科技部補助專題研究計畫成果報告
期末報告

銀行競爭對銀行系統性風險影響的全球銀行實證研究:公司治理、內部風險管理、國家治理、金融監理的角色

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報 告 附 件 ： 出席國際學術會議心得報告

中 華 民 國 106 年 04 月 13 日

中 文 摘 要 ： 本研究計畫針對2007年至2011 年間全球上市商業銀行為研究對象，進行實證檢驗銀行競爭與系統性風險的關係，不同於過去多數研究僅考慮銀行個別風險指標，本研究則特別考量銀行系統性風險具共同相依性的特性以反映出銀行的脆弱性。再者，本研究計畫擬進一步探討公司治理品質與內部風險管理機制對系統風險的影響角色，同時也探討跨國間國家治理品質與金融監理對銀行系統性風險的影響，尤其是驗證銀行競爭透過國家治理與金融監理的管道如何交互影響銀行系統性風險。本計畫發現銀行競爭程度愈大、風險管理品質愈好、公司治理品質愈佳者，則會顯著地降低其系統性風險。再者，在銀行競爭程度愈高下，風險管理品質愈好、公司治理品質愈佳、以及金融監理要求較嚴格國家的銀行，則表現出較低的系統性風險。

中 文 關 鍵 詞 ： 銀行系統性風險；銀行競爭；公司治理；內部風險管理；銀行監理；全球研究

英 文 摘 要 ： Using global bank-level data on commercial bank over 2007 to 2011, this project empirically investigates the relationship between banking competition and systemic risk based on bank-level measure with the co-dependence. Even though there are number of literature focused on the relationship between banking competition and the absolute level of risk in individual banks, this paper however examine the correlation in bank’s risk taking behavior to measure systemic fragility. This project also examines the impact of bank’s corporate governance, internal risk management and banking regulation on bank systemic risk. Empirical findings reveals that bank systemic risk would be higher with better quality of corporate governance and internal risk management, specifically in countries with stronger supervision monitoring. Besides, higher degree of bank competition mitigates bank systemic risk with better quality of corporate governance and internal risk management.

英 文 關 鍵 詞 ： Bank Systemic Risk; Banking Competition; Corporate Governance; Internal Risk Management; Bank Regulation and Supervision; International Study

科技部補助專題研究計畫成果報告

（期末報告）

銀行競爭對銀行系統性風險影響的全球銀行實證研究：公司治理、內部風險管理、國家治理、金融監理的角色

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本計畫除繳交成果報告外，另含下列出國報告，共 1 份：
□執行國際合作與移地研究心得報告
■出席國際學術會議心得報告
□出國參訪及考察心得報告

中華民國 106 年 3 月 29 日

銀行競爭對銀行系統性風險影響的全球銀行實證研究:
公司治理、內部風險管理、國家治理、金融監理的角色

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摘要

本研究計畫針對 2007 年至 2011 年間全球上市商業銀行為研究對象，進行實證檢驗銀行競爭與系統性風險的關係，不同於過去多數研究僅考慮銀行個別風險指標，本研究則特別考量銀行系統性風險具共同相依性的特性以反映出銀行的脆弱性。再者，本研究計畫進一步探討公司治理品質與內部風險管理機制對系統風險的影響角色，同時也探討跨國間國家治理品質與金融監理對銀行系統性風險的影響，尤其是驗證銀行競爭透過國家治理與金融監理的管道如何交互影響銀行系統性風險。本計畫發現銀行競爭程度愈大、風險管理品質愈好、公司治理品質愈佳者，則會顯著地降低其系統性風險。再者，在銀行競爭程度愈高下，風險管理品質愈好、公司治理品質愈佳、以及金融監理要求較嚴格國家的銀行，則表現出較低的系統性風險。

【關鍵詞】:銀行系統性風險；銀行競爭；公司治理；內部風險管理；銀行監理；全球研究

International Study of the Impacts of Banking Competition on Bank Systemic Risk: The Role of Corporate Governance, Internal Risk Management, National Governance, and Bank Regulation

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Abstract

Using global bank-level data on commercial bank over 2007 to 2011, this project empirically investigates the relationship between banking competition and systemic risk based on bank-level measure with the co-dependence. Even though there are number of literature focused on the relationship between banking competition and the absolute level of risk in individual banks, this paper however examine the correlation in bank's risk taking behavior to measure systemic fragility. This project also examines the impact of bank's corporate governance, internal risk management and banking regulation on bank systemic risk. Empirical findings reveals that bank systemic risk would be higher with better quality of corporate governance and internal risk management, specifically in countries with stronger supervision monitoring. Besides, higher degree of bank competition mitigates bank systemic risk with better quality of corporate governance and internal risk management.

Keywords: Bank Systemic Risk; Banking Competition; Corporate Governance; Internal Risk Management; Bank Regulation and Supervision; International Study

一、緒論

長久以來銀行競爭對金融脆弱性的影響，一直都是學術研究與政策辯論的熱門議題，然而基於全球金融危機的影響性被高度強調時，金融金理政策則關注於此主題上。儘管學術界與政策制定者都曾經相當質疑銀行競爭的黑暗影響程度，以及金融創新在搜尋較高邊際利益誘因上可能引發金融危機的可能性。當銀行業存在較高的競爭程度時，會誘發較高的金融創新與利益的誘因。最近，Schaeck and Cihak (2014)發現銀行競爭對銀行獲利及成本效率提升具有正向的影響力，Lin et al. (2010)與 Demirguc-Kunt et al. (2004)則發現較嚴格的金融監理制度對銀行進入及業務活動會產生較高金融仲介的成本且導致經營效率降低的問題，Turk-Ariss (2010)發現銀行市場力量(Market Power)與成本效率存在負向的關聯性。然而，對於是否銀行競爭也會導致較高的金融脆弱性的論點，則與衝突理論性的預測及不同實證估計的結果來看，仍舊沒有獲得學術論證的一致性結論。

此外，金融危機也會引發實務上對於風險評估之再檢驗需求，以及金融體系管制策略則關注於系統性脆弱的檢討上。然而，此所需關注的焦點並不在於個別金融機構的風險，而應是個別銀行對於金融體系整體風險的邊際貢獻上。因此，當有大量成長的共識來自於金融監督觀點時，對於確保金融體系穩定上，更關注於銀行風險承擔行為的關聯性，深入探討關於個別金融機構風險承擔相關程度。

本研究強調兩個議題:第一，以全球上市商業銀行為研究對象，實證檢驗競爭與銀行個別系統性風險的實證關係。儘管過去大量的文獻皆關注於銀行單獨風險上，然而本研究卻特別關注於個別銀行的系統性風險。第二，除了檢視個別銀行絕對風險的水準外，本研究也檢驗銀行風險承擔行為上的相關性(Correlation)，估計上針對個別銀行違約風險的總變異的變動下被國家內所有銀行的倒閉風險變動所解釋並衡量。

本研究遵循 Anginer and Demirguc-Kunt(2011)研究設計，並運用 Merton(1974)或有請求定價架構(Contingent Claim Pricing Framework)來衡量銀行違約風險(Default Risk)以及對系統風險的邊際貢獻。最近，Anginer, Demirguc-Kunt, and Zhu (2014)使用來自 63 個國家中在 1997 年到 2009 年期間中 1,872 家公開上市交易銀行，實證檢驗銀行競爭的效果(以 Lerner 指數代表銀行市場力量)對系統性風險的衡量，研究結果指出競爭以銀行系統性風險存在負相關系，且當銀行競爭程度越大時，會積極鼓勵銀行去從事更多角化分散風險的觀點相符合，因而導致金融體系對金融衝擊較不脆弱。作者也檢驗較強的機構與監理環境，對此關係的影響相關風險承擔行為會較強，特別發生金融監理與私人監督較弱的國家中、較高銀行政府所有權以及公開政策限制銀行競爭的國家中。競爭與系統性脆弱關係對於所屬國家機構環境也十分敏感，藉由較強的機構環境允許有效對金融機構進行公開或私有的監督活動，則發現當缺乏競爭的負向效果可以被減緩。

多數關於銀行競爭與穩定的理論文獻較關注於探討銀行的個別風險，而非與銀行所承擔的相關風險。然而，衡量相關風險承擔在金融危機後已經成為近期理論研究的焦點所在，例如 Brunnermeier (2009)、Danielsson et al. (2009)、以及 Battiston et al. (2009)等學者。此外，關於銀行系統性風險的實證證據方面，Brunnermeier et al. (2011)指出銀

行的非利息收益與系統性風險呈現正向關係，再者，Van Bekkum (2010)更發現誘因薪酬與較高的銀行系統性風險呈現正向的關聯性，但是這些研究僅考慮美國的銀行業進行分析，且未考慮銀行競爭的議題。

假定相關政策主題的相關性與衝突性的理論預測下，已有大量增加的實證研究探討銀行競爭對銀行脆弱性的影響。

首先，就個別國家的研究來看，多數集中於美國的實證分析，並非產生具一致性的結論；其中 Boyd and Runkle (1993)針對美國銀行控股公司進行分析。其次，就跨國研究分析來看，實證結果指出集中度較高的銀行體系較不會遭受系統性的銀行危機；相反地，在較競爭的銀行業中金融體系較易受到系統性銀行危機的威脅(Beck et al., 2006; Schaeck et al., 2009)。其它相關研究也指出銀行在較競爭金融體系中會計提較高的資本，可進一步解釋銀行競爭對金融穩定形成正向的影響效果(Berger et al., 2009; Schaeck and Cihak, 2014)。此外，針對使用銀行層級的研究資料來看，Beck et al. (2013)發現使用會計資訊來衡量銀行健全性與市場力量之間存在顯著的正向關係，並用來解釋此正向關係同時也存在跨國的異質性(Crosscountry Heterogeneity)，也探討國家金融管制與機構品質的影響因素。

基於上述研究動機，本研究計畫設定以下五個研究目的：

1. 本研究以 2000 年至 2014 年全球上市商業銀行為研究對象，實證估計個別銀行的系統性風險。
2. 基於全球銀行的研究基礎下，實證檢驗銀行競爭對銀行系統性風險的影響。
3. 實證探討銀行競爭、公司治理、內部風險管理機制以及國家銀行監理對銀行系統性風險的直接影響效果。
4. 考慮銀行公司治理與內部風險管理機制下，實證探討銀行競爭與公司治理、內部風險管理機制以及國家銀行監理對銀行系統性風險的交互影響效果。
5. 依據實證分析結果分別提供金融管理當局，研擬未來管理銀行系統性風險可行的對策方針。

本研究從以下四方面對過去文獻作出具體的貢獻:

1. 不同於先前研究使用銀行層級的資料來檢驗銀行競爭與脆弱性間的連結，本研究不單聚焦於個別銀行的風險而已，而是關注於銀行所面對風險因素之間的共同相依性(Co-dependence)並特別強調當前金融管理當局最感興趣的總體審慎監理政策(Macro-prudential Regulation)上。
2. 取代過去研究多使用會計資訊基礎下所計算的銀行風險，例如代表銀行健全性的 Z-分數(z-scores)，本研使用 Merton (1974)所提出結構信用風險模型(Structural Credit Risk Model)來計算銀行理論上存在的違約風險(Default Risk)。儘管使用 Z-分數來驗證銀行風險與競爭的關係可能存在問題，因為 Z-分數與代表銀行市場力量的 Lerner 指數(Lerner index)皆使用銀行的獲利指標所計算而得，因而可能使得兩者的正向關係存在潛在性的虛假問題。相較下，本研究運用 Anginer and Demirguc-Kunt (2011)研究並也參照近期估計銀行進階風險模型的相關研究，例如 Chan-Lau and Gravelle

(2005)、Elsinger et al. (2005)、Avesani et al. (2006)、Adrian and Brunnermeier (2009)以及 Huang et al. (2009)等學者以延伸至全球銀行系統性風險的實證研究。

3. 本研究採用銀行層級資料來實證探討銀行競爭與系統性風險的關聯性，並同時控制可能影響銀行系統風險的一系列的銀行財務特性變數，特加入銀行收入與資產多角化、公司治理(包括「董事會規模」、「獨立董事比例」、「高階管理薪酬」、「機構投資人持股比率」與「大股東持股比例」、以及內部風險管理機制(包含「銀行是否有指派 CRO 職位」、「是否 CRO 也是高階管理者」、「是否 CRO 的薪酬位居前五大」、「CRO 總薪酬(含股票選擇權) 」、「風險管理委員會的經歷與開會次數」、「是否 CRO 對董事會進行風險報告」等)，以擴充 Anginer, Demirguc-Kunt, and Zhu (2014)的研究設計。上市銀行於 2000 年至 2014 年間公司治理資料以及內部風險管理機制則逐筆收集自銀行年報(Annual Report)中的揭露資訊。
4. 跨國的研究本質允許本研究同時實證檢驗國家面的治理品質與金融規範及監理對銀行系統性風險，特別是銀行競爭與銀行相關風險承擔行為之間的關聯性，對於未來擬定監督銀行系統性風險的金融政策方面存在重要的意政策涵與啟示。

二、相關研究文獻

(一)銀行競爭與穩定的關係

首先，Carletti (2008)與 Degryse and Ongena (2008)認為經濟理論分析可能存在高度的衝突性，就競爭的特許價值觀點指出，可能存在顯著競爭的穩定成本，因為太多的競爭可能導致超額的承擔進而降低銀行的利潤(Marcus, 1984; Keeley, 1990; Allen and Gale, 2004)。然而，支持這個觀點學者則認為，較高的競爭環境對利潤的壓力將迫使的銀行選擇更具風險的投資組合，導致更高的脆弱性(Hellmann et al., 2000)。其他的學者認為在更競爭的環境下，銀行會賺取更少的競租，因而降低對金融監理的誘因(Boot and Thakor, 1993; Allen and Gale, 2000)。Dell'Ariccia and Marquez (2004)證實更強的競爭可能誘發銀行轉向更高風險性且不透明的借款人；再者，Hauswald and Marquez (2006)卻認為競爭使得銀行獲取借款人較少的資訊。大銀行也可以進行較佳的多角化風險分散業務，因此金融體系對少數的大銀行所獨佔且相對於很多小銀行金融體系而言，傾向於較不發生脆弱性(Allen and Gale, 2004)。最後，有些學者堅持少且大的銀行體系更容易去監督，且監理相對於競爭的金融體系存在著大量的小銀行現象，這些論點與競爭導致較高的脆弱性據一致性。

從另一方面來看，銀行業缺乏競爭可能也會加劇銀行的脆弱性，當銀行有較大的市場力量時傾向於向企業獲取較高的貸款利息，進而誘發承擔更高的風險，因此也提升金融體系整體的脆弱性(Boyd and De Nicolo, 2005)。Martinez-Miera and Repullo (2010) and Hakenes and Schnabel (2011)進一步延伸 Boyd and De Nicolo (2005)理論模型的觀點並允許貸款違約存在不完全相關，證實銀行競爭與風險之間存在 U 型的非線性關

係。再者，Wagner (2010)允許借款人可以進行風險選擇進而推翻 Boyd and De Nicolo (2005)的理論結論；Allen and Gale (2004)也證實競爭與穩定關係可能是相當複雜，其中銀行競爭也可以提升金融穩定。更要的是，大銀行經常獲得金融安全網政策中「太大而不能倒」(Too-Big-To-Fail, TBTF)的補貼，不僅扭曲銀行風險承擔的誘因，也會因而削弱整體金融體系的穩定性(Kane, 1989; Acharya et al., 2012)。最後，隨著全球金融危機的影響性已經被大量呈現，大銀行在業務複雜性上的監管活動也可能更加困難執行(Johnson and Kwak, 2011)。

(二)銀行公司治理

過去探討公司治理結構和銀行公司治理評價影響的文獻仍相對較少，金融機構也有其特殊性如高度的不透明性、高度政策監管、以及政府業務管制干預(Levine, 2004)，此意謂需要不同公司治理議題的研究分析。董事會特性和高階經理人薪酬及其所有權等銀行公司治理結構的其他方面，已在近期學術研究中被強調(Erkens et al., 2012; Minton et al., 2010; Fahlenbrach, Prilmeier, and Stulz, 2012); Beltratti and Stulz, 2012)。此外，Adams and Mehran (2003)以及 Macey and O’Hara (2003)皆強調需考慮銀行和非銀行之間在公司治理差異的重要性，以及最近由 Beltratti and Stulz (2012)與 Fahlenbrach, Prilmeier, and Stulz (2012)的兩項研究分析公司治理對銀行在信貸危機期間的表現影響。然而，這兩項研究所使用的變數為已在文獻中分析非金融機構中公司治理與公司價值之間的關係。Fahlenbrach, Prilmeier, and Stulz (2012)分析銀行 CEO 的誘因和股權對銀行績效的影響，但並沒有發現當提供銀行 CEO 更強的薪酬誘因後，即基於股權的補償比例更高，可顯著提升銀行績效的有利證據。再者，Cornett et al. (2010)以 300 家美國上市銀行為研究對象探討在金融危機中不同的公司治理機制和績效表現的關係。相較於 Erkens et al. (2012)、Beltratti and Stulz (2012)與 Fahlenbrach, Prilmeier, and Stulz (2012)，Cornett et al. (2010)發現更好的公司治理，例如更獨立的董事、較高的績效薪酬敏感性、增加內部所有權，皆與銀行在金融危機中的表現呈正相關。

這些研究建議在危機期間新興市場的公司治理對公司績效的影響，與在先進國家市場如美國和大部分歐盟成員國當地不同。過去文獻研究的分析對本研究有重要的啟發作用，尤其是銀行風險承擔行為與金融企業的權益資本籌資，如在銀行治理方面，Laeven and Levine (2009)提出一個經驗評估的理論預測，即在金融危機期間公司短期的績效和管理措施對公司主要的治理機制的影響。最後，Cheng, Hong, and Scheinkman (2010)研究是否有過多的高階管理者薪酬(以公司規模及產業調整過的總薪酬影響來衡量)與許多銀行風險衡量有關，並發現超額薪酬與風險承擔有關的證據，並建議機構投資者將經理推向高風險的商業模式和透過高薪酬作為回報。

此外，關注於董事會獨立性、機構持股、以及存在控股股東等方面進行分析，因為這些都是文獻中最常被用來檢查公司治理的基本屬性(Denis and McConnell, 2003)。值得注意的是，最近 Wintoki et al. (2012)指出公司治理研究的一個共同議題為探討董事會特徵與公司績效之間的關係可能是虛假的(Spurious)，因為這是具有內生性(Endogeneity)。

但是問題是不太可能成為本研究所欲設定的問題，因為金融危機在很大程度上是一個外生的總體經濟衝擊所致(Baek et al., 2004)；同時為減輕這種關注的相關研究皆嘗試瞭解如何影響董事會獨立性政策決定，而非僅僅是關注於公司績效表現。然而，在另一項最近的研究中，Bebchuk et al. (2010)指出在 2000 年至 2008 年期間 Bear Stearns 與 Lehman Brothers 公司中五大管理團隊兌現了大量基於績效的薪酬；同時，他們能夠在當公司倒閉獎金薪酬沒有收回兌現大筆金額，以及也能夠大量拋售手中的股票。因此，Fahlenbrach, Prilmeier, and Stulz (2012)指出管理者的激勵機制與股東的具有一致性共識之銀行，則在金融危機期間的表現不會較好。

