# 行政院國家科學委員會專題研究計畫 成果報告

## 信用衍生性商品之定價—一個改進的Copula模式
## 研究成果報告(精簡版)

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# An Improved Copula Approach for Pricing Correlation-Dependent Credit Derivatives

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## Abstract

This paper proposes a modified copula approach to defining correlation dependence used for pricing credit derivatives. In pricing single-name credit instruments, it is necessary to consider the default dependence between the reference entity and the counterparty. In pricing multiname credit instruments, the effects of the default of an obligor on the remaining obligors must be addressed. For both single-name and multiname products, how default correlations react to common shocks should be appropriately measured.

The copula approach for estimating default correlations is increasingly popular in practice due to its simplicity in specifying the joint distribution. It is in practice often combined with the structural and reduced-form approaches.

However, it is found that in the currently available copula models, default correlation structure of many obligors in which there are opposite responses to a common macro factor cannot be appropriately handled. In this paper, we use one of the models to illustrate how the deficiency can be remedied. Other copula models with the same deficiency can be similarly modified.

# 信用衍生性商品定價方法－一個改進的 Copula 模式

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## 摘要

本文提出一個改進的 copula 模式以正確評價信用衍生性商品。信用衍生性商品的評價需要估計倒帳相關性。在三種倒帳相關的估計方法中，結構模式有數值計算費時的缺點，而簡化模式則有參數過多的問題。Copula 模式可避免這些計算及估計的繁瑣，已漸成為業界的標準方法。本文所提出的修正模式試圖改善先前 copula 模式無法適當處理總體經濟因素對企業倒帳有相反衝擊的倒帳相關情況。

# I. Introduction

In pricing single-name credit instruments, it is necessary to consider the default dependence between the reference entity and the counterparty. In pricing multiname credit instruments, the effects of the default of an obligor on the remaining obligors must be addressed. For both single-name and multiname products, how default correlations react to common shocks should be appropriately measured.

For the three approaches proposed for estimating default correlation, the structural approach has the disadvantage of time-consuming numerical procedures, if asset default correlation is required. In implementing the reduced-form approach, the intensity function for each obligor has to be estimated. However, there is usually not enough market date for the cross-section or time series analysis. The copula approach specifies the joint distribution by simply taking the marginal distributions as given.[1]

However, it is found that in the currently available copula models, default correlation structure of many obligors in which there are opposite responses to common general economic factors cannot be appropriately handled. Under normal market conditions, firms usually exhibit similar responses to a common factor. But in other times, firms may show extremely different, or even opposite, responses to a common shock. This is evident when we witness a decrease in correlation. It is also documented that in a less competitive industry, the effect of a default may be beneficial due to less competition. Again, this leads to a decrease in correlation.

For example, the downgrades of Ford and General Motors to junk status by Standard & Poor’s in April 2005 result in a significant impact on default correlation. Average implied correlation in CDO equity tranches decreases from a level of around 24% in mid-April to around 12% on May 10. Consequently, the market dynamics spelt trouble for hedge funds that followed a strategy based on inappropriate models. The losses on this strategy raise serious concern about the accuracy of current correlation models (See Patel (2005)).

In this paper, we use one of the current models to illustrate how the deficiency can be remedied. Our modification can not only preserve the desired features of the copula approach, but also be implemented easily. Other copula models with the same deficiency can be similarly modified.

The remaining of the paper is organized as follows. Section II reviews and discusses the general merits of the current copula models for estimating default correlation. Section III illustrates the deficiency found in these models using Giesecke (2003) model as an example. Section IV concludes.

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[1] In the standard application, the marginal distribution for the stopping time is assumed to be exponential.

