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行政院國家科學委員會補助專題研究計畫 ■ 成果報告 □ 期中進度報告

固定期間信用違約交換之評價

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計畫參與人員：劉崇齡，鄭式傑，賴宏達

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執行單位：國立政治大學財務管理學系

中 華 民 國 98 年 10 月 31 日

1 Research Backgrounds

The growth in the credit derivatives market has been driven by the new possibilities it creates for both credit investors and hedgers. Credit derivatives facilitate the efficient transfer and repackaging of credit risks. They offer investors an opportunity to diversify portfolio risks and pursue yield enhancements. Aided by the innovation of sophisticated products, credit derivatives have provided new ways for investors to take credit risk exposures. In this research project, we examine how constant maturity credit default swap (CMCDS), one of the exotic structured credit products, works and analyze its valuation problem.

In the fixed-income markets, the well-established constant maturity swap (CMS) was originally used by insurance companies and pension funds to hedge their constant maturity liabilities. Rates with constant maturity features generally facilitate the trading of pure interest rate instruments for a selected maturity, without reducing time to maturity associated with physical bonds. CMS then quickly developed into a product with which investors can take positions on the forward interest rates between two nominated CMS rates. Das (2001)[4] gives detailed introductions to the products with constant maturity features and discusses their applications in practice.

CMCDS is an extension of CMS in the area of credit market. A vanilla credit default swap (CDS) is a contract that provides insurance against the default risk of an underlying entity. A CDS contract has a fixed premium leg and a contingent default leg. The fixed premium leg corresponds to the periodic payments made by the protection buyer to the seller until the maturity of the CDS or until the occurrence of a credit event. The default leg corresponds to the net payment made by the protection seller to the buyer in case of default. The fair spread for CDS is determined by equating the discounted cash flows of these two legs.

While a CDS offers default protection in exchange for the fixed premium payment, the premium of CMCDS however is reset periodically in reference to a prevailing CDS rate with a fixed maturity. The innovation of a CMCDS is the extension of a vanilla CDS by incorporating a premium leg which pays a floating premium, the observed market CDS spread with a fixed maturity. In this research, we will examine the mechanism of a CMCDS contract and develop a method of valuing the credit derivatives with constant maturity features. Finally, we will explore trading strategies that can be implemented using CMCDS.

2 Literature Review

CMCDS transactions are important and receiving increasing attentions because they allow investors to take a view on future credit spreads. The strategy of combining a CMCDS with an opposite position in a vanilla CDS provides a means to unbundle spread risk from default risk. The resulting net position is a floating-fixed premium swap, which enables investors to take exposure to only credit spread risk. In this way, a CMCDS becomes a pure synthetic contract used for expressing a view on spread widening or narrowing. Most transactions to date appear to be in this category. Although CMCDS has received increasing attention in practice, very few academic studies yet consider the valuation problem of the CMCDS. The only one exception is Brigo (2006)[2]. By specifying a joint dynamics of forward CDS rates, he derives the approximated pricing formula in terms of CDS forward rates and their volatilities and correlations.

Studies analysing CMS within the fixed-income market are generally large. For example, Pugachevsky (2001)[8] derives expressions for CMS rates. Brotherton-Radcliffe and Iben (1993)[3], Li and Raghavan (1996) [6], and Benhamou (2000) [1] calculate convexity corrections for different products based on Taylor approximations. Pelsser (2003)[7] proposes a theoretical framework to demonstrate that convexity adjustment appeared in CMS pricing can be interpreted as the side-effect of a change of probability measure. For a detailed discussion of the convexity adjustment on variour products, see Hull (2006) [5].

Practioners use various ad hoc rules to calculate convexity adjustments for different swaps in the fixed-income market. Despite of the importance in implementing trading strategies to betting future credit spreads, very few academic studies examine the valuation of the CMCDS in the credit derivatives market. Therefore in this research project, we will contribute the literature by analysing the CMCDS valuation using the rigorous change of numeraire technique, which has been widely adopted for pricing fixed-income products with constant maturity features.