此外，Beltratti and Stulz (2011)探討了全球銀行的樣本且證明融資脆弱且更好治理的銀行，在金融危機期間的表現上則會更差。然而，Minton et al. (2010)探討美國銀行之風險承擔與績效表現在金融危機中如何與董事會的獨立性及其金融專業有關，研究結果顯示董事會金融專業與銀行風險承擔與績效表現在金融危機發生前具正向關係，但卻與銀行在危機中的表現呈現負相關。Laeven and Levine (2009)指出由於公司擁有特有的人力資本與控制的私人利益，因此管理人往往傾向於尋求一個比股東更低的風險水準。與此觀點相一致，DeYoung et al. (2013)則發現在導致 2000 年至 2006 年的金融危機期間，銀行調整高階經理人的薪酬待遇以鼓勵管理者利用經過解除管制和債務證券化的爆發所產生新的成長機會。作者藉由迴歸公司治理因素及相同的控制變數對預期倒閉頻率(EDF)和股票報酬波動的影響，以解釋金融企業的風險承擔行為。對股東而言，在金融危機期間籌資權益資本是格外昂貴的因為此導致顯著的財富轉移從股東移轉給債務持有人(Kashyap et al., 2008)，金融業在金融危機前的風險管理即在金融危機期間的籌資活動，最終為公司董事會和股東進行成本效益權衡的結果(Kashyap et al., 2008)。最近的學術研究，強調銀行治理中的缺陷性能較差的銀行 2007 年至 2008 年(Diamond and Rajan, 2009)金融危機期間發揮重要作用。此外組織最近的一份報告得出結論在金融危機可以歸因於失敗和弱點為(Kirkpatrick, 2009)公司治理安排中的重要程度。

(三)銀行內部風險管理

首先，針對全球金融危機對銀行績效的影響來看，Fahlenbrach, Prilmeier, and Stulz (2012)發現在 1998 年表現不佳的銀行可能在最近的金融危機中更容易倒閉，意謂銀行在 1998 年的表現對倒閉率的影響是非常強的，即降低一個標準差在 1998 年金融危機期間時的報酬率與 2007 至 2008 年期間金融危機統計上高度顯著提高 5%的失敗機率間存在高度的相關性。其次，Ellul and Yerramilli (2013)驗證在信貸危機中美國 74 間大銀行控股公司的樣本中，是否銀行的穩健且獨立的風險管理與其銀行風險承擔與績效具顯著的相關性。特別是，銀行表現不佳大多為依賴短期融資在金融危機爆發前三年更加惡化，最近文獻觀點也強調短期融資在促使金融機構的脆弱性的角色，當銀行不斷加快其規模增長時將更容易遭受到危機的衝擊(Brunnermeier, 2009; Adrian and Shin, 2010; Gorton, 2010)。

最後，不同於先前的研究觀點，Acharya et al. (2009)描述積極的資產增長和短期融

資如何導致 1982 年 Continental Illinois 垮台。再者，Acharya et al. (2009)與 Acharya, Schnabl, and Suarez (2012)認為在金融危機之前資產負債表外的大規模增長，已經至少部分為解釋近期金融危機的嚴重性。正如 Brunnermeier (2009)解釋，銀行次級抵押貸款的風險暴露和短期借款依賴間的相互作用對在危機期間金融業的績效表現具有顯著的影響力。隨著風險資產在金融危機期間的價值下降，金融機構可不再依賴於短期貸款對資產的「重新評議」(Rolling Over)及被迫進行資本籌資。

就風險管理對銀行績效的實質影響來看，早期在風險管理文獻中多集中在探討單一類型的風險，卻忽略了其他風險的相互依存性(Miller, 1992)。因此，僅在 90 年代時學術文獻才開始將重點集中在對風險管理的整合性觀點上(Miller, 1992; Miccolis and Shaw, 2000; Cumming and Mirtle, 2001; Nocco and Stulz, 2006; Sabato, 2010)。特別是，在金融機構下風險管理的角色和內涵已被高度的審議。在最近的許多政策文件中，完整的風險管理框架已經被治理結構所提出與建議(Basel Committee on Banking Supervision, 2008; FSA, 2008; IIF, 2007; Walker, 2009)，有鑑於 CRO 的角色和重要性，在較一般情況下在銀行業中風險管理普遍在報紙上做各項報導而被強調(Brancato et al., 2006)，以及在實務導向的研究(Banham, 2000)，但它迄今卻一直在學術文獻中有很大程度上被忽視。此外，Acharya et al. (2009)辯稱一個強有力和獨立的風險管理是需要有效地管理風險在現代銀行的存款保險保障大到不能倒的隱性擔保削弱債權人監測，並提供市場紀律的激勵機制。DeYoung et al. (2013)認為在創新和金融市場的解除管制下，大型銀行的商業模式已經從傳統的“創設和維持”的貸款模式轉變到依靠利息收入的“創設和資產證券化”的貸款模式，此模式在過去的 20 年來大量依靠非重複且常規性的手續費收入。

在危機發生之前管理者享有高薪待遇，可能意謂公司董事會和股東鼓勵在全球性金融機構的管理者去承擔更大的風險的重要管道。此外，其研究結果也指出公司具有更複雜的經營模式在金融危機期間表現不佳，先前文獻指出董事會規模與董事會的獨立性及營運的複雜性具一定程度的關聯性(Adams and Mehran, 2012; Linck et al., 2009)。最近，Ellul and Yerramilli (2012)驗證是否在信貸危機中美國 74 間大型銀行控股公司的樣本中銀行的穩健且獨立的風險管理與其銀行風險承擔與績效具顯著的相關性，根據五個與銀行相關的風險管理強度變數來建立「風險管理指數」(RMI)，其中包括虛擬變數表示是否 CRO 是執行委員會中的委員和其他代理變數的衡量 CRO 的內部銀行管理委員會的權力。研究結果進一步指出有強大和獨立的風險管理職能傾向於有較低的企業風險，此外銀行在 2006 年擁有強的風險控管能力在 2007 至 2008 年的金融危機期間表現出較低來自自身抵押貸款證券的風險暴露、較不積極從事衍生性金融商品的交易、有較小部分不良逾期放款、較低的「下方風險」、並同時有較高夏普比率。

關於衡量個別銀行系統風險暴露的文獻方面，Acharya et al. (2010)提出一種基於系統風險衡量的模型稱之為邊際預期短缺(Marginal Shortfalls)，即衡量銀行在危機爆發時前一年中市場最差的 5%天數的平均日報酬，也可被解釋為系統性風險的衡量；再者，De Jonghe (2010)使用極值理論來產生基於市場衡量所獲得的歐洲銀行風險暴露，並檢驗此措施如何與利息收入和非利息收入如佣金和交易收入組成有關；最後，Adrian and Brunnermeier (2010)發展一個模型來估計金融機構的受限於系統性風險的實質影響。

從另一方面來看，銀行業缺乏競爭可能也會加劇銀行的脆弱性，當銀行有較大的市場力量時傾向於向企業獲取較高的貸款利息，進而誘發承擔更高的風險，因此也提升金融體系整體的脆弱性(Boyd and De Nicolo, 2005)。Martinez-Miera and Repullo (2010) and Hakenes and Schnabel (2011)進一步延伸 Boyd and De Nicolo (2005)理論模型的觀點並允許貸款違約存在不完全相關，證實銀行競爭與風險之間存在 U 型的非線性關係。再者，Wagner (2010)允許借款人可以進行風險選擇進而推翻 Boyd and De Nicolo (2005)的理論結論；Allen and Gale (2004)也證實競爭與穩定關係可能是相當複雜，其中銀行競爭也可以提升金融穩定。更要的是，大銀行經常獲得金融安全網政策中「太大而不能倒」(Too-Big-To-Fail, TBTF)的補貼，不僅扭曲銀行風險承擔的誘因，也會因而削弱整體金融體系的穩定性(Kane, 1989; Acharya et al., 2012)。最後，隨著全球金融危機的影響性已經被大量呈現，大銀行在業務複雜性上的監管活動也可能更加困難執行(Johnson and Kwak, 2011)。

(2)公司治理的影響

過去探討公司治理結構和銀行公司治理評價影響的文獻仍相對較少，金融機構也有其特殊性如高度的不透明性、高度政策監管、以及政府業務管制干預(Levine, 2004)，此意謂需要不同公司治理議題的研究分析。董事會特性和高階經理人薪酬及其所有權等銀行公司治理結構的其他方面，已在近期學術研究中被強調(Erkens et al., 2012; Minton et al., 2010; Fahlenbrach, Prilmeier, and Stulz, 2012); Beltratti and Stulz, 2012)。此外，Adams and Mehran (2003)以及 Macey and O'Hara (2003)皆強調需考慮銀行和非銀行之間在公司治理差異的重要性，以及最近由 Beltratti and Stulz (2012)與 Fahlenbrach, Prilmeier, and Stulz (2012)的兩項研究分析公司治理對銀行在信貸危機期間的表現影響。然而，這兩項研究所使用的變數為已在文獻中分析非金融機構中公司治理與公司價值之間的關係。Fahlenbrach, Prilmeier, and Stulz (2012)分析銀行 CEO 的誘因和股權對銀行績效的影響，但並沒有發現當提供銀行 CEO 更強的薪酬誘因後，即基於股權的補償比例更高，可顯著提升銀行績效的有利證據。再者，Cornett et al. (2010)以 300 家美國上市銀行為研究對象探討在金融危機中不同的公司治理機制和績效表現的關係。相較於 Erkens et al. (2012)、Beltratti and Stulz (2012)與 Fahlenbrach, Prilmeier, and Stulz (2012)，Cornett et al. (2010)發現更好的公司治理，例如更獨立的董事、較高的績效薪酬敏感性、增加內部所有權，皆與銀行在金融危機中的表現呈正相關。

這些研究建議在危機期間新興市場的公司治理對公司績效的影響，與在先進國家市場如美國和大部分歐盟成員國當地不同。過去文獻研究的分析對本研究有重要的啟發作用，尤其是銀行風險承擔行為與金融企業的權益資本籌資，如在銀行治理方面，Laeven and Levine (2009)提出一個經驗評估的理論預測，即在金融危機期間公司短期的績效和管理措施對公司主要的治理機制的影響。最後，Cheng, Hong, and Scheinkman (2010)研究是否有過多的高階管理者薪酬(以公司規模及產業調整過的總薪酬影響來衡量)與許多銀行風險衡量有關，並發現超額薪酬與風險承擔有關的證據，並建議機構投資者將經理推向高風險的商業模式和透過高薪酬作為回報。

此外，關注於董事會獨立性、機構持股、以及存在控股股東等方面進行分析，因為這些都是文獻中最常被用來檢查公司治理的基本屬性(Denis and McConnell, 2003)。值得注意的是，最近 Wintoki et al. (2012)指出公司治理研究的一個共同議題為探討董事會特徵與公司績效之間的關係可能是虛假的(Spurious)，因為這是具有內生性(Endogeneity)。但是問題是不太可能成為本研究所欲設定的問題，因為金融危機在很大程度上是一個外生的總體經濟衝擊所致(Baek et al., 2004)；同時為減輕這種關注的相關研究皆嘗試瞭解如何影響董事會獨立性政策決定，而非僅僅是關注於公司績效表現。然而，在另一項最近的研究中,Bebchuk et al. (2010)指出在 2000 年至 2008 年期間 Bear Stearns 與 Lehman Brothers 公司中五大管理團隊兌現了大量基於績效的薪酬；同時，他們能夠在當公司倒閉獎金薪酬沒有收回兌現大筆金額,以及也能夠大量拋售手中的股票。因此,Fahlenbrach, Prilmeier, and Stulz (2012)指出管理者的激勵機制與股東的具有一致性共識之銀行，則在金融危機期間的表現不會較好。

此外，Beltratti and Stulz (2011)探討了全球銀行的樣本且證明融資脆弱且更好治理的銀行，在金融危機期間的表現上則會更差。然而，Minton et al. (2010)探討美國銀行之風險承擔與績效表現在金融危機中如何與董事會的獨立性及其金融專業有關，研究結果顯示董事會金融專業與銀行風險承擔與績效表現在金融危機發生前具正向關係，但卻與銀行在危機中的表現呈現負相關。Laeven and Levine (2009)指出由於公司擁有特有的人力資本與控制的私人利益，因此管理人往往傾向於尋求一個比股東更低的風險水準。與此觀點相一致，DeYoung et al. (2013)則發現在導致 2000 年至 2006 年的金融危機期間，銀行調整高階經理人的薪酬待遇以鼓勵管理者利用經過解除管制和債務證券化的爆發所產生新的成長機會。作者藉由迴歸公司治理因素及相同的控制變數對預期倒閉頻率(EDF)和股票報酬波動的影響，以解釋金融企業的風險承擔行為。對股東而言，在金融危機期間籌資權益資本是格外昂貴的因為此導致顯著的財富轉移從股東移轉給債務持有人(Kashyap et al., 2008)，金融業在金融危機前的風險管理即在金融危機期間的籌資活動，最終為公司董事會和股東進行成本效益權衡的結果(Kashyap et al., 2008)。最近的學術研究，強調銀行治理中的缺陷性能較差的銀行 2007 年至 2008 年(Diamond and Rajan, 2009)金融危機期間發揮重要作用。此外組織最近的一份報告得出結論在金融危機可以歸因於失敗和弱點為(Kirkpatrick, 2009)公司治理安排中的重要程度。

(3)風險管理的影響

首先，針對全球金融危機對銀行績效的影響來看，Fahlenbrach, Prilmeier, and Stulz (2012)發現在 1998 年表現不佳的銀行可能在最近的金融危機中更容易倒閉，意謂銀行在 1998 年的表現對倒閉率的影響是非常強的，即降低一個標準差在 1998 年金融危機期間時的報酬率與2007 至2008 年期間金融危機統計上高度顯著提高5%的失敗機率間存在高度的相關性。其次，Ellul and Yerramilli (2013)驗證在信貸危機中美國 74 間大銀行控股公司的樣本中，是否銀行的穩健且獨立的風險管理與其銀行風險承擔與績效具顯著的相關性。特別是，銀行表現不佳大多為依賴短期融資在金融危機爆發前三年更加惡化，最近文獻觀點也強調短期融資在促使金融機構的脆弱性的角色，當銀行不斷加快其規模增長時將更容易遭受到危機的衝擊(Brunnermeier, 2009; Adrian and Shin, 2010; Gorton, 2010)。

最後，不同於先前的研究觀點，Acharya et al. (2009)描述積極的資產增長和短期融資如何導致 1982 年 Continental Illinois 垮台。再者，Acharya et al. (2009)與 Acharya, Schnabl, and Suarez (2012)認為在金融危機之前資產負債表外的大規模增長，已經至少部分為解釋近期金融危機的嚴重性。正如 Brunnermeier (2009)解釋，銀行次級抵押貸款的風險暴露和短期借款依賴間的相互作用對在危機期間金融業的績效表現具有顯著的影響力。隨著風險資產在金融危機期間的價值下降，金融機構可不再依賴於短期貸款對資產的「重新評議」(Rolling Over)及被迫進行資本籌資。

就風險管理對銀行績效的實質影響來看，早期在風險管理文獻中多集中在探討單一類型的風險，卻忽略了其他風險的相互依存性(Miller, 1992)。因此，僅在 90 年代時學術文獻才開始將重點集中在對風險管理的整合性觀點上(Miller, 1992; Miccolis and Shaw, 2000; Cumming and Mirtle, 2001; Nocco and Stulz, 2006; Sabato, 2010)。特別是，在金融機構下風險管理的角色和內涵已被高度的審議。在最近的許多政策文件中，完整的風險管理框架已經被治理結構所提出與建議(Basel Committee on Banking Supervision, 2008; FSA, 2008; IIF, 2007; Walker, 2009)，有鑑於 CRO 的角色和重要性，在較一般情況下在銀行業中風險管理普遍在報紙上做各項報導而被強調(Brancato et al., 2006)，以及在實務導向的研究(Banham, 2000)，但它迄今卻一直在學術文獻中有很大程度上被忽視。此外，Acharya et al. (2009)辯稱一個強有力和獨立的風險管理是需要有效地管理風險在現代銀行的存款保險保障大到不能倒的隱性擔保削弱債權人監測，並提供市場紀律的激勵機制。DeYoung et al. (2013)認為在創新和金融市場的解除管制下，大型銀行的商業模式已經從傳統的“創設和維持”的貸款模式轉變到依靠利息收入的“創設和資產證券化”的貸款模式，此模式在過去的 20 年來大量依靠非重複且常規性的手續費收入。

在危機發生之前管理者享有高薪待遇，可能意謂公司董事會和股東鼓勵在全球性金融機構的管理者去承擔更大的風險的重要管道。此外，其研究結果也指出公司具有更複雜的經營模式在金融危機期間表現不佳，先前文獻指出董事會規模與董事會的獨立性及營運的複雜性具一定程度的關聯性(Adams and Mehran, 2012; Linck et al., 2009)。最近，Ellul and Yerramilli (2012)驗證是否在信貸危機中美國 74 間大型銀行控股公司的樣本中銀行的穩健且獨立的風險管理與其銀行風險承擔與績效具顯著的相關性，根據五個與銀行相關的風險管理強度變數來建立「風險管理指數」(RMI)，其中包括虛擬變數表示是否 CRO 是執行委員會中的委員和其他代理變數的衡量 CRO 的內部銀行管理委員會的權力。研究結果進一步指出有強大和獨立的風險管理職能傾向於有較低的企業風險，此外銀行在 2006 年擁有強的風險控管能力在 2007 至 2008 年的金融危機期間表現出較低來自自身抵押貸款證券的風險暴露、較不積極從事衍生性金融商品的交易、有較小部分不良逾期放款、較低的「下方風險」、並同時有較高夏普比率。

關於衡量個別銀行系統風險暴露的文獻方面，Acharya et al. (2010)提出一種基於系統風險衡量的模型稱之為邊際預期短缺(Marginal Shortfalls)，即衡量銀行在危機爆發時前一年中市場最差的 5%天數的平均日報酬，也可被解釋為系統性風險的衡量；再者，De Jonghe (2010)使用極值理論來產生基於市場衡量所獲得的歐洲銀行風險暴露，並檢驗此措施如何與利息收入和非利息收入如佣金和交易收入組成有關；最後，Adrian and Brunnermeier (2010)發展一個模型來估計金融機構的受限於系統性風險的實質影響。

三、研究方法

(一)系統性違約風險指標(Systemic Default Risk Measures)