## II. Model Comparison

The copula approach to construct a dependence structure is popular. In practice, it is usually combined with the structural and reduced-form approaches. When using a copula function to simulate correlated default times, survival functions have to be specified in a reduced-form or structural framework (See, for example, Turnbull (2005), and Jarrow and Deventer (2005)). The use of copula in credit risk literature was first made explicitly by Li (2000), followed by Mashal and Naldi (2001) and Schonbucher and Schubert (2001), among others. The Gaussian copula and the t-copula are the two frequently used copula functions. The Gaussian copula is the industry norm.[2] Other copula functions proposed include: the factor copula, a special case of the Gaussian copula, (Laurent and Gregory (2003)), the Archimedean copula (Rogge and Schonbucher (2003)), and the exponential copula (Giesecke (2003)).

When applying copula function to default correlation, we will refer to it as the survival copula. Denoting the joint survival probability $s(u,v) = P(\tau_1 > u, \tau_2 > v)$, there exists a unique function $C^{\tau}$: $[0, 1]^2 \rightarrow [0, 1]$, called the survival copula of the default time vector $(\tau_1, \tau_2)$, such that the joint survival probability can be represented as $s(u,v) = C^{\tau}(F_1(\tau_1), F_2(\tau_2)) = P(\tau_1 > u, \tau_2 > v)$, where $F_1$ and $F_2$ represent the marginal distribution functions. The copula $C^{\tau}$ describes the default time dependence structure.

Using copula in dependence structure construction, like any model, has its limitations. For example, the original survival copula model and its extensions all have the disadvantage that there is no dynamics for credit spreads or their correlations. Also, there is no underlying economic rationale for the model. There is simple no physical interpretation for the copula correlation between two obligors.

When applying copula functions to pricing credit derivatives, it can result in relatively slow Monte Carlo simulations, especially for high ratings reference obligors. One-factor Gaussian copula is preferred among all copula functions because it allows for quick numerical integration techniques. Hull and White (2004) propose two alternative approaches: recurrence and bucketing, for implementing the model, in order to value an *n*-th to default credit default swaps or tranches of CDOs and indexes without Monte Carlo simulation. Exhibit 3 briefly summarizes the advantages and disadvantages of some well-known copula models.[3]

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[2] For example, it is used implicitly in CreditMetrics.

[3] Other issues raised are: the choice of copula is arbitrary; the effect of an obligor's default on the remaining obligors is dictated by the initial and arbitrary choice of the copula, among others. This means that the approach is independent of the state of the economy and the industrial structure (see Turnbull (2005).

**Exhibit 1**

**Comparison of the Advantages and Disadvantages of Copula Models**

| Model | Assumptions | Advantages | Disadvantage | Application |
|---|---|---|---|---|
| Li (2000) | Using Gaussian copula | Easy simulation using Cholesky decompositions | The choice for model parameters in the copula functions is not directly related to the credit markets | Pricing multiname credit derivatives |
| Mashal and Naldi (2001) | Using t-copula | Dependency possesses heavier tails, and the concept of tail-dependency is introduced | Difficult MLE estimation of degree of freedom parameters | Pricing multiname credit derivatives |
| Schonbucher and Schubert (2001) | Propose to form a joint distribution of default times by connecting the individual distribution through an copula | Greatly facilitate the calibration of credit spreads of obligors | 1. Bond market prices contain no information regarding the copula<br>2. The process to deal with negative default correlation is not mentioned | Incorporate default dependency in intensity-based default risk models |
| Laurent and Gregory (2003) | Default events, conditionally on some latent state variables are independent | Easy to implement and allows the market to imply default correlations from quoted prices | 1. The realization of a single factor governs the default environment in all future time periods<br>2. Negative default correlation has to be treated separately<br>3. No underlying rationale for the model | Pricing of basket credit derivatives and CDO tranches |
| Giesecke (2003) | Unpredictable default arrival times are jointly exponentially distributed | The model can be easily implemented and tractable | Negative default correlation of different firms cannot be handled | For pricing and risk management purposes |

## III. The Deficiency and the Modification

In this section, we illustrate the deficiency found in current copula models, and a modification is proposed.