Because a vanilla CDS and a CMCDS provide the same protection against a credit event of a reference entity, no arbitrage principle thus implies that the present value of the floating premium leg of a CMCDS must equal to the present value of the CDS fixed premium leg. The equivalence is achieved by expressing the floating premium as a percentage of the reference fixed maturity CDS spread. This ratio is called the "participation rate", which is fixed for the contract. To price a CMCDS is to determine the value of the participation rate.

The participation rate of a CMCDS is determined based on the expected levels of the future reference CDS spreads. The problem, however, is that we do not know how the reference fixed maturity CDS spreads will change over the life of a CMCDS. If CDS spreads follow a deterministic path, then forward spreads would be the correct forecasts of future spreads and the participation rate would be fully identified by the forward spreads accordingly. However, due to the volatility of credit spread the future is not predictable. Thus the realised spread level in the future may not be the same as the level implied by forward spreads. To account for uncertainty regarding future credit spreads, an adjustment term arises when implying future spread levels from forward credit spreads.

CMCDS is receiving increasing attention among the credit structured products. It is an important credit risky asset because it can be used by investors to take views on future credit spread levels without taking exposure on default risk. If one ignores the uncertainty of future credit spreads and naively evaluates a CMCDS using available forward spreads, he will misprice CMCDS and suffer losses in some cases. Since the valuation of a CMCDS involves computing the appropriate adjustment to the forward credit spreads, the purpose of this research project is to develop a method of deriving this adjustment terms and calculate the value of the participation rate.

3 Valuation Formulae

The valuation of a CMCDS is the determination of its participation rate. The participation rate of a CMCDS is derived based on the expected levels of the future reference CDS spreads, as reflected in the forward spreads. Uncertainty regarding future CDS rates requires an adjustment to forward spreads when calculating the participation rate. However, the exact adjustment depends on the assumptions about the dynamics of credit spread movements. In this project, we will derive the participation rate and explore how its value will be affected by the parameters in the credit risk model. In the following, we will first define the notations used here. We then derive the credit spread for a vanilla CDS. Finally, we will express the participation rate in terms of future credit spreads. The aim of this project is to calculate this participation rate using a reduced-form model.

Throughout the section we shall adapt the following notations:

τ : default time

$S(t)$: survival probability at time t; $S(t) = Pr(\tau > t) = E\left[I_{\{\tau > t\}}\right]$

T_j : the time of the j^{th} premium payment to take place, $j = 1, 2, \cdots, n$
T : time to maturity of a CDS; $T = T_n$
$\triangle_{j-1,j}$: time increment between payment at the $(j-1)^{th}$ and j^{th} time point in units of years
δ : a constant time increment; $\triangle_{j-1,j} = \delta$ for all j.
N : notional amount
R : recovery rate for the underlying obligor
$P(t, t_j)$: discount factor for maturity t_j
Q : risk-neutral probability measure
$I_{\{\bullet\}}$: indicator function
$s(t; T_0, T_n)$: the spread that makes the CDS contract, which has first payment at time T_1 and last payment at time T_n, fair at the valuation time t; i.e. the spread for protection in $[T_0, T_n]$ at initial time t
M : constant maturity defined in the floating premium leg of a CMCDS
PR : participation rate in the floating premium leg of a CMCDS

If we define $PV_t^{premium}(CDS)$ to be the present value at time t of the fixed premium leg of a CDS, then

$$\begin{aligned} PV_t^{premium}(CDS) &= E_t^Q\left[\sum_{j=1}^{n} s(t; T_0, T_n) \times N \times \triangle_{j-1,j} \times P(t, T_j) \times I_{\{\tau > T_j\}}\right] \\ &= \sum_{j=1}^{n} s(t; T_0, T_n) \times N \times \triangle_{j-1,j} \times E_t^Q\left[P(t, T_j) \times I_{\{\tau > T_j\}}\right] \\ &= s(t; T_0, T_n) \times N \times \delta \times \sum_{j=1}^{n} P(t, T_j) \times E_t^Q\left[I_{\{\tau > T_j\}}\right] \end{aligned} \quad (1)$$

where we assume that $\triangle_{j-1,j} = \delta$, a constant, for all j, and $E_t^Q\left[I_{\{\tau > T_j\}}\right] = \Pr(\tau > T_j)$, is survival probability at time T_j.