本研究運用 Merton (1974)所提出或有請求架構來衡量個別銀行的違約風險，這個方法視銀行的權益價值為銀行資產的買權選擇權(Call Option)。違約機率使用違約距離衡量來計算，即銀行資產價值與負債面值之間的差距並透過銀行資產價值的標準差來調整。Merton (1974)所提出違約距離衡量已經被許多學者證實在作為違約的預測因子時會相對優於會計基礎模型的表現(Hillegeist et al., 2004; Campbell et al., 2008; Bharath and Shumway, 2008)，而 Merton(1974)違約距離衡量更普遍使用在一般產業的破產預測中。然而，Merton (1977a, 1977b)則指出或有請求方法對於評價銀行業的存款保險具有高度的可應用性，其中 Bongini et al., (2002)、Bartram et al. (2007)以及 Hovakimian et al. (2012)等學者也曾使用 Merton(1974)模型來衡量商業銀行的違約風險。

此外，相較於傳統銀行風險的衡量指標，如 Z 分數(z-score)，但是市場基礎的違約距離衡量指標具有許多明顯的優點：第一，違約距離的衡量可以被更經常性地予以更新，

當資產負債對於全球銀行的資訊而言僅能夠獲得年資料的限制來看，股價資訊卻可以每天獲得進行評價。第二，股票市場資訊通常被視為具有往前看的特性，且因而違約距離的衡量指標反應出銀行被預期在未來營運健全性上的市場認知程度。本研究同時也延續 Campbell et al. (2008)和 Hillegeist et al. (2004)的研究來計算 Merton 違約距離的衡量，特別是銀行的市場權益價值可以被視為銀行資產的賣權選擇權而被衡量：

$$V_E = V_A e^{-dT} N(d_1) - X e^{-rT} N(d_2) + (1 - e^{-dT}) V_A \tag{1}$$

$$d_1 = \frac{\log(\frac{V_A}{X}) + (r - d + \frac{s_A^2}{2})T}{S_A\sqrt{T}};\ d_2 = d_2 - S_A\sqrt{T}$$

其中，方程式(1)V_E 假設為銀行的市場價值、V_A 代表銀行資產的價值、 X 表示為在時間點 T 時到期後負債的面額、r 為無風險利率、d 為以V_A 來表示股利發放率、 S_A 表示為資產價值的波動性與權益波動有關，可經由以下方程式來求算出：

$$S_E = \frac{V_A e^{-dT} N(d_1) S_A}{V_E} \tag{2}$$

針對方程式(2)本研究運用聯立求解方程式(1)與方程式(2)來獲得V_A 與 S_A 的數值，並且使用權益的市場價值V_E 以及總負債作為負債的面值 X 的替代變數(Proxy)，因為會計資訊主要為年度發布資料，因此本研究藉由線性化平移所有的日期到這個年底時點，將期初與期末的會計項目中的數值趨於平均。此平移的方法具有產生平滑資產隱含價值過程的優點，並避免隱含違約機率在年底時的明顯跳動。

S_E 代表過去一年每日股價報酬的標準差，在計算標準差的時候需要銀行至少有 90 天在過去的 12 個月中無遺漏的報酬率數值。T=1 年與 r=一年的美國國庫券的殖利率被視為無風險利率，本研究運用 Newton 方法來聯立求解方程式(1)與方程式(2)。針對未知變數的起始值(Starting Value)，本研究使用 $V_A = V_E + X$ 和 $S_A = S_E V_E / (V_E + X) + X$ 來估算。接著，本研究分別在分配中頭、尾端各 5%與 95%的分量水準下採用集中趨勢化(winsorize) S_E 與 $V_E / (V_E + \mathrm{X})$ 數值，以降低極端值對估計結果的影響性。在決定資產價值V_A 後，本研究遵循 Campbell et al. (2008)的研究設計，並將資產報酬率 m 設定為等於權益溢酬(6%)，因此 Merton 違約距離(dd)最後可以被計算如下：

$$dd = \frac{\log(\frac{V_A}{X}) + (m - d - \frac{s_A^2}{2})T}{S_{A\sqrt{T}}} \tag{3}$$

違約機率為違約距離衡量的常態轉換，並且被定義為 $PD=F(-dd)$，其中 F 為標準常態分配的累積分配函數。

如上述所言，本研究關注於銀行系統的穩定，因此我們檢驗銀行的風險承擔行為的相關性藉由衡量特定銀行違約風險改變的總變異被解釋從所有其他銀行在特定國家中違約機率的改變。本研究使用系統穩定的衡量 R^2，則獲得自迴歸對所有銀行違約風險的改變對特定銀行平均違約風險的改變方程式。為了計算這個數值，對每個銀行 i 在國家 j 中在第 w 週在下第 t 年，先計算每週 Merton 違約距離($dd_{i,j,t,w}$)。對每個銀行 i 在第 t 年我們估計一個時間序列迴歸式，即對銀行 i 的每週變動的違約距離在所屬國家平均每週變動的違約距離(但不包含 i 銀行自己的樣本)，估計模型設定如下:

$$\Delta dd_{i,j,t,w} = \alpha_{i,j,t} + \beta_{i,j,t} \frac{1}{n} \sum_{k=1,k\neq i}^{n} \Delta dd_{k,j,t,w} + \varepsilon_{i,j,t,w} \tag{4}$$

延續 Morck et al. (2000)和 Karolyi et al. (2012)的研究設計，將估計出 R^2 進行羅吉斯轉換(Logistic Transformation)，即 $\log(R^2_{i,j,t}/(1-R^2_{i,j,t}))$來衡量第 i 家銀行的系統風險，其中 R^2 僅僅計算銀行在一年內至少 26 週違約距離的變動。較高的 R^2 對個別銀行而言，意謂銀行曝露於相似的信用風險來源和其他銀行在相同國家中；較高的 R^2 也意謂銀行與其他銀行之間在特定國家中存在共同相依性的影響管道。相互連結與共同風險曝險，使得金融業對於經濟、流動性及資訊衝擊反應更加脆弱。此外，衡量關於國家平均的系統風險作為銀行監理與管制所執行在國家的層級中，從政策觀點來看系統性風險在國家的層級上是更具相關的。再者，Acharya (2009)指出銀行有誘因承擔相關性的風險，如果存在隱性保證來自州政府所提供政策補貼來補償因系統性危機所導致的損失。Bertay et al. (2012)也認為金融安全網可以降低銀行的國際化程度，因為全球銀行不易被所經營的在地政府提供財務援助。

基於穩健性檢定的考量，進一步額外使用其他的系統性的風險指標，依循 Adrian and Brunnermeier (2009)的研究設計，本研究也計算條件風險值(Conditional Value at Risk measure, CoVar)使用分量迴歸(Quantile Regression)來計算樣本中的每家銀行的系統性風險。分量迴歸的估計變數在不同分量上的函數關係(Koenker and Hallock, 2001))並允許在財務危機期間更精準的估計信用風險的共同相依性(Co-dependence)，特別當存較大的負面衝擊時藉由考慮非線性的關係來處理。本研究使用 Adrian and Brunnermeier (2009)的

研究設計下，使用一系列的狀態變數來估計時間序列的 CoVar 風險衡量指標，因此在個別銀行樣本期間估計以下分量迴歸:

$$\Delta dd_{i,t} = \alpha_i + \gamma_i M_{t-1} + \varepsilon_{i,t}$$

$$\Delta Systemdd_t = \alpha_{system|i} + \beta_{system|i} \Delta dd_{i,t} + \gamma_{system|i} M_{t-1} + \varepsilon_{system|i,t} \quad (5)$$

在方程式(5)中 $\Delta dd_{i,t}$ 表示銀行 *i* 在第 *t* 週時 Merton 違約距離的改變、$\Delta Systemdd_t$ 表示在特定國家中所有銀行價值加權平均計算出 Merton 違約距離的變動、M_{t-1} 為落遲的狀態變數並包括利率期間差異的改變(TERM)、違約差異的改變(DEF)、CBOE 隱含波動指數(VIX)、SP500 報酬率(SPRET)以及 3 個月國庫券利率的改變(RATE)。$\Delta CoVar$ 變數接著從體系的 VaR 改變所計算而得,當銀行位於第 *q* 個分量或當銀行在財務危機期間扣除當銀行為超過 50%的分量時體系的 VaR，估計式如下所示：

$$CoVarSYS_t^q = \beta_{SYS|i}^q (\Delta dd_{i.t}^q - \Delta dd_{i.t}^{50\%}) \quad (6)$$

本研究計算個別銀行在 *q*=1%下的 $\Delta CoVar$ ，並分別在以下三個樣本期間：2002 之前、2002~2007、2007 年之後，為了要涵蓋時間變異的景氣條件，在此三個期間中(Moore and Zhou, 2011)；$\Delta CoVar$ 衡量個別銀行的風險貢獻以較低的數值來指出更大的風險貢獻。

就衡量風險共同相依性來看，使用 R^2 具有在不同風險指標的選擇的優點，已被學者 Pukthuanthong and Roll (2009)和 Bekaert and Wang (2009)所認可。例如 $\Delta CoVar$ 為系統風險的衡量可能遭遇波動性的偏誤，主要因為可能會低估系統性風險在穩定期間的估計。Billio et al. (2012)指出在實質金融創新期間中，金融機構的風險共同相依性可能是相當高的，但是金融體系的實質損失卻可能因而不會發生，此導致低的 $\Delta CoVar$ 水準因為無法精準地捕捉金融機構之間高的風險共同相依性。使用 R^2 作為本研究主要系統風險的衡量，能夠較佳捕捉在金融危機期間銀行風險承擔的相關性，且使用 $\Delta CoVar$ 作為穩健性檢定，以確保不同系統性風險的衡量在估計結果中表現出可靠的分析。

(二)衡量銀行競爭的程度

本研究使用 Lerner 指數(Lerner Index)作為衡量銀行競爭的主要指標，Lerner 指數

定義為銀行利潤在市場中定價能力的結果，為主要衡量銀行層級並廣泛在金融的研究中被使用的一種替代變數(Demirguc-Kunt and Martinez-Peria, 2010; Beck et al., 2013)，本研究依據 Demirguc-Kunt and Martinez-Peria (2010)研究設計，並對每個國家估計以下的對數成本函數：

$$
\begin{aligned}
\log(C_{it}) = {} & \alpha + \beta_1 \times \log(Q_{it}) + \beta_2 \times (\log(Q_{it}))^2 + \beta_3 \times \log(W_{1,it}) + \beta_4 \times \log(W_{2,it}) \\
& + \beta_5 \times \log(W_{3,it}) + \beta_6 \times \log(Q_{it}) \times \log(W_{1,it}) + \beta_7 \times \log(Q_{it}) \times \log(W_{2,it}) \\
& + \beta_8 \times \log(Q_{it}) \times \log(W_{3,it}) + \beta_9 \times (\log(W_{1,it}))^2 + \beta_{10} \times (\log(W_{2,it}))^2 \\
& + \beta_{11} \times (\log(W_{3,it}))^2 + \beta_{12} \times \log(W_{1,it}) \times \log(W_{2,it}) + \beta_{12} \times \log(W_{1,it}) \times \log(W_{2,it}) \\
& + \beta_{13} \times \log(W_{1,it}) \times \log(W_{3,it}) + \beta_{14} \times \log(W_{2,it}) \times \log(W_{3,it}) + \Theta \times \text{年虛擬變數} \\
& + \Omega \times \text{銀行類型虛擬變數} + \varepsilon_{it}
\end{aligned} \quad (7)
$$

方程式(7)中，i 為銀行 t 為年。C_{it} 為總成本，加總利息費用、傭金費用、手續費用、交易費用、人事費用以及行政管理費用與其他營運費用並以美元衡量。Q_{it} 為產出的數量，以美元計價的總資產來衡量。$W_{1,it}$ 表示為利息費用佔總資產比率、$W_{2,it}$ 為人事費用佔總資產比率、$W_{3,it}$ 為管理與其他營運費用佔總資產比率。對所有的變數進行自然對數的計算並使用一般最小平方法(OLS)，分別對研究樣本中的國家進行迴歸估計，特別包含年與銀行類別的虛擬變數在回歸模型的估計中；同時在所有的變數在頭尾分配之 1%及 99%下都採取集中趨勢化處理，以降低極端值估計結果的偏誤影響。再者，進一步在迴歸係數中附加五個條件限制式，以確保要素投入價格須服從同質性的特性:

$$
\begin{aligned}
& \beta_3 + \beta_4 + \beta_5 = 1;\ \beta_6 + \beta_7 + \beta_8 = 0;\ \beta_9 + \beta_{12} + \beta_{13} = 0; \\
& \beta_{10} + \beta_{12} + \beta_{14} = 0;\ \beta_{11} + \beta_{13} + \beta_{14} = 0
\end{aligned} \quad (8)
$$

接著使用來自於以上的迴歸式的估計係數值，進一步估計銀行 i 在第 t 年的邊際成本(MC)，如下實證模型所示:

$$
\begin{aligned}
MC_{it} &= \partial C_{it} / \partial Q_{it} \\
&= C_{it} / \mathrm{Q}_{it} \times \left[\beta_1 + 2 \times \beta_2 \times \log(\mathrm{Q}_{it}) + \beta_6 \times \log(\mathrm{W}_{1,it}) + \beta_7 \times \log(\mathrm{W}_{2,it}) + \beta_8 \times \log(\mathrm{W}_{3,it}) \right]
\end{aligned}
$$

(9)

因此，Lerner 指數可以透過下式計算而得：

$$Lerner_{it} = \left(P_{it} - MC_{it}\right) / P_{it}$$

(10)

其中，P_{it} 為銀行資產的價格，等於總收益(加總利息收益、傭金與手續費收益、交易收益及其他營業收益的加總)佔總資產的比率。本研究也運用過去在相關文獻中常用的競爭指標，如根據 Panzar and Rosse (1987)的研究方法所推估 H-statistic。本研究也遵循 Claessens and Laeven (2004)估計作法，對每個樣本銀行國家下每一個年度中，估計以下的銀行收益迴歸式之縮減式(Reduced Form)：

$$\begin{aligned}\log(P_i) = {} & \alpha + \beta_1 \times \log(W_{1,i}) + \beta_2 \times \log(W_{2,i}) + \beta_3 \times \log(W_{3,i}) + \gamma_1 \times \log(Y_{1,i}) \\ & + \gamma_2 \times \log(Y_{2,i}) + \gamma_3 \times \log(Y_{3,i}) + \Omega \times D_{\text{銀行種類}} + \varepsilon_i\end{aligned}$$

(11)

其中，i 為銀行。P_i 為總利息收入佔總產的比率作為衡量銀行放款的產出價格、$W_{1,i}$ 為利息費用佔總資產比率(作為衡量銀行放款的投入價格)、$W_{2,i}$ 為人事費用佔總資產比率(作為衡量銀行在勞動投入價格的替代變數)、$W_{3,i}$ 為管理與其他營運費用佔總資產比率(作為衡量銀行在資本投入要素價格)。控制變數包括:$Y_{1,i}$ 為總股東權益佔總資產比率、$Y_{2,i}$ 為淨放款佔總資產比率、$Y_{3,i}$ 為以美元來計價的銀行總資產金額。對所有的變數都取自然對數進行處理，並使用一般最小平方法(OLS)來估計實證迴歸模型，同時也對所有的變數在頭尾單分配下 1%與 99%水準進行集中趨勢化處理，以降低極端值對估計結果的偏誤影響。

H-statistic 衡量收益彈性對 3 個要素價格彈性的加總值，即 $\beta_1 + \beta_2 + \beta_3$。$H$-statistic 的數值範圍應介於 $-\infty$ 到 1 之間:第一，H-statistic 等於或小於 0 時，則銀行市場結構位於為獨佔(Monopoly)或完全勾結(Perfect Collusion)的型態；第二，若 H-statistic 的數值介於 0 到 1 之間，則銀行市場結構表現出寡占(oligopolistic)或獨佔性競爭(Monopolistic Competition)的型態;第三,若 H-statistic 的數值等於 1 代表完全競爭(Perfect Competition)。因此,當 H-statistic 數值愈高,則意謂更競爭的市場,在此本研究將 H-statistic 取負數值，以利於方便解釋更高的值代表更高的市場力量。

以下進一步檢驗銀行市場結構，在 Panzar–Rosse 模型中被滿足是否符合長期均衡

的條件，藉由檢驗以下的迴歸設定：

$$\begin{aligned}\log(1+ROA_i) &= \alpha+\beta_1\times\log(W_{1,i})+\beta_2\times\log(W_{2,i})+\beta_3\times\log(W_{3,i}) \\ &+\gamma_1\times\log(Y_{1,i})+\gamma_2\times\log(Y_{2,i})+\gamma_3\times\log(Y_{3,i})+\varepsilon_i\end{aligned} \quad (12)$$

其中，ROA_i 表示為銀行的資產報酬率，即銀行稅前利潤佔總資產比率。如果銀行體系處於長期均衡下，則要素價格應該不會受到資產報酬率的影響。換言之，則表示在均衡時存在 $\beta_1+\beta_2+\beta_3=0$ 的結果。

許多研究使用銀行集中度作為銀行業競爭的替代變數(Beck et al., 2006)，因此本研究也使用銀行資產的 Hirschmann–Herfindahl index (HHI)以及一國中部分總資產被前三大商業銀行所持有份額(CR3)，進一步檢驗銀行競爭與系統性風險的實證關係。最近的文獻指出並強調競爭與集中度的差異，Claessens and Laeven (2004)強調集中程度可能在銀行業的可競爭性上是一個不理想的替代變數，Schaeck and Cihak (2014)與 Love and Martinez-Peria (2012)皆指出集中度僅能衡量市場競爭行為下的市場結構；此外，Bikker and Spierdijk (2008)認為集中度衡量指標可能會誇大了小國家的競爭水準,尤其是當銀行家數較少時更不可靠。

然而，使用 Lerner 指數則有許多優點，尤其是在市場競爭的可選擇潛在指標上：第一，Beck et al. (2013)認為 Lerner 指數為衡量銀行的定價能力並且具有符合較佳捕抓銀行特許價值的理論觀念。第二，這些學者認為 Lerner 指數(計算銀行資產利潤與銀行經營成本之間的差異)使用銀行資產與籌資資訊且因而有效捕捉定價能力在銀行資產與籌資面的影響。第三，不同於 *H*-statistic 指標，Lerner 指數的計算不需要理論符合銀行體系達到長期均衡的狀態下使用(Schaeck and Cihak, 2014)。第四，Aghion et al. (2005)認為 Lerner 指數的優點對於市場集中度以及競爭的市場份額的衡量,主要在於不需依賴區域產品市場精準的定義下來進行估計;其中,對銀行業而言定義區域市場是相當困難的，因為許多銀行通常在許多國家間跨區或跨國營運。第五，Lerner 指數只是競爭的指標，可以在銀行層級的資料中獲得但卻不同於市場份額。有鑑於此，本研究的研究目的在於檢驗競爭與系統性風險之間的個別銀行層級關係，因此依據 Beck et al. (2013)並使用 Lerner 指數作為主要衡量銀行競爭的指標。同時,也使用 *H*-statistic、銀行集中度(CR3)、以及 HHI 指數，作為在穩健性檢定時可供選擇銀行競爭與結構的指標。