### The Deficiency

Exhibit 1 lists the restrictive assumption of same response to a common macro factor by different obligors as one common disadvantage of these models. In reality, firms may have different, or even opposite, responses to a common factor. In the following, we will use the Giesecke (2003) model to illustrate how to modify a model to take into account the opposite responses and remedy the deficiency found generally in the copula approach.[4]

Giesecke uses bivariate exponential distribution commonly used in reliability theory to describe joint survival probability. The merits of his model are that it is given in closed-form and can be easily implemented. The efficient simulation of dependent default times for pricing and risk management purposes is straightforward as well.

Suppose there are Poisson processes $N_1$, $N_2$, and $N$ with respective intensities $\lambda_1$, $\lambda_2$, and $\lambda$, where $\lambda_i$ is the idiosyncratic shock intensity of firm $i$, while $\lambda$ is the intensity of a macro-economic shock affecting both firms simultaneously. Then, default time $\tau_i$ of firm $i$ is

$$\tau_i = \inf\{t \geq 0 : N_i(t) + N(t) > 0\} \tag{1}$$

Using exponential copula, the joint survival probability can be obtained by

$$\begin{aligned} s(t_1,t_2) &= P[\tau_1 > t_1, \tau_2 > t_2] = P[N_1(t_1) = 0, N_2(t_2) = 0, N(t_1 \vee t_2) = 0] \\ &= \exp[-\lambda_1 t_1 - \lambda_2 t_2 - \lambda(t_1 \vee t_2) = s_1(t_1)s_2(t_2)\min(e^{\lambda t_1}, e^{\lambda t_2})] \end{aligned} \tag{2}$$

where $s_i(t) = P[\tau_i > t] = P[N_i(t) + N(t) = 0] = e^{-(\lambda_i + \lambda)t}$. It can also be written as

$$s(s_1^{-1}(u), s_2^{-1}(v)) = C(u,v) = \min(vu^{1-\theta_1}, uv^{1-\theta_2}) \tag{3}$$

where $\theta_i = \dfrac{\lambda}{\lambda_i + \lambda}$.

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4 The Giesecke (2003) model is in the spirit of Duffie and Garleanu (2001).

As noted by Giesecke, in this model, defaults can only be positively related. This can be seen from equation (1) where default time correlation is governed by a common factor that can only have same impact on different obligors. Other models in Exhibit 1 also have similar problems when one takes into account negative default correlations. Furthermore, for modeling default correlation among a group of firms, it is desirable to define various common factors and measures the responses of those firms to the common shocks. However, it is difficult to incorporate common factors in models using the Gaussian copula, the t-copula, and the Archimedean copula, such as $N(t)$ in equation (1). Although the factor copula overcomes this problem, conditional independence has to be assumed. That is, $N_i(t)$ is assumed to be independent to each other conditional on the common factor. The exponential copula approach of Giesecke (2003) can be modified as follows that allows negative correlations.

**The Modification**

Consider default time $\tau_1$ and $\tau_2$ of firm 1 and firm 2:

$$\tau_1 = \inf\{t \geq 0 : N_1(t) + N(t) > 0\}$$

$$\tau_2 = \inf\{t \geq 0 : N_2(t) - N(t) > 0\} \tag{4}$$

That is, firm 2 responds differently to the common factor from firm 1.

$$P[N_2(k) \leq N(k)] = \sum_{i=0}^{\infty} \sum_{j=0}^{i} P[N(k) = i, N_2(k) = j]$$

$$\approx e^{-\lambda k} \cdot e^{-\lambda_2 k} + e^{-\lambda k}(\lambda k) \cdot (e^{-\lambda_2 k} + e^{-\lambda_2 k} \cdot \lambda_2 k) = e^{-(\lambda+\lambda_2)k} + e^{-(\lambda+\lambda_2)k} \cdot \lambda k + e^{-(\lambda+\lambda_2)k}(\lambda k)(\lambda_2 k) =$$
$$e^{-(\lambda+\lambda_2)k}[1 + \lambda k + (\lambda k)(\lambda_2 k)] \tag{5}$$

