio is greater than 60%, it marks the beginning of the financial crisis.

Pre-crisis: 2007.12-2008.07

During crisis: 2008.08-2010.03

Post-crisis: 2010.04-2012.12

## 4.1 Linear Correlation/Rank Correlation

Firstly, using Matlab to calculate the Pearson linear correlation and Rank correlation (Spearman and Kendall) to measure the correlation between US and Thailand.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%相关系数%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear
data=xlsread('post_crisis.xlsx');
X=data(:,1);
Y=data(:,2);
Pearson=corr(X,Y);
disp(Pearson);
Kendall=corr([X,Y],'type','Kendall');
Spearman=corr([X,Y],'type','Spearman');
disp(Kendall);
disp(Spearman);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
U=ksdensity(X,X,'function','cdf');
V=ksdensity(Y,Y,'function','cdf');
%求copula中参数的估计值
%调用copulafit函数估计二元正态copula中线性相关参数
[rho_t,nuhat,nuci]=copulafit('t',[U(:),V(:)]);
disp(rho_t);
disp(nuhat);
disp(nuci);
rho_norm=copulafit('Gaussian',[U(:),V(:)]);
```

Fig.1.Code of Matlab to calculate correlations.

Table.1.Outcomes of linear and rank correlation.

	Pre-crisis	During crisis	Post-crisis
Pearson	0.3591	0.9131	0.8628
Rank(Kendall)	0.2315	0.7225	0.6774
Rank(Spearman)	0.3122	0.9016	0.8736

## 4.2 Tail dependence

The code mentioned above can also use to calculate tail dependence.

From Part 3 Methodology, we know Gumbel copula can describe the correlation under extreme conditions more precisely.

Table.2.Outcomes of Gumbel Copula

	Pre-crisis	During crisis	Post-crisis
Gumbel copula	0.2546	0.7625	0.7508
Clayton copula	0.2589	0.8714	0.7146

### 4.3 Visualization

Using the estimated copula parameters, we can plot the density functions of Gumbel copula which was the best-fitting model for most pairs. By using Matlab, we can visualize the whole process before and after financial crisis.

```

27 — disp(rho_cl);
28 %*****绘制Copula的密度函数和分布函数图*****
29 — [Udata,Vdata] = meshgrid(linspace(0,1,31)); % 为绘图需要,产生新的网格数据
30 % 调用copulapdf函数计算网格点上的二元正态Copula密度函数值
31 — Cpdf_gu = copulapdf('Gumbel',[Udata(:), Vdata(:)],rho_gu);
32 % 调用copulacdf函数计算网格点上的二元正态Copula分布函数值
33 — Ccdf_gu = copulacdf('Gumbel',[Udata(:), Vdata(:)],rho_gu);
34 % 绘制二元正态Copula的密度函数和分布函数图
35 figure; % 新建图形窗口
36 — surf(Udata,Vdata,reshape(Cpdf_gu,size(Udata))); % 绘制二元正态Copula密度函数图
37 xlabel('U'); % 为X轴加标签
38 ylabel('V'); % 为Y轴加标签
39 zlabel('c(u,v)'); % 为z轴加标签
40 figure; % 新建图形窗口
41 — surf(Udata,Vdata,reshape(Ccdf_gu,size(Udata))); % 绘制二元正态Copula分布函数图
42 xlabel('U'); % 为X轴加标签
43 ylabel('V'); % 为Y轴加标签
44 zlabel('C(u,v)'); % 为z轴加标签
45

```

Fig.2.Code of Matab to show Gumbel Copula distribution function diagram

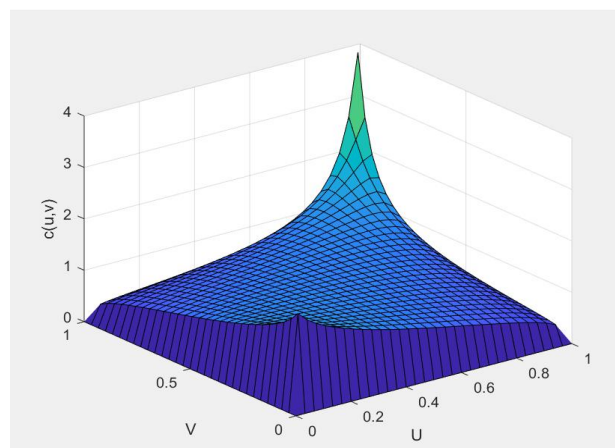


Fig.3.Before Sub-prime mortgage crisis

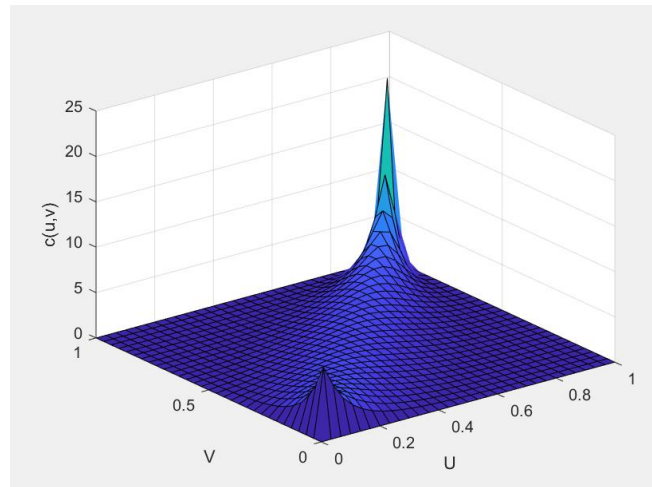


Fig.4.During Sub-prime mortgage crisis

## 4.4 Summary

From the outcomes and graphs, we can know the correlation between U.S. market and Thailand market is the highest during the crisis compared to pre-crisis and post-crisis.

## 4.5 Suggestions

During financial crisis, U.S. government implemented contractionary monetary policy by increasing taxes and decreasing government expenditures. And the government also implemented expansionary monetary policy by increasing monetary supply, decreasing discounting rate and deposit-reverse ratio. From this severe financial crisis, we can get some implications:

1. Lenders are required to disclose accurate information when conducting securitization.
2. Try to avoid the formation of complexity, long chain of trade structure and product structure.



3. The government must step in to regulate. Much of the world would not have been affected if derivatives had been more accurately assessed and rated when they were launched.

## **5.Conclusion**

By using the different correlation coefficients to investigate the risk contagion between the American stock market and the representative Thailand stock market in the stable and crisis periods, and when the crisis occurs, the contagion increases significantly, which reminds us that if the crisis is not well controlled, it will quickly spread to the financial markets in other regions. Therefore, the government should make more efforts to improve policies so as to maintain the sustainable development of the economy.