(三)實證模型設定

本研究依據 Anginer, Demirguc-Kunt, and Zhu (2014)與 Beck et al. (2013)的實證研究假構，來設計本研究的實證模型:

第一，估計銀行競爭對銀行個別系統性風險的影響:

$$\begin{aligned}(\text{系統性風險})_{ijt} &= \alpha_0 + \alpha_1 \times (\text{銀行競爭})_{ijt-1} + \Phi \times (\text{銀行控制變數})_{ijt-1} \\ &+ \Psi \times (\text{國家虛擬變數})_{jt} + \delta_i + \varpi_t + \xi_{ijt}\end{aligned} \tag{13}$$

主要衡量銀行競爭對系統性風險的影響，銀行競爭變數以及銀行控制變數採用落遲一年的數值。

第二，同時考慮銀行公司治理與內部風險管理機制後，再估計銀行競爭對銀行個別系統性風險的影響:

$$\begin{aligned}(\text{系統性風險})_{ijt} &= \alpha_0 + \alpha_1 \times (\text{銀行競爭})_{ijt-1} + \alpha_2 \times (\text{公司治理})_{ijt-1} \\ &+ \alpha_3 \times (\text{風險管理})_{ijt-1} + \Phi \times (\text{銀行控制變數})_{ijt-1} \\ &+ \Psi \times (\text{國家虛擬變數})_{jt} + \delta_i + \varpi_t + \xi_{ijt}\end{aligned} \tag{14}$$

銀行公司治理與內部風險管理變數皆採用落遲一年的數值；其中，上市銀行於 2000 年至 2014 年間公司治理資料(包括「董事會規模」、「獨立董事比例」、「高階管理薪酬」、「機構投資人持股比率」與「大股東持股比例」；此外，內部風險管理機制(包含「銀行是否有指派 CRO 職位、「是否 CRO 也是高階管理者」、「是否 CRO 的薪酬位居前五大」、「CRO 總薪酬(含股票選擇權) 」、「風險管理委員會的經歷與開會次數」、「是否 CRO 對董事會進行風險報告」等)則逐筆收集自樣本銀行年報(Annual Report)中的所揭露資訊中。

第三，估計銀行競爭透過國家治理與金融監理對銀行個別系統性風險的交互影響效果:

$$\begin{aligned}(\text{系統性風險})_{ijt} &= \gamma_0 + \gamma_1 \times (\text{銀行競爭})_{ijt-1} + \gamma_2 \times (\text{公司治理})_{jt-1} + \gamma_3 \times (\text{風險管理})_{jt-1} \\ &+ \phi_1 \times (\text{國家治理品質})_{jt-1} + \phi_2 \times (\text{銀行監理})_{jt-1} \\ &+ \mu_1 \times (\text{銀行競爭})_{ijt-1} \times (\text{國家治理品質})_{jt-1} \\ &+ \mu_2 \times (\text{銀行競爭})_{ijt-1} \times (\text{銀行監理})_{jt-1} \\ &+ \Upsilon \times \text{銀行控制變數}_{ijt-1} + \Xi \times \text{國家虛擬變數}_{jt-1} \\ &+ \pi_i + \upsilon_t + \zeta_{ijt}\end{aligned} \tag{15}$$

主要考慮銀行監理分別與國家治理品質的交乘項，即
$\left[(\text{銀行競爭})_{ijt-1} \times (\text{國家治理品質})_{jt-1}\right]$，以及與銀行監理的交乘項，即
$\left[(\text{銀行競爭})_{ijt-1} \times (\text{銀行監理})_{jt-1}\right]$兩個部分。

A.控制變數

實證模型(方程式(13)至(15))所使用的控制變數，包括銀行規模、籌資結構、商業模式以及獲利性，個別銀行層級的控制變數資料收集自 Bankscope 資料庫。計算銀行規模(對總資產取自然對數)、非存款短期融資的依賴(非存款性短期融資佔存款與非存款短期融資總額的比率)、獲利性(淨利佔總資產的比率)、市價帳面價值比(資產的市值佔資產的帳面價值比率)、非利息收益比率(非利息收益佔總營運收益的比率)、以及備抵呆帳比率(放款損失準備佔總資產比率)。本研究也針對全部的財務變數分配頭尾 1%及 99%進行集中趨勢化處理，以降低極端值及潛在資料錯誤的影響。

此外，國家層級的控制變數主要蒐集自以下不同的資料來源：第一，國家經濟發展指標主要來自於世界銀行 WDI 資料庫(World Development Indictor)，使用對每人年均 GDP 並進行自然對數轉換來衡量一國的經濟發展指標，GDP 成長率的變異數主要用來衡量一國的經濟穩定度以及使用進口加上出口及服務佔 GDP 的比率，來衡量全球整合的程度(Global Integration) (Karolyi et al., 2012)。此外私人信用佔 GDP 的比率主要收集自 Financial Structure Dataset 資料庫(Beck et al., 2010)來控制銀行業發展的程度；同時，本研究也控制每個國家銀行的總家數取對數值，因為 R^2 衡量可能與橫斷面銀行的家數有關。

B.國家治理(機構)與金融監理變數

本研究使用國家治理指標來自世界銀行中主要由 Kaufmann, Kraay, and Mastruzzi (2010) 等人所建立的 WGI 資料庫(Worldwide Governance Indicators)(http://info.worldbank.org/governance/wgi/)。主要包含以下六類的指標: 公民參政與政治人權(Voice and Accountability)、政治穩定度與(Political Stability and Absence of Violence)、政府效能(Government Effectiveness)、管制品質(Regulatory Quality)、法令規則(Rule of Law)、貪腐控制(Control of Corruption)等構面。

再者，金融管制與監理的變數來自於 Barth et al. (2013)全球 180 個國家在 1999 年至 2011 年間銀行監理與管制的國家資料，本研究考慮以下 3 大類型的銀行管制與機構變數：第一，競爭限制或鼓勵的國家政策性變數，即進入障礙指數(Entry barrier index)，衡量銀行進入要求並且由 8 個調查問券項目所構成此指標(當一國符合法律申請要求以獲得法定經營牌照、過去五年內銀行設立申請而被拒絕的比例、銀行的政府持股所有權超過 50%或更高)。第二，銀行管制與監理面的變數：業務活動性指數(衡量全國法規主管機關允許銀行去從事證券、保險、及不動產事業的程度)、資本嚴格指數(衡量銀行必須維持的資本數量)、監管能力指數(指出是否金融監督機構有實質力量或授權去執行特定保護性的或糾正性的活動)、多角化指數(規範銀行資產多角化是否具有明顯、可驗證

性、可量化性的指導方針，以及是否銀行可被允許進行跨境放款的業務)。第三，投資人保護指數以及信用資訊分享的深度，資料來自於 Djankov et al. (2007)以及世界銀行所設立 Doing Business Survey 資料庫中(www.doingbusiness.org)、存款保險保額(若國家提供存款人全額存款保險保障時則為 1)(存款保險保額比率為存款保險保額佔每人存款金額的比率，此部分資料來收集自於 Demirguc-Kunt et al. (2008)。

四、資料來源

實證研究對象主要使用 Bankscope 資料庫中上市商業銀行於 2000 年至 2014 年間的樣本為主，進一步將樣本銀行的財務資訊之基本訊息進行完整性的比對，並剔除財務資訊缺漏的樣本銀行。另外，上市銀行於 2000 年至 2014 年間公司治理資料(包括「董事會規模」、「獨立董事比例」、「高階管理薪酬」、「機構投資人持股比率」與「大股東持股比例」，以及內部風險管理機制(包含「銀行是否有指派 CRO 職位、「是否 CRO 也是高階管理者」、「是否 CRO 的薪酬位居前五大」、「CRO 總薪酬(含股票選擇權) 」、「風險管理委員會的經歷與開會次數」、「是否 CRO 對董事會進行風險報告」等)則逐筆收集自銀行年報(Annual Report)中的揭露資訊。搜尋方式主要以銀行網站中的資訊為主，若遇有年報遺漏者則輔以書面電郵詢問該銀行，以獲取最完整的資訊。

國家總體特性變數主要收集自世界銀行的 WDI (World Development Index)資料庫、國家治理指標來自世界銀行中主要由 Kaufmann, Kraay, and Mastruzzi (2010)等人所建立的 WGI 資料庫 (Worldwide Governance Indicators)(http://info.worldbank.org/governance/wgi/index.aspx#home)。最後，「國家監理變數」來自世界銀行中主要為 Barth, Caprio, and Levine (2013)等人所建構的「Bank Regulation and Supervision 資料庫」中。

五、實證結果

首先，就研究變數的基本統計量來看，銀行系統性風險的平均值 CoVaR (90%)、CoVaR (95%)、CoVaR (99%)分別為-11.026、-14.114、-19.917。再者，銀行競爭(Lerner 指數)(%)以及內部風險管理品質、機構投資人持股比率、獨立董事比率、董事會規模、高階經理人薪酬趣自然對數值後的平均數分別為：22.920%、2.523、0.242、0.194、11.230、14.115。表 2 為銀行競爭、風險管理、公司治理以及銀行監理對銀行系統性風險的影響之估計結果，指出無論何種銀行系統性風險，即 CoVaR (90%)、CoVaR (95%)、CoVaR (99%)，指出當銀行競爭程度愈大、風險管理品質愈好以及公司治理品質愈佳時，則會顯著地降低個別銀行的系統性風險。此外，表 3 為在銀行競爭下，風險管理、公司治理以及銀行監理對銀行系統性風險的交互影響，指出在銀行競爭程度愈高前提下，當風險管理品質愈好、公司治理品質愈佳、以及金融監理要求較嚴格國家的銀行，則明顯表現出較低的系統性風險。

六、結論

本研究計畫針對 2007 年至 2011 年間全球上市商業銀行為研究對象，進行實證檢驗銀行競爭與系統性風險的關係，不同於過去多數研究僅考慮銀行個別風險指標，本研究則特別考量銀行系統性風險具共同相依性的特性以反映出銀行的脆弱性。再者，本研究計畫進一步探討公司治理品質與內部風險管理機制對系統風險的影響角色，同時也探討跨國間國家治理品質與金融監理對銀行系統性風險的影響，尤其是驗證銀行競爭透過國家治理與金融監理的管道如何交互影響銀行系統性風險。本計畫發現銀行競爭程度愈大、風險管理品質愈好、公司治理品質愈佳者，則會顯著地降低其系統性風險。再者，在銀行競爭程度愈高下，風險管理品質愈好、公司治理品質愈佳、以及金融監理要求較嚴格國家的銀行，則表現出較低的系統性風險。

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表 1、基本敘述統計

研究變數	樣本數	平均數	標準差	10 分位數	中位數	90 分位數
CoVaR (90%)	1,856	-11.026	11.334	-21.289	-8.254	-3.337
CoVaR (95%)	1,856	-14.114	14.538	-27.282	-10.575	-4.244
CoVaR (99%)	1,856	-19.917	20.558	-38.567	-14.917	-5.982
銀行競爭(Lerner 指數)(%)	2,243	22.920	18.529	5.211	18.884	44.239
內部風險管理品質	2,500	2.523	5.987	0.000	2.253	4.953
機構投資人持股比率	2,500	0.242	0.305	0.001	0.100	0.786
獨立董事比率	2,500	0.194	0.224	0.000	0.192	0.500
董事會規模	2,500	11.230	3.640	7.000	11.148	15.500
Ln(高階經理人薪酬)	2,500	14.115	9.101	0.000	16.315	23.021
收益多角化程度	2,500	0.350	0.195	0.089	0.340	0.594
Ln(總資產)	2,500	23.822	1.387	22.240	23.755	25.768
資本比率	2,500	8.413	4.569	4.175	8.115	13.720
ROA	2,500	0.978	2.238	0.103	0.970	2.306
成本比率	2,500	56.362	22.169	36.429	53.892	74.956
GDP 成長率	2,500	0.485	10.100	-0.041	0.022	0.083
銀行業資本比率	2,500	7.967	3.173	4.50	7.50	12.30
銀行監理	2,500	5.933	2.096	3.00	6.00	9.00

表 2、銀行競爭、風險管理、公司治理以及銀行監理對銀行系統性風險的影響

研究變數	銀行系統性風險		
	CoVaR (90%)	CoVaR (95%)	CoVaR (99%)
常數項	-16.814***	-21.434***	-30.096***
	(-7.036)	(-6.992)	(-6.944)
銀行競爭(Lerner 指數)	-0.030***	-0.038***	-0.054***
	(-3.752)	(-3.755)	(-3.757)
內部風險管理品質	-0.101***	-0.129***	-0.182***
	(-4.146)	(-4.145)	(-4.145)
機構投資人持股比率	-0.819**	-1.053**	-1.490**
	(-2.412)	(-2.419)	(-2.425)
獨立董事比率	-2.860***	-3.659***	-5.143***
	(-2.861)	(-2.850)	(-2.831)
董事會規模	0.359***	0.460***	0.651***
	(3.303)	(3.304)	(3.306)
Ln(高階經理人薪酬)	-0.028**	-0.036**	-0.051**
	(-2.423)	(-2.418)	(-2.422)
收益多角化程度	-2.582***	-3.296***	-4.644***
	(-4.107)	(-4.088)	(-4.074)
Ln(總資產)	0.316***	0.400***	0.559***
	(3.395)	(3.356)	(3.311)
資本比率	0.364***	0.466***	0.658***
	(4.780)	(4.775)	(4.771)
ROA	0.800***	1.025***	1.448***
	(5.639)	(5.637)	(5.642)
成本比率	0.008	0.010	0.014
	(1.253)	(1.238)	(1.226)
GDP 成長率	0.028***	0.036***	0.051***
	(11.161)	(11.187)	(11.216)
銀行業資本比率	-0.204***	-0.260***	-0.365***
	(-4.431)	(-4.416)	(-4.398)
銀行監理	-4.904***	-6.310***	-8.952***
	(-2.828)	(-2.841)	(-2.855)
樣本數	1,671	1,671	1,671
χ^2	500***	500***	501***

【說明】：*、**、***分別表示在信賴水準 10%、5%、1%下具統計上的顯著性。

表 3、在銀行競爭下，風險管理、公司治理以及銀行監理對銀行系統性風險的交互影響

研究變數	CoVaR (90%)	CoVaR (95%)	CoVaR (99%)	CoVaR (90%)	CoVaR (95%)	CoVaR (99%)	CoVaR (90%)	CoVaR (95%)	CoVaR (99%)	CoVaR (90%)	CoVaR (95%)	CoVaR (99%)	CoVaR (90%)	CoVaR (95%)	CoVaR (99%)
常數項	-17.359***	-22.173***	-31.173***	-15.393***	-19.645***	-27.576***	-13.107***	-16.683***	-23.387***	-15.456***	-19.745***	-27.835***	-19.242***	-24.588***	-34.652***
	(-8.418)	(-8.391)	(-8.351)	(-7.599)	(-7.567)	(-7.516)	(-6.137)	(-6.092)	(-6.040)	(-8.179)	(-8.187)	(-8.223)	(-11.352)	(-11.384)	(-11.443)
銀行競爭*風險	-0.004***	-0.005***	-0.007***												
管理品質	(-4.486)	(-4.504)	(-4.524)												
銀行競爭*機構				-0.037***	-0.047***	-0.066***									
投資人持股比率				(-2.756)	(-2.751)	(-2.756)									
銀行競爭*獨立							-0.173***	-0.221***	-0.309***						
董事比率							(-4.465)	(-4.435)	(-4.392)						
銀行競爭*高階										-0.002***	-0.002***	-0.003***			
經理人薪酬										(-4.922)	(-5.000)	(-5.105)			
銀行競爭*金融													-0.161***	-0.207***	-0.293***
監理													(-5.933)	(-5.943)	(-5.973)
收益多角化程度	-3.450***	-4.411***	-6.221***	-3.406***	-4.358***	-6.146***	-3.603***	-4.612***	-6.508***	-2.549***	-3.245***	-4.536***	-2.587***	-3.310***	-4.660***
	(-5.962)	(-5.944)	(-5.932)	(-5.612)	(-5.599)	(-5.586)	(-6.038)	(-6.028)	(-6.020)	(-4.380)	(-4.357)	(-4.322)	(-4.954)	(-4.946)	(-4.946)
Ln(總資產)	0.418***	0.533***	0.748***	0.332***	0.422***	0.591***	0.241***	0.305***	0.424***	0.333***	0.424***	0.597***	0.459***	0.586***	0.825***
	(5.217)	(5.192)	(5.156)	(4.228)	(4.200)	(4.155)	(2.889)	(2.848)	(2.801)	(4.533)	(4.531)	(4.549)	(7.303)	(7.324)	(7.361)
資本比率	0.349***	0.447***	0.629***	0.380***	0.486***	0.685***	0.354***	0.454***	0.641***	0.282***	0.360***	0.505***	0.272***	0.347***	0.488***
	(5.090)	(5.094)	(5.093)	(5.133)	(5.130)	(5.122)	(4.909)	(4.911)	(4.914)	(4.830)	(4.826)	(4.817)	(4.557)	(4.561)	(4.565)
ROA	0.905***	1.159***	1.636***	0.911***	1.168***	1.649***	0.908***	1.162***	1.641***	1.025***	1.313***	1.857***	1.004***	1.286***	1.817***
	(6.783)	(6.788)	(6.796)	(6.476)	(6.478)	(6.478)	(6.607)	(6.602)	(6.603)	(8.109)	(8.128)	(8.171)	(8.002)	(8.022)	(8.053)
成本比率	0.007	0.009	0.012	0.007	0.009	0.012	0.006	0.007	0.010	0.008	0.011	0.015	0.008	0.010	0.014
	(1.064)	(1.044)	(1.022)	(1.073)	(1.060)	(1.044)	(0.883)	(0.868)	(0.853)	(1.303)	(1.291)	(1.280)	(1.205)	(1.187)	(1.172)
GDP 成長率	0.025***	0.032***	0.046***	0.023***	0.030***	0.042***	0.021***	0.027***	0.038***	0.023***	0.029***	0.042***	0.022***	0.029***	0.041***
	(12.028)	(12.079)	(12.106)	(9.005)	(9.021)	(9.039)	(11.085)	(11.130)	(11.182)	(14.803)	(14.934)	(15.134)	(16.582)	(16.711)	(16.953)
銀行業資本比率	-0.263***	-0.336***	-0.470***	-0.291***	-0.371***	-0.521***	-0.247***	-0.314***	-0.441***	-0.250***	-0.319***	-0.447***	-0.272***	-0.347***	-0.485***
	(-6.281)	(-6.287)	(-6.269)	(-6.850)	(-6.840)	(-6.803)	(-5.493)	(-5.477)	(-5.460)	(-6.057)	(-6.058)	(-6.065)	(-6.999)	(-6.991)	(-6.976)
銀行監理	-7.538***	-9.618***	-13.539***	-7.692***	-9.850***	-13.910***	-6.440***	-8.247***	-11.654***	-6.521***	-8.323***	-11.703***			
	(-4.605)	(-4.594)	(-4.589)	(-4.609)	(-4.606)	(-4.605)	(-3.805)	(-3.806)	(-3.812)	(-3.980)	(-3.977)	(-3.974)			
樣本數	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671	1,671
χ^2	773***	775***	770***	387***	387***	386***	614***	616***	621***	1625***	1652***	1724***	3448***	3586***	3910***