Thus we have

$$s_2(t) = P[\tau_2 > t] = \prod_{k=1}^{t} P[N_2(k) \leq N(k)]$$

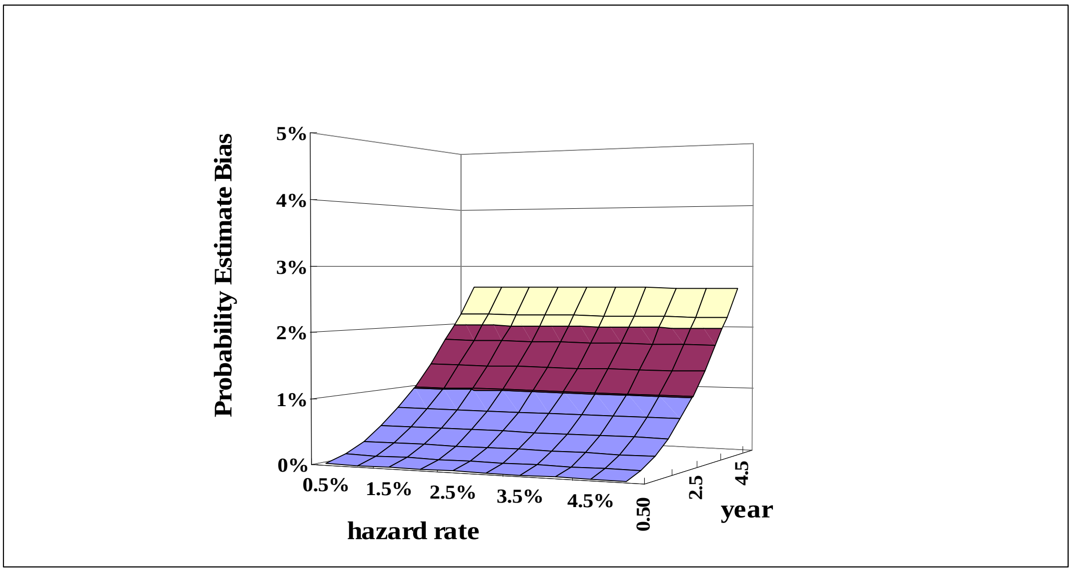
$$\cong \prod_{k=1}^{t} e^{-(\lambda+\lambda_2)k} \cdot (1 + \lambda k + \lambda\lambda_2 k^2)$$

$$\cong e^{-(\lambda+\lambda_2)t(t+1)/2}(1 + \lambda t(t+1)/2) \cong e^{-\lambda_2 t(t+1)/2} \tag{6}$$

The approximation in equation (5) under-estimates $P[N_2(k) \le N(k)]$ by dropping some terms. It is noted that the resulting bias is acceptable for time horizon no more than five years and hazard rate less than 5%. For example, for $\lambda_2 = \lambda = 5\%$ and five years horizon, the approximate survival probability is 79.6%, that under-estimates the true value 82.2% by 2.6%. In fact, the maturity of most default-correlated products is shorter than five years, and the default probability, for firms with Moody's credit rating Baa or above, is under 5% over years 1970-2005, except for year 1986. The estimate bias is shown in Exhibit 2.

## Exhibit 2

**Survival Probability Estimate Bias using Approximation**




Therefore, for $t_1 > t_2$, the joint survival probability is found to be

$$s(t_1,t_2) = P[\tau_1 > t_1, \tau_2 > t_2] = P[N(t_1)=0, N_1(t_1)=0, N_2(t_1)=0]$$
$$= \exp[-(\lambda + \lambda_1 + \lambda_2)t_1] \qquad (7)$$

and for $t_1 < t_2$,

$$s(t_1,t_2) = P[\tau_1 > t_1, \tau_2 > t_2] = P[N(t_1)=0, N_1(t_1)=0] \prod_{k=t_1+1}^{t_2} P[N_2(k) \le N(k)]$$