We define $PV_t^{default}(CDS)$ to be the present value at time t of the default leg of a CDS, then

$$\begin{aligned} PV_t^{default}(CDS) &= E_t^Q\left[(1-R) \times N \times P(t, \tau) \times I_{\{0 \le \tau \le T_n\}}\right] \\ &= (1-R) \times N \times E_t^Q\left[P(t, \tau) \times I_{\{0 \le \tau \le T_n\}}\right] \end{aligned} \quad (2)$$

By equating the present values of both legs, we have the fair spread $s(t; T_0, T_n)$ as

$$s(t; T_0, T_n) = \frac{(1-R) \times E_t^Q\left[P(t, \tau) \times I_{\{0 \le \tau \le T\}}\right]}{\delta \times \sum_{j=1}^{n} P(t, T_j) \times E_t^Q\left[I_{\{\tau > T_j\}}\right]} \quad (3)$$

In a CMCDS with first payment in T_1 and with final maturity T_n, protection on a reference credit against default in $[T_0, T_n]$ is given from protection seller to a protection buyer. However, in exchange for this protection, a "constant maturity" CDS spread is paid. A contract that protects in $[T_0, T_n]$ can be in principle decomposed into a stream of contracts, each single contract protecting in $[T_{j-1}, T_j]$, for $j = 1, \cdots, n$, with default payment postponed to T_j if default occurs in $[T_{j-1}, T_j]$. In each single period $[T_{j-1}, T_j]$, the rate $s(T_j; T_j, T_j + M)$ paid at time T_j makes the exchange fair, so that a contract offering protection on a reference credit in $[T_0, T_n]$ in exchange for payment of spread $s(T_1; T_1, T_1 + M), \cdots, s(T_n; T_n, T_n + M)$ at time $T_1, \cdots, T_n$, is fair, i.e. has zero initial value at time t.

We can thus express the present value of a premium leg of a CMCDS at time t, $PV_t^{premium}(CMCDS)$, as

$$
\begin{aligned}
PV_t^{premium}(CMCDS) &= N \times \delta \times \sum_{j=1}^{n} P\left(t, T_j\right) \times E_t^Q\left[s\left(T_j; T_j, T_j + M\right) \times I_{\left\{\tau > T_j\right\}}\right] \\
&= N \times \delta \times P\left(t, T_j\right) \times \sum_{j=1}^{n} E_t^Q\left[s\left(T_j; T_j, T_j + M\right) \times I_{\left\{\tau > T_j\right\}}\right]
\end{aligned}
$$

where we again assume that $\triangle_{j-1,j} = \delta$, a constant, for all j.

Since the default leg of a CMCDS is identical to the default leg of a plain vanilla CDS written on the same reference entity, it follows that the premium legs of both instruments should be identical too.

$$
PV_t^{premium}(CDS) = PV_t^{premium}(CMCDS)
$$

That is,

$$
\begin{aligned}
& s\left(t; T_0, T_n\right) \sum_{j=1}^{n} P(t, T_j) \times E_t^Q\left[I_{\left\{\tau > T_j\right\}}\right] \\
= & \sum_{j=1}^{n} P\left(t, T_j\right) \times E_t^Q\left[s\left(T_j; T_j, T_j + M\right) \times I_{\left\{\tau > T_j\right\}}\right] \times PR
\end{aligned} \tag{4}
$$

Therefore, the question of pricing a CMCDS reduces to finding the value of participation rate, PR,

$$
PR = \frac{s\left(t; T_0, T_n\right) \sum_{j=1}^{n} P(t, T_j) \times E_t^Q\left[I_{\left\{\tau > T_j\right\}}\right]}{\sum_{j=1}^{n} P\left(t, T_j\right) \times E_t^Q\left[s\left(T_j; T_j, T_j + M\right) \times I_{\left\{\tau > T_j\right\}}\right]} \tag{5}
$$

where $E_t^Q\left[I_{\left\{\tau > T_j\right\}}\right] = \Pr\left(\tau > T_j\right)$, is survival probability at time T_j.