【說明】：*、**、***分別表示在信賴水準 10%、5%、1%下具統計上的顯著性。

科技部補助專題研究計畫出席國際學術會議心得報告

日期：2016 年 7 月 12 日

計畫編號	MOST-104-2410-H-343-001		
計畫名稱	銀行競爭對銀行系統性風險影響的全球銀行實證研究:公司治理、內部風險管理、國家治理、金融監理的角色		
出國人員姓名	陳昇鴻	服務機構及職稱	南華大學財務金融系 副教授
會議時間	2016 年 6 月 9 日至 2016 年 6 月 10 日	會議地點	芬蘭/赫爾辛基 Hanken School of Economics
會議名稱	(中文)2016 財務管理學會歐洲地區學術研討會 (英文) 2016 FMA European Conference		
發表題目	(中文)時間變動避險比率和避險有效性在美國天然氣市場：天氣與總體經濟消息的角色 (英文) Time-Varying Hedge Ratio and Hedging Effectiveness in the U.S. Natural Gas Market: The Role of Weather and Macroeconomic News		

一、參加會議經過

本人經由台北桃園機場經由奧地利維也納轉機至芬蘭赫爾辛基,參加由 2016 美國財務管理學會(FMA)在歐洲地區所舉辦的論文學術研討會。2016 年 FMA 歐洲地區的學術研討會由 Hanken School of Economics 財金系主辦這場具相當學術水準盛會。此次研討會的會期是從 2016 年 6 月 9 日至 10 日共計 2 天，共有 88 個共同場次將近 250 篇論文進行口頭發表，與會學者多來自歐洲、美洲、亞洲及大洋洲等區域，而今年台灣僅 2 篇論文被接受進行口頭發表。在各財務與金融場次安排上，金融機構有 3 場次，國際金融 3 場次，公司理財有 4 場次，公司治理有 3 場次，投資理財有 5 場次。由大會安排場次的多寡可見，金融機構、國際金融及行為財務似乎是國際財務管理學會的相對較為重要的研究領域。

大會將本人安排於 2016 年 6 月 10 日下午 15:30~17:00 間，在以 Firm Risk Management with Derivatives 為主題的大會最後一個場次 Session 88 進行論文口頭發表，報告的論文題目為“Time-Varying Hedge Ratio and Hedging Effectiveness in the U.S. Natural Gas Market: The Role of Weather and Macroeconomic News”。本論文也獲得目前就讀於德國 Leuphana University 大學 Saska Stoerch 博士生的寶貴評論與建議(stoerch@leuphana.de),特別對於章節呈現與分析的結構方面給予相當中肯的建議，有利於本論文後續修改的工作。

二、與會心得

本此大會僅安排一場專題講座，由目前任職於 BlackRock 投資公司之 Antti Petäjistö 教授進行演說，主要針對共同基金之投資組合管理為題所進行學術探討的研究方向。

整體而言，本人參與此次研討會深感獲益匪淺，而且也特別是與幾位研究國際財務金融與全球銀行研究相當出色的學者，例如：Iftekhar Hasan 教授 (美國 Fordham University)、Wolfgang Bessler (德國 Justus-Liebig University Giessen)、Jens Forssbaeck (瑞典 Lund University)等人，有相當充分的學術請益與研究交流心得。

三、發表論文全文或摘要

How to effectively manage risk is an important issue which the financial and commodity industries face. One of the issues is the estimation of the financial and consumption asset price volatility and estimation of the optimal hedge ratio. We illustrate the importance of the incorporating fundamental variables in estimating price returns and volatility by studying the U.S. natural gas market. In doing so, we explain the spot and futures returns and volatilities based on market fundamental variables such as weather, storage and macroeconomic news. We find significant impacts of these variables. In addition, we calculate the optimal hedge ratio based on the price and volatility estimation. Our empirical evidence suggests that, as expected, the optimal hedge ratio was not constant and fluctuated significantly. Incorporating time-varying hedge ratio improved hedging effectiveness by a large percentage. Our study suggests that correctly modeling the

price and volatility is a key step in successfully managing the risks in the financial markets.

四、建議

本次研討會在風險管理、金融機構管理、投資分析與公司理財場次的與會學者其研究水準相當不錯，對於論文問題詢問與建議相當務實與中肯，特別是評論人都非常認真對論文提出很好的建議，對於投資理財與公司治理研究有興趣的學者，可藉由此研討會獲得相當重要的寶貴意見。

五、攜回資料名稱及內容

2016 年 FMA European Conference 年會的議程與論文資料皆可在網站下載(http://www.fma.org/Helsinki/HelsinkiProgram.htm)。

六、其他

本次研討會大會並無安排任何考考察參觀活動，僅舉辦 1 場學術演講、迎賓招待與晚宴等活動。

本人於論文評論人 Saska Stoerch 於會後之合影

Time-Varying Hedge Ratio and Hedging Effectiveness in the U.S. Natural Gas Market: The Role of Weather and Macroeconomic News

Abstract

How to effectively manage risk is an important issue which the financial and commodity industries face. One of the issues is the estimation of the financial and consumption asset price volatility and estimation of the optimal hedge ratio. We illustrate the importance of the incorporating fundamental variables in estimating price returns and volatility by studying the U.S. natural gas market. In doing so, we explain the spot and futures returns and volatilities based on market fundamental variables such as weather, storage and macroeconomic news. We find significant impacts of these variables. In addition, we calculate the optimal hedge ratio based on the price and volatility estimation. Our empirical evidence suggests that, as expected, the optimal hedge ratio was not constant and fluctuated significantly. Incorporating time-varying hedge ratio improved hedging effectiveness by a large percentage. Our study suggests that correctly modeling the price and volatility is a key step in successfully managing the risks in the financial markets.

Keywords: Natural Gas Market; Hedge Ratio; Volatility; Weather; Macroeconomic News

JEL classification: G13; Q40

1. Introduction

Asset and commodity prices are volatile and hedging has been used to mitigate price risks. Futures contract prices have been used as a hedging tool to reduce risks involving spot transactions. In order for the futures contract to be used effectively to manage the risk, optimal hedge ratio needs to be estimated. There is a sizable literature on the estimation of the optimal hedge ratio. Among others, Baillie and Myers (1991) estimated the optimal hedge ratio for six commodities, beef, coffee, corn, cotton, gold and soybean, using a bivariate GARCH (BGARCH) model for futures and spot prices, recognizing that the conventional regression method such as Ederington (1979) may not be appropriate. Zainudin (2013) employed a regime switching model to estimate the optimal hedge ratio for the crude palm oil (CPO) market. In a more recent study, Park and Jei (2014) examined the optimal hedge ratio estimation using a different variation of the BGARCH models. Liu et al (2014) estimated optimal hedge ratio for China's copper and aluminum markets. Harris and Shen (2003), Choudhry (2003) estimated optimal hedge ratio for the stock futures, among other studies of hedging in the stock market. Balea (2014) reviewed in the crude oil risk management process the evolution of the optimal hedge ratio and hedge effectiveness. Salisu and Oloko (2015) used the adopted model to compute optimal portfolio weight and hedge ratios between oil price and US stocks using different sample data based on the break date. Their empirical evidence suggested that ignoring breaks exaggerate the hedging effectiveness. There are many studies estimating hedge ratios for other assets and commodities.

This paper makes contributions in two aspects. Even though other studies emphasized on methods used to estimate the optimal hedge ratio, our paper studies the importance of including fundamental economic variables in explaining price returns and volatilities. In addition, we provide a study that focuses on a growingly important market – the natural gas market. The hedge ratio estimation and hedging effectiveness literature for energy markets including electricity, oil and natural gas is limited. Haigh and Holt (2002) estimated optional hedge ratio and examined the effectiveness for hedging crack spread by linking the crude oil, heating oil and unleaded gasoline futures contracts. They found that accounting for volatility spillovers between the markets leads to significant reduction in uncertainty. Chen and Sutcliff (2012) studied the cross hedging between stock and crude oil markets.

Ederington and Salas (2008) investigated the cross hedging effectiveness in the natural gas market for 17 hubs using the linear regression method and found that incorporating expected changes in the spot-futures relationship could increase efficiency and reduce bias. Woo et al. (2011) developed a linear regression model using natural gas futures as a cross hedge against electricity spot price risk. They found that hedge ratios varied substantially from month to month even though they did suggest that the natural gas cross hedge provided an effective tool to reduce electricity price risk. Martinez (2015) investigated the hedging strategies for the European natural gas market and considered seasonality in the estimation of the mean and volatility equations. They found incorporating seasonality slightly improved the hedging effectiveness.

This paper adds to the literature of optimal hedge ratio estimation and hedging effectiveness for the financial assets and commodity markets in general and the natural gas market in particular. We incorporate fundamental factors available to the market participants in explaining the natural gas prices in the price and volatility equations and estimate the optimal hedge ratio using BGARCH models to account for non-linearity and non-constancy of the hedge ratios. Specific factors considered include natural gas storage, weather information and macroeconomic news. In doing so, we emphasize the importance of these variables in influencing natural gas prices thus price volatilities. We feel like adding these variables could better account for the sources of the price volatility thus lead to better control of price risks.

2. Determinants of Natural Gas

2.1 Weather Impact

Weather is clearly behind the pricing of many agricultural and energy commodities. Hansen, Hodges, and Jones (1998) showed that one weather event, ENSO (El Niño–Southern Oscillation), influenced crop production and was associated with low grain yield. Carcedo and Otero (2005), Cancel et al. (2008), as well as Koirala et al. (2015) all examined the relationship between weather and commodity prices. Their findings indicated that weather factors, especially temperature variable, had significantly influenced the commodity prices. Lee and Oren (2009) showed that energy and agriculture are good example of weather sensitive industries. They found that the profit of each industry shared some common factors, and retail price, cost, and demand all were affected by weather. They also pointed out that the energy industry is especially exposed to weather risk on the ground and that the energy demand is highly dependent on weather condition. For example, according to Considine (2000), the demand for gasoline and jet fuel has a strong seasonal factor, but is not sensitive to temperature. Electricity, natural gas, and heating oil consumptions, however, are greatly sensitive to weather. Hong, Chang and Lin (2013) also suggested that weather has a significant impact on electricity demand and energy use, and directly influences the price of electricity. Despite the importance of the weather in determining demand for natural gas, few have studied the direct role of weather in the natural gas market (an exception is Mu (2007)). Given that the U.S. natural gas market evolved from a highly regulated market to a largely deregulated market in more recent history, natural gas prices driven by weather made natural gas market is one of the most volatile markets.

To capture the impact of the weather on gas prices, we utilize temperature variables directly with an assumption that temperature directly affects demand for natural gas. We also employ a couple of weather variables with the intention to capture the psychology of the traders, and thus weather's possible impact on gas prices through this behavioral channel. It was confirmed by psychologists that weather conditions could influence peoples' emotion or mood, which in turn could lead to a particular behavior. Nelson (1902) showed that psychological factors were extremely strong as speculators were less likely to trade as freely and confidently in wet and stormy weather. Symeonids, Daskalakis, and Markellos (2010) found that sunshine could have a positive influence on peoples' behavior. Saunders (1993) found that cloud cover had a significant impact on the behavior of market traders. Yoon and Kang (2009) found empirical evidence relating extreme weather conditions to stock returns. Kamstra, Kramer, and Levi (2003) also proposed a seasonal affective disorder effect; and in their opinion, seasonal variations in returns were closely connected to the length of the day. In addition, Frühwirth and Sögnerb (2015) investigated the relationship between weather or seasonal affective disorder (SAD) and the financial market and revealed some weather related, but no SAD related effects on the financial market. More recently, Shim et al.

(2015) examined how weather affects the stock market volatilities of a leading emerging market, and found that the historical volatility better captured the weather effect than the implied volatility. We suspect that natural gas prices could also be influenced by weather through traders' behavior change due to the psychological influence of weather.

2.2 Storage Impact

Natural gas storage affecting gas prices is a theoretically valid proposition and empirically observed regularity. The relationship between storage and the commodity price has been discussed since the theory of storage emerged in 1933 by Holbrook Working. Brennan (1958) pointed out the connection between the value of storage commodity and the amount of commodity in storage and showed the importance of how storage would influence the yield of holding the commodity. Deaton and Laroque (1992, 1996) and Chambers and Bailey (1996) presented an elaboration of the theory of storage and suggested that the changing amount of a commodity under storage can generate price variability of that commodity.

Linn and Zhu (2004) focused on natural gas supply and demand conditions as reflected in the change of natural gas storage amount. Linn and Zhu investigated how gas storage changes would have an impact on the residual volatility in natural gas futures prices. In addition, Chiou-Wei el al. (2013) provided empirical evidence that supports the significant influence of storages on natural gas price and its volatility.

2.3 Macroeconomic News

Earlier studies suggested that macroeconomic news was significantly related to the commodity prices and was a well-known key driver for asset prices. Frankel and Hardouvelis (1985) and Barnhart (1989) focused on the effect of monetary variables, and revealed that surprises in interest rate and declines of money supply caused a higher commodity price. Fleming and Remolona (1999) found that news announcement had a great influence on commodity prices and trading activity when public information arrived, and it was so especially when the uncertainty was high. According to Ederington and Lee (1993), Hautsch and Hess (2002) and Bartolini et al. (2008), the financial market price responses to macroeconomic news announcements are generally the strongest for the employment situation summary, the GDP advance release report, the Institute for Supply Management's Manufacturing Report, Consumer Sentiment, Consumer Confidence and Retail Sales. More recently, Tang and Xiong (2012) presented the evidence that commodity prices had been exposed to market-wide shocks, and they suggested that macroeconomic announcements had a substantial influence on commodity prices.

Recent studies such as Hess, Huang, and Niessen (2008), David and Chaudhry (2000), Christie–David, Chaudhry, and Koch (2000) assumed that commodity price's sensitivity to the announcements was symmetrical and constant over time. However, Kilian and Vega (2011) suggested that it was reasonable to question these assumptions. They presented two possible factors that might have impact on the response of commodity prices to the news announcements. They found that the good news and bad news factors had different influences on the commodity price.

Recently, Karali and Ramirez (2014) analyzed the time-varying volatility and spillover effects in crude oil, heating oil, and natural gas futures markets by incorporating changes in important macroeconomic variables, including major political and weather-related events into the conditional variance equations. These authors showed the presence of asymmetric effects in both random disturbances and macroeconomic variables, while crude oil volatility was found to increase following major political, financial, and natural events.

Even though it is natural for macroeconomic news to influence natural gas prices through the link between economic conditions and demand for natural gas, the empirical study of macroeconomic news on natural gas price and volatility is essentially a void in the literature. As economic activities determine commodity prices in general, we expect economic news announcement to impact natural gas prices as well. In our study, we select six news items which include advance retail sales, business inventory, changes in nonfarm payroll, housing starts, industrial production and construction spending.

To summarize, in an attempt to estimate the optimal hedge ratio and hedge effectiveness, we consider several weather factors, storage, traders' psychology and macroeconomic news announcements in modeling natural gas price and volatility. While the first two factors are conventionally adopted by researchers, the last two factors are new to the literature and can possibly provide additional understanding of the natural gas price and volatility dynamics.

3. Data

We obtained the weekly natural spot prices (at Henry Hub) and futures contract prices, and storage data from the US Energy Information Administration (EIA). The sample period starts in January, 2000 and ends in December, 2013. EIA releases a weekly survey report of the actual level and changes of natural gas storage in the United States regularly on Thursday morning at 10:30 AM Eastern Time; and it gives an updated storage data as of the previous Friday. If the EIA weekly storage report contained a revision, we would omit the observation and also the previous week's observation.

The EIA storage report reveals important information about natural gas market supply and demand balance. Since storage contains such critical information, industry players usually monitor the gas flows from pipeline nominations and transportation, or survey a limited number of storage operator to attempt to gain storage information. EIA provides comprehensive and complete information of U.S. natural gas storage. As a result, industry players are able to access the storage information thoroughly and promptly.

Our weather data were obtained from National Climate Data Center (NCDC), which is the division of the National Oceanographic and Atmospheric Administration (NOAA). The data spans the period of January, 2000 to December, 2013. NOAA's National Climatic Data Center (NCDC) is the world's largest climate data archive and offers climatological services and data to not only every sector of the United States economy but also to users worldwide. NCDC's reports range from paleoclimatology data to data less than an hour old. The Center maintains these data and makes them available to the public, business, industry, government, and researchers. NCDC's stations, land-based, collect the climate data from instruments sited at locations on every continent. The observations include temperature, dew point, relative humidity, cloud cover, precipitation, wind speed and direction, visibility, atmospheric pressure and types of weather occurrences. NCDC provides service with wide level that is associated with land-based observations. Data are available on sub-hourly, hourly, daily, monthly, annual, and multi-year timescales. We compiled our weather data for the following cities: Dallas, Baton Rouge, Atlanta, Chicago, Los Angeles, Phoenix, Saint Louis, New York, Philadelphia, Oklahoma City and Salt Lake City. These cities represent the major gas consumption regions. We computed an average day temperature by daily T_{max}, T_{min} measured from midnight to midnight. We then computed a Cooling Degree Day (CDD) measure, a Heating Degree Day (HDD) and a cloud cover (CC) measure for each week. We also compiled information on relative humidity (RH).

We used Bloomberg as our source to collect the macroeconomic news data during the period of January, 2000 to December, 2013. Bloomberg provides a description of any announcement releases, including the number of observations, the agency that reported the news, and the release time (see Table 1 for the news items we selected). Our data includes retail sales (ARS), business inventories (BI), changes in nonfarm payrolls (CNP), housing starts (HS), industrial production (IP), and construction spending (CS).

4. Research Design

4.1 Modeling the Storage Surprises of Natural Gas

To measure storage surprise, the level of storage is assumed to be based on demand influenced by temperature. Therefore, we considered temperature as the key variable that influence the expected changes in natural gas storage. Thus we defined the determination of storage change according to Chiou-Wei, Linn, and Zhu (2013) as below:

$$\Delta NGS_t = \alpha_0 + \alpha_1 \times TEMP_t + \varepsilon_t \qquad (1)$$

where ΔNGS_t is the change of storage released by the EIA for a particular week *t*. $TEMP_t$ is the natural gas consumption weighted weekly average temperature in week *t*. Therefore, the storage news would be the difference between the actual storage change as announced by the EIA and the expected storage change.