$$\cong e^{-(\lambda+\lambda_1)t_1} \prod_{k=t_1+1}^{t_2} e^{-(\lambda+\lambda_2)k} \cdot (1 + \lambda k + \lambda\lambda_2 k^2)$$

$$\cong e^{-(\lambda+\lambda_1)t_1} e^{-(\lambda+\lambda_2)(t_2+t_1+1)(t_2-1)/2} e^{-\lambda(t_2+t_1+1)(t_2-1)/2} = e^{-(\lambda+\lambda_1)t_1} e^{-\lambda_2(t_2^2-t_1^2+t_2-t_1)/2} \qquad (8)$$

These survival probabilities can then be used to compute the linear correlation of the default indicator variables:

$$\rho(1_{\{\tau_1 \le t\}}, 1_{\{\tau_2 \le t\}}) = \frac{s(t,t) - s_1(t)s_2(t)}{\sqrt{(1-s_1(t))s_1(t)(1-s_2(t))s_2(t)}} \tag{9}$$

Following the discussion of Giesecke, default indicator correlation can lead to severe misinterpretations of the true default correlation structure, as pointed by Embrechts, McNeil and Straumann (2001). Defined on the level of the copula, Spearman's rank correlation $\rho^S$ does not have the same problems.

Denoting $s_1(t_1) = u$, $s_2(t_2) = v$, and $\theta = \lambda_2 / (\lambda + \lambda_1)$, we obtain $t_1 = -\ln u / (\lambda + \lambda_1)$, $t_2 = (\sqrt{1 - \frac{4 \ln v}{\lambda_2}} - 1)/2$. Thus, $s\ (t_1, t_2) = u^{1+\theta}$ when $t_1 > t_2$, and $s(t_1, t_2) = u^{1-\theta} v$ when $t_1 < t_2$. Besides, if $t_1 > t_2$ and $t_2 \le 3$, we have

$$\frac{u^{1+\theta}}{u^{1-\theta} v} = \frac{u^{2\theta}}{v} = \frac{\exp(2\theta \ln u)}{\exp(\ln v)} = \frac{\exp(-2\lambda_2 t_1)}{\exp(-\lambda_2 (t_2^2 + t_2)/2)} \le \frac{\exp(-2\lambda_2 t_1)}{\exp(-2\lambda_2 t_2)} < 1 \tag{10}$$

Therefore, the survival copula becomes $C^\tau(u,v) = s(s_1^{-1}(u), s_2^{-1}(v)) \cong \min(u^{1+\theta}, u^{1-\theta} v)$. Denoting the equivalent copula by $K^\tau$, then

$$\begin{aligned} K^\tau(u,v) &= C^\tau(1-u, 1-v) + u + v + 1 \\ &= \min[(1-u)^{1+\theta}, (1-u)^{1-\theta}(1-v)] + u + v - 1 \end{aligned} \tag{11}$$

Therefore, Spearman's rank correlation $\rho^S$, for two firms with opposite response to the joint shock, is simply the linear correlation of the copula $K^\tau$, given by:

$$\rho^S(\tau_1, \tau_2) = \rho(p_1(\tau_1), p_2(\tau_2)) = 12 \int_0^1 \int_0^1 K^\tau(u,v)\,du\,dv - 3$$