4 Models and Results

If we assume the default intensity process $\lambda(t)$ follows a mean-reverting process as

$$
d\lambda(t) = (K - \alpha\lambda(t))dt + \sigma dW(t).
$$

Suppose that we have the first-order approximation of $Q(\lambda(t_j))$ with Taylor expansion around $\lambda(t)$, namely,

$$
Q(\lambda(t_j)) \approx Q(\lambda(t)) + Q'(\lambda(t))(\lambda(t_j) - \lambda(t)).
$$

A naive application of the result in the credit risk literature implies that on $\{\tau > t_j\}$,

$$
E_t[s(t_j, t_j + T)1_{\{\tau > t_j\}}] = E_t\Big[s(t_j, t_j + T)\exp\Big(-\int_t^{t_j} \lambda(\theta)d\theta\Big)\Big].
$$

After some computations, we can derive the following . For $t_j \geq t$,

$$\begin{aligned}
\lambda(t_j) &= \lambda(t)e^{-\alpha(t_j-t)} + \frac{K}{\alpha}(1-e^{-\alpha(t_j-t)}) + \sigma e^{-\alpha t_j}\int_t^{t_j} e^{\alpha s} dW(s) \\
E_t[\lambda(t_j)] &= \lambda(t)e^{-\alpha(t_j-t)} + \frac{K}{\alpha}(1-e^{-\alpha(t_j-t)}) \\
P(t,t_j) &= E_t\Big[\exp\Big(-\int_t^{t_j}\lambda(\theta)d\theta\Big)\Big] \\
&= \exp\Big\{-(t_j-t)\Big(\frac{K}{\alpha}-\frac{\sigma^2}{2\alpha^2}\Big) + \frac{1-e^{-\alpha(t_j-t)}}{\alpha}\Big(\frac{K}{\alpha}-\frac{\sigma^2}{2\alpha^2}-\lambda(t)\Big) \\
&\qquad - \frac{\sigma^2}{4\alpha^3}(1-e^{-\alpha(t_j-t)})^2\Big\}.
\end{aligned}$$

$$E_t\left[s\left(t_j,t_j+T\right)I_{\left\{\tau>t_j\right\}}\right] \approx P\left(t,t_j\right)\left\{f\left(t,t_j,t_j+T\right) - Q'\left(\lambda\left(t\right)\right)\left[\frac{\sigma^2}{2\alpha^2}\left(1-e^{-\alpha\left(t_j-t\right)}\right)^2 + \lambda\left(t\right)\right]\right\} \tag{6}$$

Based on the following equation,

$$E_t\left[s\left(t_j,t_j+T\right)I_{\left\{\tau>t_j\right\}}\right] \approx P\left(t,t_j\right)f\left(t,t_j,t_j+T\right) + \text{ convexity adjustment term}$$

we know the convexity adjustment term is equal to $-P\left(t,t_j\right)Q'\left(\lambda\left(t\right)\right)\left[\frac{\sigma^2}{2\alpha^2}\left(1-e^{-\alpha\left(t_j-t\right)}\right)^2 + \lambda\left(t\right)\right]$.

5 Self Project Evaluation

I am trying to write a academic paper based on the results derived from this project. The contribution might not be so significant, because the analytical expression for the convexity adjustment term can be derived only in a mean-reverting stochastic intensity framework. However, it is still worth of a trail.