4.2 Modeling Related Weather Factors

Next, we defined the temperature measures as cooling degree days (CDD) and heating degree days (HDD). When the actual temperature minus 65°F is greater than zero then it is defined as the cooling degree day. We set heating degree day when 65°F minus the actual temperature is greater than zero. The following shows the definition of HDD and CDD.

$$TD_t = \frac{Tmax_t + Tmin_t}{2} \qquad (2)$$

$$CDD_t\text{=max(0, TD}_t\text{-65F)} \qquad (3)$$

$$HDD_t = \max(0, 65F - TD_t) \qquad (4)$$

where TD_t is the temperature for day t, $Tmax_t$ is the daily maximum temperature, and $Tmin_t$ is the daily minimum temperature on date t. Weekly HDD and CDD are weekly accumulation of daily CDDs and HDDs for the week.

In addition to the temperature variation, we defined a relative humidity factor. We model the relative humidity enthalpy latent days as defined by Huang (1987).

$$RH_t = \frac{1}{24}\sum_{i=1}^{365}\sum_{j=1}^{24}(\alpha_{tij})\{E_{tij} - E_{tij}^{0}\} \qquad (5)$$

where RH_t is the relative humidity enthalpy latent days of week t, E is the enthalpy and E^0 is the enthalpy at the humidity ratio of 0.0116 and the temperature measured.

The last weather factor deals with the psychological aspect. Many researchers indicated that sunshine had a positive impact on the investors' trading behavior; therefore, we use cloud cover as our proxy variable.

4.3 Measuring Surprises associated with Macroeconomic News

In this study, we select six news items related macroeconomic issues, which are Advanced Retail Sales (ARS), Business Inventory (BI), Change in Nonfarm Payroll (CNP), Construction Spending (CS), Housing Start (HS), and Industrial Production (IP). These variables represent various aspect of the real economic activities and are expected to have influences on consumers' demand for natural gas. For example, ARS and CNP represent income levels, which are expected to have a positive impact on natural gas demand. HS and CS may be directly related to the demand for natural gas in space heating, and IP is expected to be an indicator of demand for natural gas from industrial sectors.

All of these news items are announced monthly. The macroeconomic news surprise component is computed as followed:

$$NRS_{i,m} = \frac{A_{i,m} - F_{i,m}}{STD(A_i - F_i)} \tag{6}$$

where $NRS_{i,m}$ is the news release shock (*i*=1 to 6, each corresponding to an economic news item), *STD* is the standard deviation, $A_{i,m}$ is the actually released value, and $F_{i,m}$ is the median analyst forecast. This standardization affects neither the statistical significance of the estimated response coefficients nor the fitness of the regressions. This procedure facilitates a comparison of the estimated coefficients. The standardized surprise $NRS_{i,m}$ is used in our empirical analysis.

4.4 Econometric Methodology

As we model the natural spot and futures prices together, we use a Bi-variate GARCH (BGARCH) Model to examine the return and volatility between spot and futures markets. In particular, we relied on the use of two relatively flexible volatility models that explicitly incorporate the direct transmission of shocks and volatility across spot and futures markets. This section begins with the presentation of the conditional means in the bi-variate framework, and then introduces the BGARCH specifications under consideration.

4.4.1. VAR Model for the Conditional Mean Specification

For the empirical analysis on return spillovers across the futures and spot markets, we assume that the conditional mean of returns on the spot and futures markets can be described by a vector autoregressive (VAR) model. In the two-variable case, a VAR model can be set up as follows. The appropriate lag length of the VAR model is determined using several measures including AIC, SIC and others. See also Table 6 for more details. The base model shown below shows that the futures and spot prices depend on the lagged values.

$$NG_t^F = \mu^F + \alpha^F \times NG_{t-1}^F + \beta^S \times NG_{t-1}^S + \xi_t^F \tag{7}$$

$$NG_t^S = \mu^S + \alpha^S \times NG_{t-1}^S + \beta^F \times NG_{t-1}^F + \xi_t^S \tag{8}$$

where NG_t^F and NG_t^S are the logarithmic returns of the spot and futures natural gas price series, respectively. The residuals, ξ_t are assumed to be serially uncorrelated, but the covariance $E(\xi_t^S, \xi_t^F)$ needs not be zero. The coefficients α^S and α^F provide the measures of own-mean spillovers, whereas the coefficients β^S and β^F

measure the cross-mean spillovers between the logarithmic returns of the spot and futures natural gas prices.

4.4.2. BGARCH Models for Conditional Variance

We modeled the dynamics of the conditional volatility and volatility interdependence between the logarithmic returns of the spot and futures prices for natural gas by using two multivariate GARCH(1,1) specifications: VECH-GARCH and BEKK-GARCH models developed by Engle and Kroner (1995), which are much suitable for accounting for not only volatility persistence of energy market but also for the own- and cross-volatility spillover effects between the spot and futures natural gas prices. We defined the conditional variance–covariance matrix (H_t) of the residuals (ξ_t^S and ξ_t^F) as follows:

$$\xi_t | \Omega_{t-1} \sim N(0, H_t), \quad H_t = \begin{bmatrix} h_t^{SS} & h_t^{SF} \\ h_t^{FS} & h_t^{FF} \end{bmatrix} \tag{9}$$

where ξ_t is the (2 × 1) vector of residuals that we obtain from the VAR model and Ω_{t-1} is the information set containing all the information available up to time t. Note that different specifications of H_t will lead to different multivariate GARCH models. For instance, Engle and Kroner (1995) introduced the BEKK representation of the multivariate GARCH models by specifying the positive definite covariance matrix. Specifically, the bivariate BEKK-GARCH takes the following form

$$H_t = CC' + A\xi_{t-1}\xi'_{t-1}A' + BH_{t-1}B' \quad (10)$$

where C is a (2 × 2) upper triangular matrix of constants with elements c_{ij}; A is a (2 × 2) matrix of coefficients where a_{ij} that captures the effects of own shocks and cross-market shock interactions; and B is a (2 × 2) matrix of coefficients where b_{ij} captures the own volatility persistence and the volatility interactions between markets *i* and *j*. The estimation of the BEKK-GARCH models is carried out by the *Quasi-Maximum Likelihood* (QML) method, where the conditional distribution of ε_t is assumed to follow a joint Gaussian log-likelihood function for a sample of *T* observations and *k*=2 in bivariate model as follows.

$$\log L = -\frac{1}{2}\sum_{t=1}^{T}\left[k\log(2\pi) + \ln\left|H_t\right| + \xi'_t H_t^{-1}\xi_t\right] \quad (11)$$

If the conditional distribution is not normal, the quasi-maximum likelihood estimation is used to maximize the log-likelihood function. For the asymptotic properties of the ML and QML estimator, see Jeantheau (1998) and Comte and Lieberman (2003).

We provide several difference choices of the model for comparison purposes.

Model 1 is the base model without the storage of natural gas, weather, and macroeconomic new and is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p} \alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p} \beta_l^S \times NG_{t-l}^S + \xi_t^F \quad (12)$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p} \alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p} \beta_l^F \times NG_{t-l}^F + \xi_t^S \quad (13)$$

Model 2 includes the base model with storage of natural gas and is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p} \alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p} \beta_l^S \times NG_{t-l}^S + \gamma \times \Delta NGS_t + \xi_t^F \quad (14)$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p} \alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p} \beta_l^F \times NG_{t-l}^F + \gamma \times \Delta NGS_t + \xi_t^S \quad (15)$$

where ΔNGS_t denotes the current actual storage change reported in the *Weekly Natural Gas Storage Report* issued by the EIA, minus the expected storage change as measured by Equation (1).

Model 3 includes the base model with storage of natural gas as well as weather factors, and then is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p} \alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p} \beta_l^S \times NG_{t-l}^S + \gamma \times \Delta NGS_t + \sum_{r=1}^{p} \delta_r \times \left(Weather_t\right) + \xi_t^F \text{ ,} \quad (16)$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p} \alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p} \beta_l^F \times NG_{t-l}^F + \gamma \times \Delta NGS_t + \sum_{r=1}^{p} \delta_r \times \left(Weather_t\right) + \xi_t^S \text{ ,} \quad (17)$$

where $\left(Weather_t\right)$ denotes the series of weather factors including RH_t, HDD_t, CDD_t and CC_t.

Model 4 includes the base model with storage of natural gas, weather factors as well as macroeconomic news, and is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p} \alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p} \beta_l^S \times NG_{t-l}^S + \gamma \times \Delta NGS_t + \sum_{r=1}^{p} \delta_r \times (Weather_t)$$
$$+ \sum_{v=1}^{p} \phi_v \times (MacroNews_t) + \xi_t^F \tag{18}$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p} \alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p} \beta_l^F \times NG_{t-l}^F + \gamma \times \Delta NGS_t + \sum_{r=1}^{p} \delta_r \times (Weather_t)$$
$$+ \sum_{v=1}^{p} \phi_v \times (MacroNews_t) + \xi_t^S \tag{19}$$

where $(MacroNews_t)$ stands for a series of macroeconomic news NRS_t (the news release surprises including retail sales (ARS), business inventories (BI), change in nonfarm payrolls (CNP), housing starts (HS), industrial production (IP), and construction spending (CS).

Model 5 includes the base model with storage of natural gas, and mean equation is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p} \alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p} \beta_l^S \times NG_{t-l}^S + \gamma \times \Delta NGS_t + \xi_t^F \tag{20}$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p} \alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p} \beta_l^F \times NG_{t-l}^F + \gamma \times \Delta NGS_t + \xi_t^S \tag{21}$$

Similarly, the bivariate BEKK-GARCH includes the (ΔNGS_t) and takes the following form:

$$H_t = CC' + A\xi_{t-1}\xi'_{t-1}A' + BH_{t-1}B' + D\Delta NGS_t D' \qquad (22)$$

Model 6 includes the base model with storage of natural gas as well as weather factors, and is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p}\alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p}\beta_l^S \times NG_{t-l}^S + \gamma \times \Delta NGS_t + \sum_{r=1}^{p}\delta_r \times \left(Weather_t\right) + \xi_t^F \qquad (23)$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p}\alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p}\beta_l^F \times NG_{t-l}^F + \gamma \times \Delta NGS_t + \sum_{r=1}^{p}\delta_r \times \left(Weather_t\right) + \xi_t^S \qquad (24)$$

Similar to **Model 5**, the bivariate BEKK-GARCH model includes $\left(Weather_t\right)$ and takes the following form:

$$H_t = CC' + A\xi_{t-1}\xi'_{t-1}A' + BH_{t-1}B' + D\left(\Delta NGS_{t-1}\right)D' + E\left(Weather_t\right)E' \qquad (25)$$

Model 7 includes the base model with storage of natural gas, weather factors as well as macroeconomic news, and the mean equation is specified as follows:

$$NG_t^F = \mu^F + \sum_{k=1}^{p}\alpha_k^F \times NG_{t-k}^F + \sum_{l=1}^{p}\beta_l^S \times NG_{t-l}^S + \gamma \times \Delta NGS_t + \sum_{r=1}^{p}\delta_r \times \left(Weather_t\right) + \sum_{v=1}^{p}\phi_v \times \left(MacroNews_t\right) + \xi_t^F \qquad (26)$$

$$NG_t^S = \mu^S + \sum_{k=1}^{p}\alpha_k^S \times NG_{t-k}^S + \sum_{l=1}^{p}\beta_l^F \times NG_{t-l}^F + \gamma \times \Delta NGS_t + \sum_{r=1}^{p}\delta_r \times (Weather_t) + \sum_{v=1}^{p}\phi_v \times (MacroNews_t) + \xi_t^S \quad (27)$$

Similar to **Model 6**, the bivariate BEKK-GARCH includes the $(MacroNews_t)$ and takes the following form:

$$H_t = CC' + A\xi_{t-1}\xi_{t-1}'A' + BH_{t-1}B' + D(\Delta NGS_{t-1})D' + E(Weather_t)E' + F(MacroNews_t)F' \quad (28)$$

4.4.3 Calculating the Time-Varying Hedge Ratio

The H^* optimal hedge ratio is computed as conditional covariance between spot return and futures divided by the conditional variance of futures return. Thus the minimum variance hedge ratio has now become time-varying as it varies with the changes in conditional covariance matrices as follows:

$$H^* = \frac{h_{sf}}{h_{ff}} \quad (29)$$

where $h_{ss,t} = c_{ss} + \alpha_{ss}\varepsilon_{s,t-1}^2 + \beta_{ss}h_{ss,t-1}$, $h_{sf,t} = c_{sf} + \alpha_{sf}\varepsilon_{s,t-1}\varepsilon_{f,t-1} + \beta_{sf}h_{sf,t-1}$, and $h_{ff,t} = c_{ff} + \alpha_{ff}\varepsilon_{f,t-1}^2 + \beta_{ff}h_{ff,t-1}$ are specified and estimated as in the above equations.

4.4.4 Evaluating the Hedging Effectiveness

Following Johnson (1960) and Ederington (1979), the hedging effectiveness (HE) is defined as the gain or loss in the variance of terminal revenue due to price changes in an unhedged position relative to those in a hedged position an therefore is defined as:

$$HE_t = \frac{\left[VAR^{Unhedged}(\Omega_t) - VAR^{Hedged}(\Omega_t)\right]}{VAR^{Unhedged}(\Omega_t)} \qquad (30)$$

where $VAR^{Unhedged}(\Omega_t)$ and $VAR^{Hedged}(\Omega_t)$ are the variances for the unhedged and hedged positions, respectively. The return of the hedged portfolio during the holding period is defined by $R_t^{Hedged} = R_t^S - H_t \times R_t^F$. According to Eq. (30), the closer the HE is to 1, the higher the degree of hedging effectiveness.

5. Empirical Results

5.1 Unit-Root Testing

Figure 1 shows the time series plots of natural gas prices and several other fundamental variables including CDD, HDD, RH and storage. Both the spot and futures prices exhibit large volatilities with prices reaching the high of $14 to $15 followed soon by the low of $2 to $3. Such a high price volatility warrantees active price risk management. CDD, HDD and storage show strong seasonal variations.

We performed the Augmented Dickey–Fuller (ADF) and the Phillips–Perron (PP) unit root tests as well as the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) stationarity test (Table 2). The results reported in Panel A of Table 2 indicate that all the log-differences in series are stationary at the 1% level while the log of the spot price is also stationary. We further tested the conditional heteroscedasticity in the second moment of the price series. The Engle (1982) test for conditional heteroscedasticity (Panel B of Table 2) shows that the ARCH effects are significantly present in all the return series, which provides support to our decision to use the GARCH-based approach to examine the return and volatility transmission between the spot and futures natural gas prices in the U.S. market.

Table 3 shows the conventional Granger causality test to obtain information of how spot and futures markets are linked to each other. Panel A in table 3 shows that both the spot and futures prices are Granger causing each other. Panel B also suggests that the bi-directional causality exists when we use log price differences or gas price returns. However, from both Panel A and Panel B, the null hypothesis of no futures price causing spot price can be rejected at a much higher marginal significance level than the null hypothesis of spot price causing futures price. This result appears to be consistent with Chiou-Wei et al (2013) which found futures price moving ahead of spot price when they used daily prices. This is mainly due to the different price settings of spot and futures contracts for the same day. Spot transactions usually finish most of the transactions early in a day due to gas nomination for transportation and futures trading ends the trading day in the afternoon. Therefore, spot prices in the second day usually reacts to information already contained in the previous day’s futures price. Even though our data is weekly rather than daily, it still picked up the information difference existed in the daily spot and futures prices.

5.2 Return and Volatility Spillovers between Spot and Futures Market for Natural Gas

The selection of the optimal lag of the VAR system is presented in Table 4. We present five statistical tests and three tests (AIC, SC, and HQ) suggest a similar lag order. Therefore, we chose 3 as the optimal numbers of lags for the VAR system of spot and futures prices.

5.2.1 Estimations of VAR-VECH-BGARCH Models

Table 5 shows the estimation results of the VAR-VECH-BGARCH models with different specifications. Several results stand out. First, there were significant lagged price effect for both the spot and futures prices as many of the lagged futures price and spot price coefficient estimates are statistically significant. This result seems to hold regardless of the model specification. This suggests that both the futures and spot prices can be predictable to a certain degree. In addition, the one-period lagged futures price influences futures prices positively while the one-period lagged spot price influences spot price returns negatively. In addition, by examining the mean equation looking for the cross price effect, we do observe some statistically significant cross price effect. The lagged futures price had a positive effect on spot price changes (the total effect of 0.99) while the lagged spot prices had a negative impact on futures prices (the total effect of -0.185). Combining the own-price and cross-price effect, it appears that the futures price was mainly affected by futures price itself (the total effect of 0.34) while the spot price was influenced more by the futures price rather than by the lagged own price (own price effect of -0.7).

The storage effect on both spot and futures prices are negative, indicating that a higher than expected storages decreases prices, which is consistent with our expectation and earlier results by Linn and Zhu (2007) and Chiou-Wei et al (2013). This particular result is consistent across various model specifications. Linn and Zhu (2007) found the negative storage effect in the 5-minute data and Chiou-Wei (2013) found the same effect using the daily data. In this study, we used the weekly price data and the effect is still detectable with high significances. This piece of evidence simply points to the extreme importance of the storage in influencing natural gas prices.

Weather variables, especially the CDD and HDD, had some statistically significant influence of gas prices even though the effects are negative, contrary to what one would expect. Perhaps a better variable in places of actual weather information is the weather forecast and/or difference between actual weather and forecasted weather. However, this go beyond the scope of this paper and remains to be a topic to be explored in the future. Regarding the effect of other variables, we did not find statistical significances of those variables explaining gas prices. Similarly we were not able to find much impact of the macroeconomic news on prices, even though the news regarding CS had some significantly positive effect on prices.

The conditional variance-covariance estimation results presented in Table 5 suggests that storage variables, weather variables and macroeconomic news variables do have some significant impact on volatilities, even though the effects are not universally positive and consistent across model specifications.

Across all specifications, it appears that the best model is Model 7 which has the largest likelihood function value, even though it may not be statistically different from Model 3 and Model 5.

5.2.2 Estimations of VAR-BEKK-BGARCH Models

For comparison purposes, we estimated the VAR-BEKK-BGARCH model for the spot and future for natural gas markets and report the results in Table 6. Overall, the estimation results are similar to the results obtained from the VAR-VECH-BGARCH model.

5.3 Time-Varying Hedge Ratio and Multiple Structural Breaks in Trend

Figure 2 plots the estimated optimal hedge ratio using different specifications based on VAR-VECH-BGARCH (Figures 2-A to 2-G corresponding to Models [1] to [7]). It is obvious that the estimated HRs fluctuate significantly. Even though the average values of the HRs are close to 1.0, but frequently the HRs deviate significantly from the value of 1.0. Occasionally the values can reach as high as 1.5 and above and as low as 0.5 and below. These values are possible as sometimes spot and futures prices can deviate significantly from each other. Figure 3 shows that the optimal hedge ratios estimated using the VAR-BEKK-BGARCH (Figures 3-A to 3-G corresponding to Models [1] to [7]) are similar to those obtained from the VAR-VECH-BGARCH models (Figure 2).