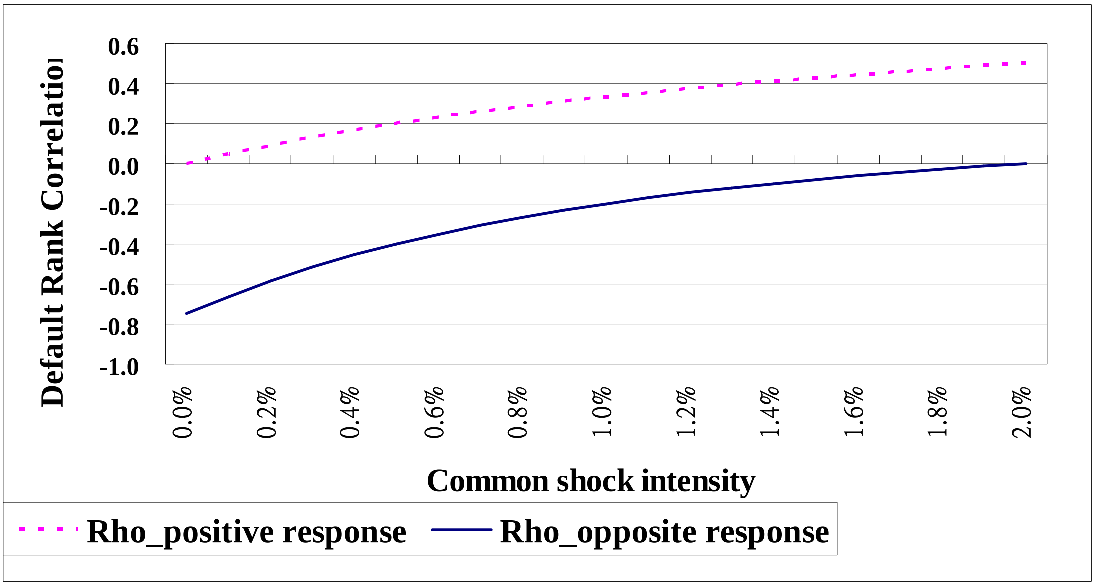
$$= 12\left[\frac{1}{(2+\theta)(\frac{3}{2} + \frac{1}{\theta})} - \frac{1}{(2-\theta)(\frac{3}{2} + \frac{1}{\theta})} + \frac{1}{2(2-\theta)}\right] - 3 = \frac{9\theta^2 - 24\theta + 12 - \frac{20}{\theta}}{(2+\theta)(2-\theta)(3+\frac{2}{\theta})} \tag{12}$$

where $p_i(t) = P[\tau_i \le t] = 1 - s_i(t)$ is the distribution function of $\tau_i$.

In Exhibit 3, rank default correlation of two firms with opposite response to the joint shock and that with same response are compared. Rank default correlation is plotted as functions of the joint shock intensity $\lambda$. We set $\lambda_1 = 0.01$, $\lambda_2 = 0.02$, which corresponds to a one-year default probability of about 1% and 2% when $\lambda = 0$. With increasing $\lambda$, the default correlation increases for both firms with positive and opposite common shock response, due to the common shock component of the default risk dominating the idiosyncratic component. The result for the firm with positive common shock response is consistent with Giesecke's.