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國外短期研究進修心得報告

政大財管岳夢蘭

此次利用暑假至日本東京一橋大學（Hitotsubashi University）做二個星期的短期研究進修，可謂獲益良多。一橋大學在接到我短期研究的申請案後，便在短時間內回覆我可以提供予我使用的資源。他們在 faculty 與交換學者使用的空間中，提供我一張辦公桌、一台雷射印表機以及網路連線。該系所提供的研究設備對一個僅做兩個星期短期進修的研究人員而言，實在非常慷慨，也讓我在東京該校的研究期間中，可以不受干擾地思考從事我的學術研究。

抵達該校的第一天，系秘書 Emiko 便帶我認識該系及學校的環境。由於仍值暑假期間，大樓內並沒有大量學生，只有利用暑假期間仍到校做研究的教授們，因此顯得非常安靜。Emiko 帶我至 Professor Miura 的辦公室和他打招呼，告知我以抵達。並約好下星期一中午的一個 welcome lunch，要讓我認識系上其它的 faculty。

我在一橋大學短期進修的兩個星期中，Professor Miura 提供了許多研究資源上的協助。除了讓我使用該校圖書館的資源外，也花時間帶我參觀並使用該校所購置的財務資訊系統 Bloomberg。

Professor Miura 以在財金系當了十多年的系主任，前兩年才卸去系主任一職，可謂相當資深。雖然 Professor Miura 的研究專長較偏重統計，不過他對於財務工程領域相當熟悉，也常參加國際性的財務方面研討會。Professor Miura 和我分享了他最近的幾篇 working papers 以及目前的研究領域。其中一篇關於 quantile exotic option 訂價問題的研究，Professor Miura 說此商品在實務上並沒有交易，但數學問題卻相當有趣。我在思考是否有機會利用此商品建構出可供實際交易的結構性商品，這部分的研究想法是此次短期進修的一項收穫。Professor Miura 的另一個計劃是關於 hedge fund 報酬的研究。他目前的研究方向是將 hedge fund 視為一項資產，並分析加入此項新資產後，對投資人資產配置問題的影響。這項研究和我之前所指導的碩一生的碩士論文有些共通點。兩者相異的是，我們的研究由於經費缺乏，使用的是 public available 的 free data – hedge fund index。而 Professor Miura 則是使用系上經費購置的 hedge fund data base，因此可以較清楚地分析個別避險基金的報酬特性。

該系目前的系主任 Professor Ohashi 曾有一篇文章發表在 Journal of Financial Economics 上。他目前的研究方向之一是 security design，這個 topic 也是 subprime crisis 之後較熱門的一個研究領域。另外和我研究相關的是 Professor Ohashi 和其指導的博士生的一篇關於 commodity spread 的論文。此論文的第一部份是理論模型的建構，目前已經完全。而他們現在進行的是第二部分的實證工作。由於他們使用的是我也非常熟悉的 Health, Jarrow and Morton 的模型架構，故我們也就模型的實證估計議題，分享了彼此的經驗。

Professor Nakagawa 是一橋大學財金系的老師們中，和我目前研究領域最接近的一位老師。他目前也在做和信用風險相關的研究。其中又以傳染效果（contagion effect）爲主要探討議題。由於 Professor Natagawa 有很強的數理背景，因此他的研究中，統計和數學的語言非常多。我和他討論了一個信用衍生性商品的訂價問題，由於我們兩個人所 follow 的文獻極爲相似，因此在這個基礎上，我們開始了共同的研究對話。

在兩個星期的短期進修中，一橋大學財金系也爲我安排了一場 Seminar，讓我有機會和系上老師們分享我的研究成果，也讓系上老師們更了解我的研究方向，增加未來可能的合作機會。

整體而言，在暑假接近尾聲的開學前夕，能有機會至東京一橋大學短期進修兩個星期，是一個難得的寶貴經驗。系上老師們的誠心接待，也讓我一個人在東京的兩個星期的進修期間，感到非常舒適充實。也希望明年暑假前，能夠將合作的研究完成，投稿至相關領域的期刊。