Table 7 provides the descriptive statistics of the time-varying hedge ratio, and the results of statistical tests of zero mean, median, and variance. Panel A of Table 7 shows that the average hedge ratio from VAR-VECH-BGARCH ranges from 0.9349 (for Model [7]) to 0.9828 (for Model [3]). The unconditional volatility as measured by the standard deviation ranges from 0.1616 (for Model [7]) to 0.2160 (for Model [1]). The skewness coefficients are positive for all hedge ratio series with a minimum of 0.5621 (for Model [2]). The kurtosis coefficients are above three for all the estimated hedge ratio series. These findings indicate that the probability distributions of the hedge ratio are skewed and leptokurtic. The formal tests rejects the normality assumption. Finally, we find statistical significance in mean, median and variance form zero for all specifications. Again, the results obtained from the VAR-BEKK-BGARCH models as presented in Panel B of Table 7 are much similar.

The results presented in Table 8 suggest that there were structural breaks in the hedge ratio series estimated with different model specifications. The null hypothesis of no structural breaks against the alternative of an unknown number of structural breaks is clearly rejected. All test statistics are above their critical values at common levels of significance. As proposed by Bai and Perron (2003), we used the Bayesian information criterion (BIC) to condense the information given by the tests. This criterion is most appropriate in our case, as structural breaks have to be expected a priori. In Panel A, the BIC suggests two breaks in the series of hedge ratio based on Models [4] – [7]; and there was at least one break for all the estimated series. To some extent, this large number of structural breaks may be due to the high level of sensitivity that we chose for our tests. We set the trimming parameter to 10% which results in a minimum length of a segment of 725 days. This length is close to the 300-day window from our rolling regressions and allows for 5 structural breaks detected in every single series at the maximum. In Panel B, the results from VAR-BEKK-BGARCH models are similar even though there were two breaks in hedge ratios estimated using Models [2] to [7]. The break dates are similar as well.

5.4 Hedging Effectiveness

Table 9 shows hedging effectiveness based on variance reduction of hedged portfolios compared to the unhedged positions under different model specifications. In Panel A, the dynamic hedging strategy using VAR-VECH-BGARCH models did work for natural gas market with more than 60% of variance reductions. The highest HE ratio of 66.50% was obtained based on the optimal hedge ratio estimation by model [5] while model [1] generates the lowest HE ratio of 64.0038%. In panel B, the HEs from dynamic hedging strategy using VAR-BEKK-BGARCH models are very similar to the HE using VAR-VECH-BGARCH models. All the specifications incorporating additional fundamental variables lead to more than 60% of variance reductions. Model [7] with the most fundamental variables generated the highest HE ratio of 70.299%.

Our result reveals that using the dynamic hedge ratios from the BEKK-BGARCH models incorporate storage, weather factors and macroeconomic news achieved a highest risk reduction compared with using other strategies. Incorporating all available information and engaging in dynamic hedging help to reduce risk. This is evident from the comparison of the HEs generated with models that incorporated fundamental variables to the HEs generated with models that employed only the lagged price variables.

6. Conclusions

Price risks faced by the investors of financial and consumption assets can be large. This is particular true for participants of the energy markets including investors, producers and consumers. How to effectively manage risk is always an important issue.

This paper studies the effect of incorporating fundamental factors in modeling asset prices with the focus on the U.S. natural gas market. The price and volatility of natural gas have been modeled using various fundamental factors such storage news, weather information, and macroeconomic news. Our modeling results suggest that incorporating these factors improves the model performance and leads to better estimation of the optimal hedge ratio.

Our estimated results reveal that the optimal hedge ratio fluctuated quite significantly during the sample period. In addition, there were structural breaks in the estimated hedge ratios. As the result, hedging against price risks in the energy market in general, natural gas market in particular, requires dynamic hedge of the portfolio. Our analysis of hedge effectiveness using various models suggests that hedging using a constant hedge ratio can lead to subpar hedging performances and dynamic hedging using time-varying hedge ratios under the guidance of economic theory can improve hedging effectiveness quite significantly. Our modeling results suggests the variance of the hedged assets can be 60% lower than the variance of the unhedged portfolio.

Even though the hedging effectiveness can be improved quite significantly by utilizing the dynamic hedging and incorporating all economic information, we do note that there could be some practical issues related to the implementation of such approaches. One such issue is the cost of the dynamic hedging resulted in from constant rebalance of the portfolio, which is expected to increase the transaction cost. The second issue is that in order to effectively model the price and volatility of asset prices, one needs to have reliable information about fundamentals. In the natural gas markets, these include at least the variables modeled in this paper and those variables include storage, weather and economic conditions. In the practice, the successful modeling of the price and volatility requires accurate forecasts of these variables. While the accurate forecasts can be hard to come by, it is beneficial for market participants to actively seek out these information.

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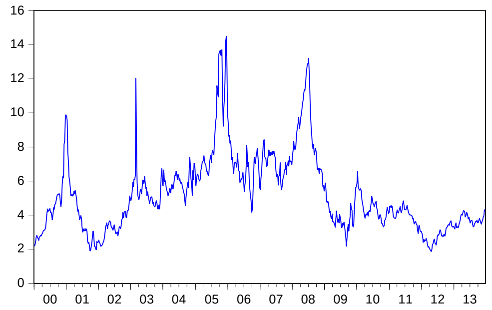
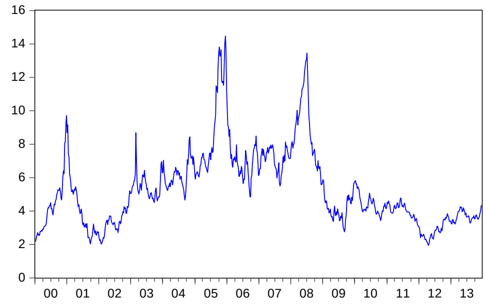
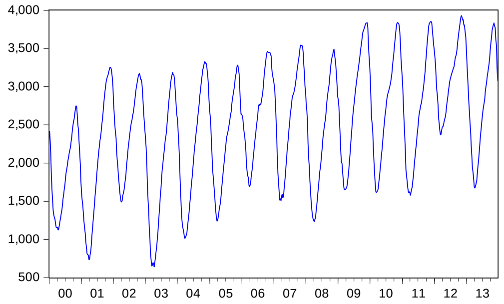


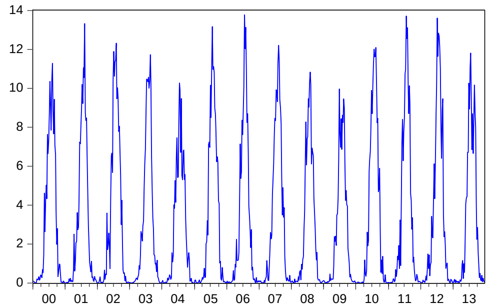
A. Spot price of natural gas



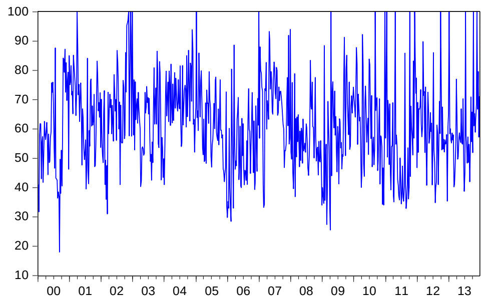
B. Futures price of natural gas



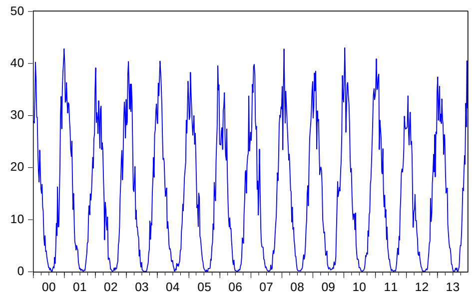
C. Storages of natural gas



C. CDD

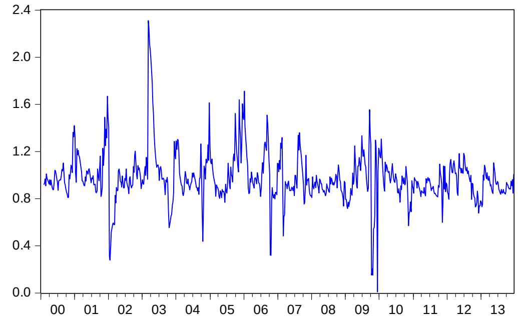


E. Relative Humidity

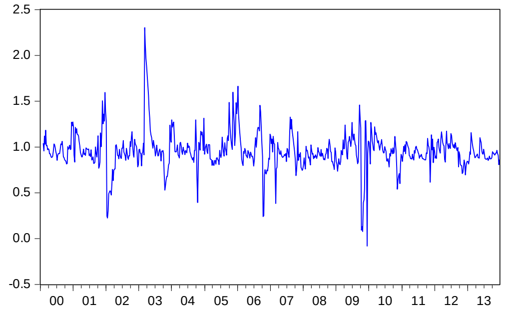


F. HDD

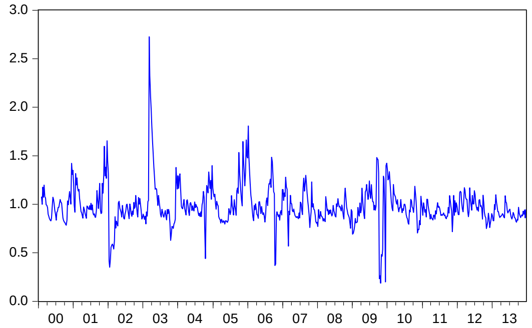
Figure 1
Time-series plot of key variables



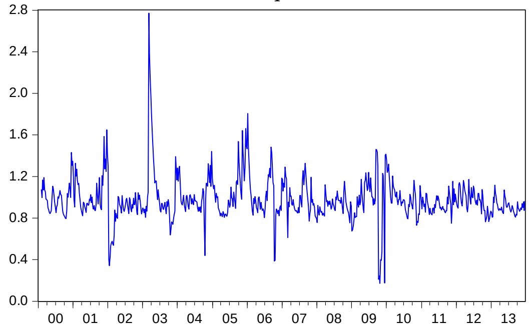
A. Base model



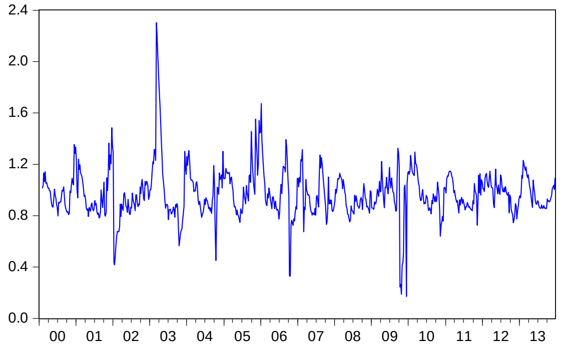
B. Base model with storeages in conditional mean equation



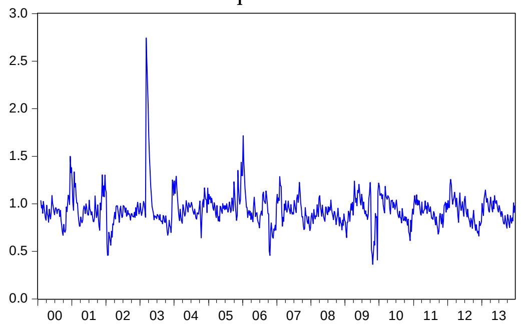
C. Base model with storages and weather factors in conditional mean equation



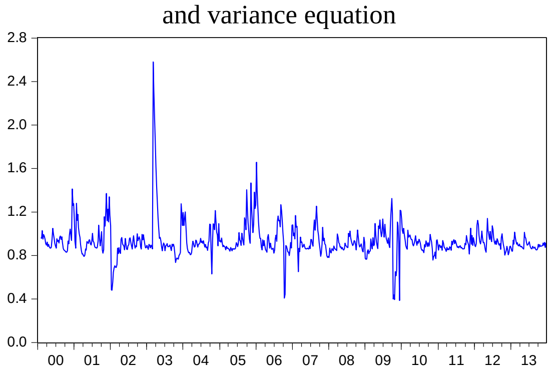
D. Base model with storages, weather factors and macroeconomic news in conditional mean equation



E. Base model with storages in conditional mean and variance equation

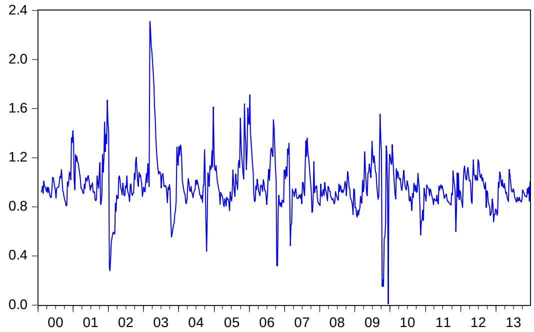


F. Base model with storages and weather factors in conditional mean and variance equation

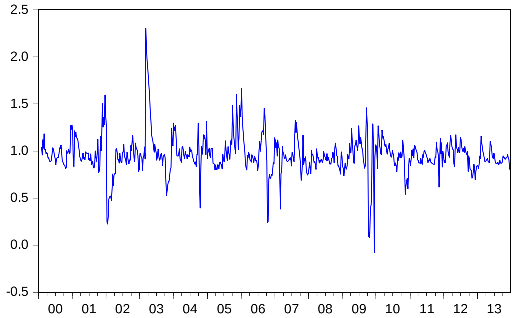


G. Base model with storages, weather factors and macroeconomic news in conditional mean and variance equation

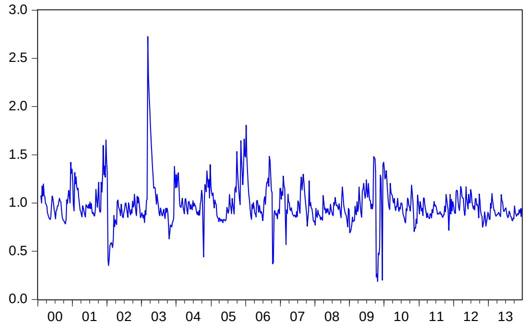
Figure 2
Time-series hedging raio estimated by VAR-VECH-GARCH under different specifications



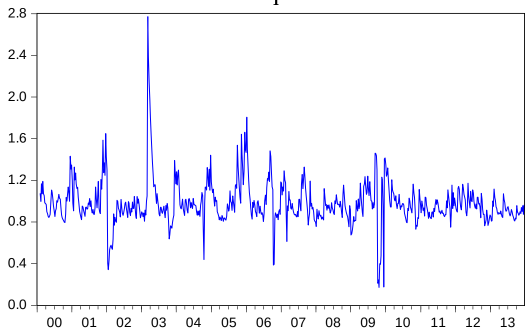
A. Base model



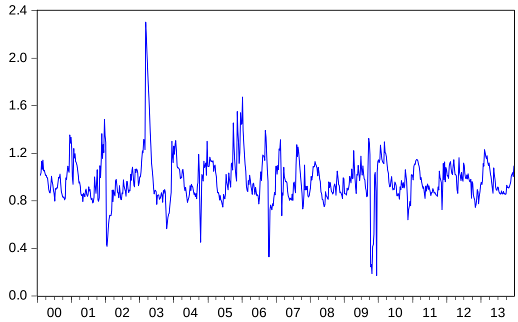
B. Base model with storeages in conditional mean equation



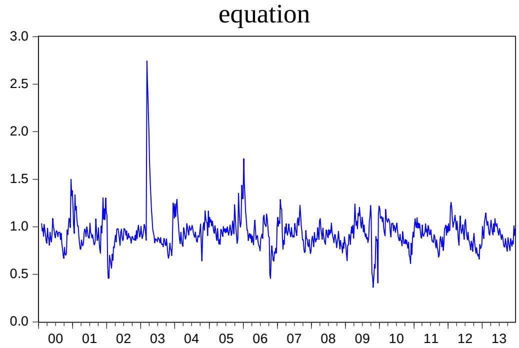
C. Base model with storeages and weather factors in conditional mean equation



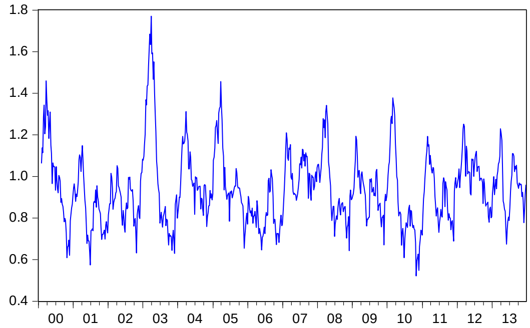
D. Base model with storages, weather factors and macroeconomic news in conditional mean equation



E. Base model with storeages in conditional mean and variance equation



F. Base model with storeages and weather factors in conditional mean and variance equation



G. Base model with storages, weather factors and macroeconomic news in conditional mean and variance equation

Figure 3

Time-series hedging raio estimated by VAR-BEKK-GARCH under different specifications

Table 1

Announcements of macroeconomic news

Time	New item	Observation (actual value)	Consensus forecast	Shock	S.D
08:30	Retail sales (ARS)	244	122	203	0.602
08:30	Business inventories (BI)	243	122	448	0.271
08:30	Change in nonfarm payrolls (CNP)	283	142	1	111.148
08:30	Housing starts (HS)	310	155	1148	0.135
09:15	Industrial production (IP)	266	133	482	0.276
10:00	Construction spending (CS)	248	124	123	1.006
	Total	1,594			

Table 2

Unit root tests and conditional heteroscedasticity test

Panel A. Unit root tests

Variables	ADF	PP	KPSS
Spot Price of Natural Gas	-3.463**	-3.230*	0.480
	(0.044)	(0.079)	(0.216)
Futures Price of Natural Gas	-2.986	-2.973	0.502
	(0.137)	(0.141)	(0.216)
Log-Difference in	-23.197***	-22.937***	0.041
Spot Price of Natural Gas	(0.000)	(0.000)	(0.216)
Log-Difference in	-22.304***	-22.184***	0.041
Futures Price of Natural Gas	(0.000)	(0.000)	(0.216)

Panel B. conditional heteroscedasticity test

Variables	ARCH-LM Tests
Spot Price of Natural Gas	436.780[a] (0.000)
Futures Price of Natural Gas	1042.634[a] (0.000)
Log-Difference in Spot Price of Natural Gas	11.166[a] (0.000)
Log-Difference in Futures Price of Natural Gas	5.126[a] (0.000)

Note: ADF, PP and KPSS are the empirical statistics of the Augmented Dickey and Fuller (1979), and the Philips and Perron (1988) unit root tests, and the Kwiatkowski et al. (1992) stationarity test, respectively. [a] Denotes the rejection of the null hypotheses of normality, no autocorrelation, unit root, non-stationarity, and conditional homoscedasticity at the 1% significance level. The P-values are reported in the parentheses.