## Exhibit 3

**Comparison of Rank Default Correlation for Firms with Same Response and Opposite Response to the Common Shock**

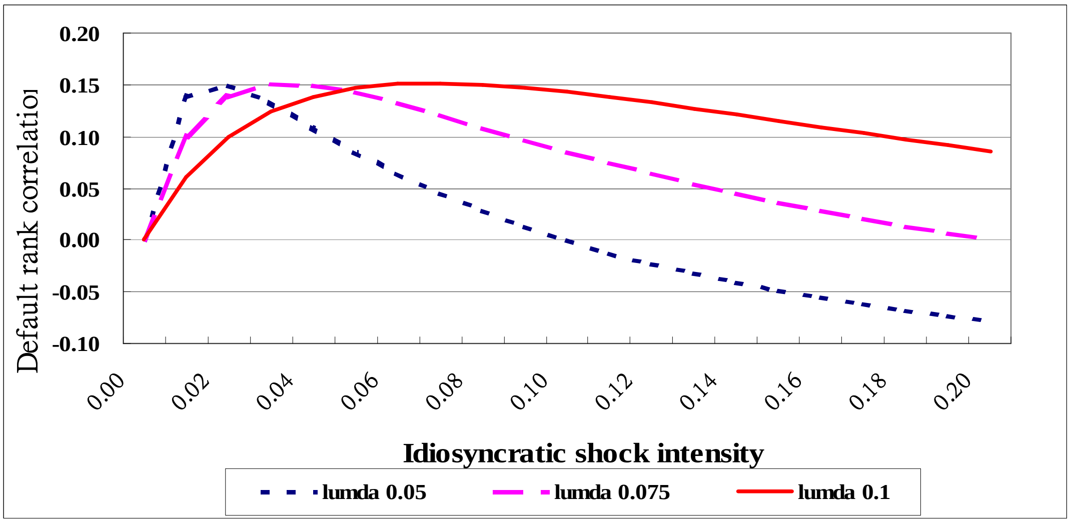



The relationship between $\rho^S$, idiosyncratic intensities, and common shock intensities for two firms with opposite response is shown in Exhibit 4, where $\rho^S$ is plotted as a function of $\lambda_1 = \lambda_2$ for varying $\lambda$. When idiosyncratic default risk is relatively high, rank default correlation is decreasing in idiosyncratic default risk, because the idiosyncratic risk component dominates the correlation. Especially for high joint risk, rank default correlation is decreasing more obviously. This is similar with what happens in the same firm response model.

On the contrary, when idiosyncratic default risk is low, rank default correlation is increasing in idiosyncratic default risk, because idiosyncratic default risk reduces negatively correlated effect of the joint risk on the rank default correlation. Especially for high joint risk, the effect is diminished more evidently. Thus, default correlation is higher for greater joint risk.

## Exhibit 4

**Rank Default Correlation as a Function of Idiosyncratic Shock Intensity**




Not involved in the problem of complicated calibration and too many parameters encountered in the implementation of the structural models and the reduced-form models, the copula models become the market's standard for valuing correlation dependent credit derivatives. However, the copula models are often restricted to positive correlations. The modification we propose in this paper overcomes the disadvantage of previous copula models. The model can handle default correlation structure in which there are opposite responses to a common macro factor.

## References


Duffie, D. and N. Garleanu, 2001, Risk and valuation of collateralized debt obligations, *Financial Analysts Journal*, 57(1), 41-59.

Embrechts, P., A. McNeil and D. Straumann, 2001, Correlation and dependency in risk management, in M. Dempster, ed., *Risk Management: Value at Risk and beyond*, Cambridge University Press.

Giesecke, K., 2003, A simple exponential model for dependent defaults, *Journal of Fixed Income* 13(3), 74-83.

Hull , J. and A. White, 2004, Valuation of a CDO and an *n*-th to default CDS without Monte Carlo simulation, *Journal of Derivatives* 12(2), 8-23.

Jarrow, R. and D. van Deventer, 2005, Estimating default correlations using a reduced-form model, *Risk*, January.

Laurent J.-P. and J. Gregory, 2003, Basket default swaps, CDOs, and factor copulas, Working paper, University of Lyon.

Li, D., 2000, On default correlation: a copula function approach, *Journal of Fixed Income* 9(3), 43-54.

Mashal, R., and M. Naldi, 2001, Pricing multiname credit derivatives: heavy tailed

hybrid approach, Working paper, Columbia Business School.
Patel, N., 2005, Crisis of correlation, *Risk* 18(6), 46-48.
Rogge, E. and P. J. Schonbucher, 2003, Modeling dynamic portfolio credit risk, Working paper, ABN AMRO Bank and ETH Zurich.
Schonbucher, P., and D. Schubert, 2001, Copula-dependant default risk in intensity models, Working paper, Bonn University.
Turnbull, S. M., 2005, Unresolved Issues in Modeling Credit-Risky Assets, *The Journal of Fixed Income*, 15(1), 68-87.