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

98 年 04 月 01 日

報告人姓名	岳夢蘭	服務機構 及職稱	國立政治大學財務管理學系 助理教授
會議時間 地點	民國九十八年三月十九、二十日 法國巴黎	本會核定 補助文號	NSC 97-2410-H-004-175
會議 名稱	(中文)第二屆國際財務研究論壇-風險管理與金融危機 (英文)2nd International Financial Research Forum - Risk Management and Financial Crisis		
發表論文 題目	(中文)固定比例投資組合保險策略的應用-信用風險投資組合 (英文)Constant Proportion Portfolio Insurance Strategies for Credit Portfolios		

報告內容應包括下列各項:

一、參加會議經過

今年 3 月 19 日、20 日兩天在法國巴黎舉行第二屆國際財務研究論壇(International Financial Research Forum),此次會議的主題為風險管理與金融危機(Risk Management and Financial Crisis)。此次會議共接受發表之論文共有 60 篇(含 Poster 之論文)。除了部分歐美學者之外,與會者大多來自於法國當地各大學,另外亦包含任職於專業投資機構的實務界人士。兩天的會議共舉行了 16 個學術論文發表的場次,2 個 Poster session,以及 4 個大型的討論會。學術論文以及 Poster session 所發表的文章多以風險管理為主,其中又以信用風險、流動性風險以及交易對手風險為主,而這些議題也正是當今金融業所特別關注的課題。另外在 4 場大型的討論會中,主辦單位邀請任職於實務界的管理階層,例如:紐約聯邦準備銀行(Federal Reserve Bank of New York),法國中央銀行(Banque de France),以及多位投資銀行及信評機構的人員,對此次世界金融危機進行分析,並回顧此危機發生的原因,以及提出此次金融危機對風險管理議題所帶來的全新挑戰。此次兩天的會議中,兼顧理論與實務的需求,從更廣的角度分析風險管理,對於提昇研究視野亦有極大助益

二、與會心得

由於此次國際會議的參與者除了來自於學術界的學者外,亦有多位服務於金融機構的實務界人士,本人在參與會議的過程中,除了對風險管理研究領域中各重要的課題,例如:流動性風險(Liquidity risk)以及交易對手風險(Counterparty risk)的最新發展有了更新的認識外,也由和業界人士的交談與演講中,了解到此次金融危機發生的原因以及今後風險管理所將面臨的挑戰,本人由會中發表之論文以及 4 場討論會中學得許多新知識,也構思了幾個未來可能的研究課題。在多場演講中,本人對由 Jean-Michel Lasry 主講的"New Markets for Post-Crisis" 感到最有趣。講者利用 SWOT 分析的方式,列舉出造成此次金融危機的兩大主要商品(信用衍生性商品以及證券化商品)的各項優劣。這個分析讓我深刻體會到金融商品與金融創新本身是沒有錯誤的,端賴使用者如何利用它們從事避險或投機。在眾多場學術演講中,我對第 4 場中的一篇文章深感興趣。這篇文章的題目是"Dynamic Hedging of Portfolio Credit Derivatives"。由於我的研究領域也是在信用衍生性商品,因此對於動態避險此類商品的效果非常好奇。作者分析了多種不同模型下的避險績效,結論是有考慮跳躍項(jump terms)的模型其動態避險成效較佳。

三、建議

由參加本次會議,了解到財務學界日漸走向國際化,有許多論文均是由身處不同國家地區之學者合作完成。此次世界金融危機發生後,世界金融秩序需要重整,對於風險管理議題的思考也應有所調整。本人建議國內財務學者可以透過各種國際學術會議與其他國家地區之學者以及業界實務人士交流,以了解當下較受關注的研究課題。

四、攜回資料名稱及內容

本次會議的議程及論文皆可於下列網站下載:http://www.finance-innovation.org.risk09/

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