# 出席國際會議報告

2007 年 10 月 15 日

| | | | |
|---|---|---|---|
| 報告人<br>姓名 | 郭震坤 | 所屬學校<br>及系所 | 國立臺灣大學<br>國際企業學系 |
| 會議時間<br>及地點 | 2007.7.18 至 2007.7.24<br>Salt Lake City, USA | 補助金額 | NT$ 60,000 元 |
| 會議名稱 | (中文）資訊科學聯合研討會<br>(英文）Joint Conference on Information Sciences | | |
| 發表論文<br>題目 | (中文）一個預期市場的混沌現象<br>(英文）The Chaos Phenomena in An Anticipated Market | | |

## 一、參加會議經過

**七月十八日**

本年度資訊科學聯合研討會所排定的議程為七月十八日至七月二十四日止，共計七天的議程。本人於七月十七日搭乘長榮航空公司經洛杉磯轉鹽湖城，七月十八日抵達會議舉辦的地點 Marriott Salt Lake City, Utah。本日為正式會議的第一天，開放與會者報到及發放會議資料。

資訊科學聯合研討會（Joint Conference on Information Sciences）由 10 個學術研討會聯合舉行。本人文章是在其中的 6th International Conference on Computational Intelligence in Economics & Finance 發表。

**七月十九日**

此日參加兩場主要演講：

1. Keynote: Chengde Mao: *Elements of DNA Computing*。

2. Keynote: Benjamin Wah: *On Data Mining*。

以及其他排定發表的論文。並跟其他各國與會者交換意見。

**七月二十日**

早上參加一場主要演講：Keynote: Katsutoshi Yada: *Data Mining Application for Time-Series Data*。

本人排定的議程在下午 1:20 至 3:20。本場「財務資訊之預測與分析」指定本人為主持人。共有三篇文章發表，在場約 20 位參與者。本人發表之文章探討新興期貨市場可能產生的混沌現象，引起參與者討論的興趣。主要是未來仍可能有新興預期性市場的籌設，且全球市場的整合日益加速，本文的研究成果可作為學術與實務之參考。

**七月二十一日**

此日參加兩場主要演講：

1. Keynote: Yukio Ohsawa: *Chance Discovery Overviews*。

2. Keynote: Berham Turksen: *The Philosophy of Fuzzy Logic*。

以及其他排定發表的論文。並跟其他各國與會者交換意見。

**七月二十二日**

本日主要參加 CIEF 的一場特別會議。議題是：Innovative Computing in Finance。此外，亦參加另一場關於交易策略之論文發表及討論。

**七月二十三日**

此日參加一場主要演講：

Keynote: Ching Y. Suen: *High Performance Pattern Recognition Systems*。以及其他排定發表的論文。並跟其他各國與會者交換意見。

**七月二十四日**

離開 Salt Lake City。飛至印地安那州 Purdue 大學參訪。於七月三十日動身回國。

## 二、與會心得

從事學術研究應該多與相關領域之學者切磋與交流，而出席國際會議是一個提供此交流切磋的最佳機會。資訊科學聯合研討會甚至提供一個與不同領域之學者互相激盪的機會。因此，個人覺得無論是參與會議的相關活動，聆聽各國學者的相關文章發表，甚至是自己的文章發表，都大大提昇了本身的研究興趣與能力。

## 三、結論與建議

本次會議本人跟研究興趣相符的各國學者討論，藉此了解各國學者研究的內容，以吸取寶貴的研究經驗。參與國際學術活動對於學術視野及研究

能力之提昇具有極大的幫助，國內對於出席國際學術會議之補助應該持續的給予支持。此外，對於國內相關學術單位爭取舉辦國際性學術會議也應該給予支持與鼓勵，提供國內學術研究與國際學術研究交流與接軌的機會。

由衷感謝國科會給予出席國際會議之經費補助，得以有幸與國際研究之知名學者進行學術交流，開拓個人的學術視野與提昇研究之能量。希望日後若有機會再次參與國際學術會議，能夠繼續給予鼓勵與支持。