Table 3

Pairwise Granger causality tests – log natural gas spot and futures prices

Null Hypothesis:	# of Lag	Observations	*F*-Statistic	(*P*-value)
Panel A. Level				
Spot Price does not Granger Cause Futures Price	3	725	4.477***	(0.004)
Futures Price does not Granger Cause Spot Price	3	725	33.786***	(0.000)
Panel B. Log-Differences				
Log-Difference in Spot Price does not Granger Cause Log-Difference in Futures Price	3	725	2.948**	(0.032)
Log-Difference in Futures Price of does not Granger Cause Log-Difference in Spot Price	3	725	24.630***	(0.000)

Note: *, ** and *** indicate a rejection of the null hypothesis at the 10%, 5%, and 1% significance levels, respectively.

Table 4

Selection criteria of optimal VAR lag order

# of Lag	LogL	LR	AIC	SC	HQ
0	2222.981		-6.187	-6.174	-6.182
1	2257.824	69.395	-6.272	-6.234	-6.258
2	2269.141	22.476	-6.293	-6.229	-6.268
3*	2287.408	36.179	**-6.345***	**-6.243***	-6.298
4	2295.837	16.646	-6.338	-6.230	-6.301*
5	2298.169	4.592	-6.340	-6.200	-6.286
6	2301.432	6.408	-6.338	-6.173	-6.274
7	2303.679	4.401	-6.333	-6.142	-6.260
8	2304.501	1.604	-6.325	-6.108	-6.241
9	2311.317	13.272*	-6.332	-6.090	-6.239
10	2314.833	6.826	-6.331	-6.063	-6.228

Note: * indicates lag order selected by the criterion.

Table 5

Estimation results of the VAR-VECH-GARCH model using different specifications

Variables	**Model [1]**		**Model [2]**		**Model [3]**		**Model [4]**		**Model [5]**		**Model [6]**		**Model [7]**	
	Base model		Base model with storage in conditional mean equation		Base model with storage and weather factors in conditional mean equation		Base model with storage, weather factors and macroeconomic news in conditional mean equation		Base model with storage in conditional mean and variance equations		Base model with storage and weather factors in conditional mean and variance equations		Base model with storage, weather factors and macroeconomic news in conditional mean and variance equations	
Panel A. Conditional mean equation														
Log-difference in futures price of natural gas														
Constant	-0.001	(0.785)	0.006***	(0.005)	0.079***	(0.000)	0.066***	(0.000)	0.003	(0.120)	0.024*	(0.079)	0.069***	(0.000)
Futures price (t-1)	0.203***	(0.001)	0.256***	(0.000)	0.251***	(0.000)	0.240***	(0.000)	0.260***	(0.000)	0.236***	(0.000)	0.246***	(0.000)
Futures price (t-2)	-0.008	(0.907)	0.007	(0.924)	-0.072	(0.314)	-0.042	(0.498)	-0.043	(0.548)	0.005	(0.943)	-0.059	(0.403)
Futures price (t-3)	0.145**	(0.037)	0.190***	(0.006)	0.140**	(0.029)	0.127**	(0.045)	0.167**	(0.012)	0.144**	(0.018)	0.170**	(0.014)
Spot price (t-1)	-0.038	(0.404)	-0.084*	(0.098)	-0.105**	(0.025)	-0.101**	(0.017)	-0.102**	(0.045)	-0.076*	(0.090)	-0.102**	(0.021)
Spot price (t-2)	-0.033	(0.532)	0.007	(0.912)	0.089	(0.117)	0.033	(0.495)	0.058	(0.314)	0.037	(0.497)	0.052	(0.345)
Spot price (t-3)	-0.114**	(0.034)	-0.157***	(0.004)	-0.145***	(0.006)	-0.120**	(0.018)	-0.171***	(0.001)	-0.166***	(0.001)	-0.145***	(0.009)
Storage surprises (t)			-0.218***	(0.000)	-0.806***	(0.000)	-0.807***	(0.000)	-0.020	(0.694)	-0.192*	(0.050)	-0.802***	(0.000)
Weather factors														
CC(t)					0.321	(0.483)	-0.809	(0.341)			0.433	(0.348)	-0.911	(0.406)
CDD(t)					-0.603***	(0.000)	-0.538***	(0.000)			-0.219**	(0.039)	-0.564***	(0.000)
HDD(t)					-0.399***	(0.000)	-0.360***	(0.000)			-0.125**	(0.014)	-0.384***	(0.000)
RH(t)					0.014	(0.921)	0.111	(0.316)			0.024	(0.851)	0.094	(0.533)
Macroeconomic news														
ARS(t)							-0.018**	(0.017)					-0.208	(0.871)
BI(t)							0.849	(0.195)					0.127	(0.171)
CNP(t)							0.559	(0.429)					0.803	(0.365)
CS(t)							-0.187	(0.673)					0.709	(0.271)
HS(t)							0.777	(0.332)					0.013	(0.228)
IP(t)							-0.013*	(0.078)					-0.018*	(0.073)
Log-difference in spot price of natural gas														
Constant	-0.085	(0.664)	0.008***	(0.000)	0.065***	(0.000)	0.049***	(0.000)	0.004	(0.111)	-0.003	(0.801)	0.057***	(0.000)
Futures price (t-1)	0.581***	(0.000)	0.671***	(0.000)	0.740***	(0.000)	0.691***	(0.000)	0.694***	(0.000)	0.665***	(0.000)	0.745***	(0.000)
Futures price (t-2)	0.150**	(0.023)	0.178***	(0.007)	0.136**	(0.038)	0.102*	(0.088)	0.123*	(0.072)	0.184***	(0.002)	0.149**	(0.029)
Futures price (t-3)	0.260***	(0.000)	0.329***	(0.000)	0.292***	(0.000)	0.269***	(0.000)	0.311***	(0.000)	0.318***	(0.000)	0.327***	(0.000)
Spot price (t-1)	-0.279***	(0.000)	-0.375***	(0.000)	-0.481***	(0.000)	-0.437***	(0.000)	-0.413***	(0.000)	-0.388***	(0.000)	-0.501***	(0.000)
Spot price (t-2)	-0.224***	(0.000)	-0.179***	(0.003)	-0.115*	(0.055)	-0.110*	(0.066)	-0.119*	(0.063)	-0.158***	(0.003)	-0.143**	(0.017)
Spot price (t-3)	-0.211***	(0.001)	-0.276***	(0.000)	-0.278***	(0.000)	-0.240***	(0.000)	-0.307***	(0.000)	-0.318***	(0.000)	-0.289***	(0.000)
Storage surprises (t)			-0.313***	(0.000)	-0.816***	(0.000)	-0.791***	(0.000)	-0.079	(0.164)	-0.016	(0.871)	-0.807***	(0.000)
Weather factors														
CC(t)					-0.208	(0.630)	-0.781	(0.318)			-0.258	(0.543)	-0.935	(0.339)
CDD(t)					-0.409***	(0.000)	-0.321***	(0.000)			0.101	(0.309)	-0.368***	(0.000)
HDD(t)					-0.328***	(0.000)	-0.277***	(0.000)			0.034	(0.498)	-0.314***	(0.000)
RH(t)					0.014	(0.914)	0.091	(0.392)			-0.049	(0.674)	0.052	(0.717)
Macroeconomic news														
ARS(t)							-0.014	(0.101)					0.091	(0.943)
BI(t)							0.525	(0.396)					0.106	(0.255)
CNP(t)							0.193	(0.783)					0.503	(0.563)
CS(t)							0.426	(0.335)					0.121*	(0.050)
HS(t)							0.512	(0.459)					0.964	(0.310)
IP(t)							-0.784	(0.271)					-0.148	(0.152)

Note: P-values are reported in parentheses. *, **, *** denoted statistically significant at 10%, 5%, and 1%. HQ(20) and $HQ^s(20)$ are Hosking's multivariate portmanteau *Q*-statistics on the standardized residuals and the standardized squared residuals, respectively.

Table 5 (Continued)

Variables	Model [1]		Model [2]		Model [3]		Model [4]		Model [5]		Model [6]		Model [7]	
	Base model		Base model with storage in conditional mean equation		Base model with storage and weather factors in conditional mean equation		Base model with storage, weather factors and macroeconomic news in conditional mean equation		Base model with storage in conditional mean and variance equations		Base model with storage and weather factors in conditional mean and variance equations		Base model with storage, weather factors and macroeconomic news in conditional mean and variance equations	
Panel B. Conditional variance-covariance equation														
GARCH=M+A1*RESID(t-1)*RESID(t-1)'+B1*GARCH(t-1)+E1*(STORAGE SURPRISES)(t)+E2*CC(t)+E3*CDD(t)+E4*HDD(t)+E5*RH(t) +E6*ARS(t)+E7*BI(t)+E8*CNP(t)+E9*CS(t)+E10*HS(t)+E11*IP(t)														
M(Futures,Futures)	0.052***	(0.000)	0.562***	(0.000)	0.477***	(0.000)	0.470***	(0.000)	0.461***	(0.000)	0.454	(0.131)	-2.031***	(0.008)
M(Futures,Spot)	0.044***	(0.000)	0.534***	(0.000)	0.464***	(0.000)	0.462***	(0.000)	0.505***	(0.000)	0.373	(0.218)	-3.451**	(0.010)
M(Spot,Spot)	0.041***	(0.000)	0.054***	(0.000)	0.048***	(0.000)	0.048***	(0.000)	0.630***	(0.000)	0.483	(0.163)	-6.227**	(0.012)
A1(Futures, Futures)	0.206***	(0.000)	0.232***	(0.000)	0.203***	(0.000)	0.211***	(0.000)	0.171***	(0.000)	0.108***	(0.000)	0.087***	(0.000)
A1(Futures, Spot)	0.270***	(0.000)	0.271***	(0.000)	0.238***	(0.000)	0.243***	(0.000)	0.190***	(0.000)	0.130***	(0.000)	0.083***	(0.000)
A1(Spot, Spot)	0.354***	(0.000)	0.354***	(0.000)	0.331***	(0.000)	0.336***	(0.000)	0.249***	(0.000)	0.186***	(0.000)	0.080***	(0.000)
B1(Futures, Futures)	0.716***	(0.000)	0.686***	(0.000)	0.707***	(0.000)	0.705***	(0.000)	0.733***	(0.000)	0.825***	(0.000)	0.737***	(0.000)
B1(Futures, Spot)	0.700***	(0.000)	0.671***	(0.000)	0.687***	(0.000)	0.684***	(0.000)	0.713***	(0.000)	0.763***	(0.000)	0.752***	(0.000)
B1(Spot, Spot)	0.685***	(0.000)	0.644***	(0.000)	0.647***	(0.000)	0.644***	(0.000)	0.678***	(0.000)	0.699***	(0.000)	0.767***	(0.000)
Storages of natural gas														
E1(Futures, Futures)									-0.001	(0.621)	0.001	(0.573)	0.022***	(0.000)
E1(Futures, Spot)									-0.003**	(0.071)	0.002	(0.101)	0.035***	(0.000)
E1(Spot, Spot)									-0.006***	(0.000)	0.001	(0.262)	0.057***	(0.000)
Weather factors														
E2(Futures, Futures)											0.009	(0.862)	-0.083	(0.505)
E2(Futures, Spot)											0.016	(0.713)	-0.276	(0.175)
E2(Spot, Spot)											0.027	(0.494)	-0.574*	(0.090)
E3(Futures, Futures)											0.737	(0.730)	0.013***	(0.005)
E3(Futures, Spot)											0.143	(0.503)	0.020**	(0.0110
E3(Spot, Spot)											0.673	(0.775)	0.034**	(0.027)
E4(Futures, Futures)											-0.512	(0.563)	0.010***	(0.000)
E4(Futures, Spot)											0.242	(0.782)	0.016***	(0.000)
E4(Spot, Spot)											0.129	(0.899)	0.025***	(0.000)
E5(Futures, Futures)											-0.286	(0.317)	0.013**	(0.037)
E5(Futures, Spot)											-0.244	(0.473)	0.023**	(0.039)
E5(Spot, Spot)											-0.252	(0.539)	0.042**	(0.042)
Macroeconomic news														
E6(Futures, Futures)													0.176	(0.338)
E6(Futures, Spot)													0.192	(0.508)
E6(Spot, Spot)													0.165	(0.696)
E7(Futures, Futures)													-0.160	(0.195)
E7(Futures, Spot)													-0.455**	(0.040)
E7(Spot, Spot)													-0.102**	(0.010)
E8(Futures, Futures)													-0.097	(0.309)
E8(Futures, Spot)													-0.177	(0.292)
E8(Spot, Spot)													-0.310	(0.312)
E9(Futures, Futures)													0.133**	(0.024)
E9(Futures, Spot)													0.213*	(0.058)
E9(Spot, Spot)													0.550**	(0.015)
E10(Futures, Futures)													-0.003	(0.978)
E10(Futures, Spot)													0.177	(0.269)
E10(Spot, Spot)													0.756**	(0.014)
E11(Futures, Futures)													0.573***	(0.000)
E11(Futures, Spot)													0.135***	(0.000)
E11(Spot, Spot)													0.028***	(0.000)
Log-likelihood	2,535		2,547		2,594		2,536		2,582		2,545		2,598	
Observations	725		725		725		725		725		725		725	
HQ(20)	90.175	(0.205)	86.005	(0.303)	84.535	(0.343)	84.515	(0.344)	84.373	(0.348)	78.522	(0.526)	73.245	(0.690)
$HQ^{S}(20)$	88.699	(0.237)	84.876	(0.333)	81.187	(0.442)	83.341	(0.377)	84.423	(0.346)	75.956	(0.607)	72.789	(0.721)

Note: P-values are reported in parentheses. *, **, *** denoted statistically significant at 10%, 5%, and 1%. HQ(20) and $HQ^{S}(20)$ are Hosking's multivariate portmanteau *Q*-statistics on the standardized residuals and the standardized squared residuals, respectively.

Table 6

Estimation results of the VAR-BEKK-GARCH model using different specifications

Variables	Model [1]		Model [2]		Model [3]		Model [4]		Model [5]		Model [6]		Model [7]	
	Base model		Base model with storage in conditional mean equation		Base model with storage and weather factors in conditional mean equation		Base model with storage, weather factors and macroeconomic news in conditional mean equation		Base model with storage in conditional mean and variance equations		Base model with storage and weather factors in conditional mean and variance equations		Base model with storage, weather factors and macroeconomic news in conditional mean and variance equations	
Panel A. Conditional mean equation														
Log-difference in futures prrice of natural gas														
Constatnt	-0.056	(0.785)	0.005**	(0.022)	0.071***	(0.000)	0.069***	(0.000)	0.003	(0.224)	0.036**	(0.018)	0.027*	(0.055)
Futures price (t-1)	0.203***	(0.001)	0.250***	(0.000)	0.243***	(0.000)	0.246***	(0.000)	0.242***	(0.000)	0.185***	(0.001)	0.317***	(0.000)
Futures price (t-2)	-0.082	(0.907)	0.033	(0.649)	-0.047	(0.489)	-0.059	(0.403)	-0.014	(0.844)	-0.010	(0.876)	-0.079	(0.218)
Futures price (t-3)	0.145**	(0.037)	0.193***	(0.008)	0.157**	(0.023)	0.170**	(0.014)	0.173**	(0.013)	0.143**	(0.024)	0.177***	(0.003)
Spot price (t-1)	-0.038	(0.404)	-0.081*	(0.081)	-0.097**	(0.017)	-0.102**	(0.021)	-0.079*	(0.087)	-0.044	(0.295)	-0.127***	(0.009)
Spot price (t-2)	-0.033	(0.532)	-0.032	(0.566)	0.043	(0.411)	0.052	(0.345)	0.013	(0.817)	0.023	(0.677)	0.078	(0.131)
Spot price (t-3)	-0.114**	(0.034)	-0.148***	(0.008)	-0.133**	(0.017)	-0.145***	(0.009)	-0.157***	(0.004)	-0.104**	(0.047)	-0.139***	(0.007)
Storage surprises (t)			-0.218***	(0.000)	-0.820***	(0.000)	-0.802***	(0.000)	0.020	(0.681)	-0.227**	(0.048)	-0.241**	(0.016)
Weather factors														
CC(t)					0.612	(0.210)	-0.911	(0.406)			0.890*	(0.091)	-0.200*	(0.072)
CDD(t)					-0.576***	(0.000)	-0.564***	(0.000)			-0.447***	(0.000)	-0.240**	(0.015)
HDD(t)					-0.393***	(0.000)	-0.384***	(0.000)			-0.196***	(0.001)	-0.136***	(0.009)
RH(t)					0.109	(0.471)	0.094	(0.533)			0.084	(0.529)	0.038	(0.766)
Macroeconomic news														
ARS(t)							-0.002	(0.871)					0.007	(0.574)
BI(t)							0.013	(0.171)					0.012	(0.123)
CNP(t)							0.008	(0.365)					0.014	(0.114)
CS(t)							0.007	(0.271)					-0.002	(0.740)
HS(t)							0.013	(0.228)					0.020*	(0.065)
IP(t)							-0.018	(0.073)					-0.022**	(0.010)
Log-difference in spot price of natural gas														
Constant	-0.009	(0.664)	0.007***	(0.001)	0.062***	(0.000)	0.057***	(0.000)	0.004	(0.141)	0.013	(0.358)	0.010	(0.453)
Futures price (t-1)	0.581***	(0.000)	0.669***	(0.000)	0.738***	(0.000)	0.745***	(0.000)	0.672***	(0.000)	0.694***	(0.000)	0.836***	(0.000)
Futures price (t-2)	0.150**	(0.023)	0.183***	(0.005)	0.148**	(0.024)	0.149**	(0.029)	0.123*	(0.073)	0.181***	(0.003)	0.145**	(0.023)
Futures price (t-3)	0.260***	(0.000)	0.331***	(0.000)	0.306***	(0.000)	0.327***	(0.000)	0.321***	(0.000)	0.299***	(0.000)	0.294***	(0.000)
Spot price (t-1)	-0.279***	(0.000)	-0.375***	(0.000)	-0.486***	(0.000)	-0.501***	(0.000)	-0.382***	(0.000)	-0.440***	(0.000)	-0.541***	(0.000)
Spot price (t-2)	-0.224***	(0.000)	-0.187***	(0.001)	-0.141**	(0.016)	-0.143**	(0.017)	-0.132**	(0.040)	-0.166***	(0.003)	-0.148***	(0.008)
Spot price (t-3)	-0.211***	(0.001)	-0.269***	(0.000)	-0.270***	(0.000)	-0.289***	(0.000)	-0.303***	(0.000)	-0.245***	(0.000)	-0.257***	(0.000)
Storage surprises (t)			-0.314***	(0.000)	-0.838***	(0.000)	-0.807***	(0.000)	-0.044	(0.412)	-0.093	(0.423)	-0.119	(0.218)
Weather factors														
CC(t)					0.002	(1.000)	-0.935	(0.339)			0.425	(0.410)	-2.050**	(0.035)
CDD(t)					-0.397***	(0.000)	-0.368***	(0.000)			-0.184*	(0.060)	-0.018	(0.842)
HDD(t)					-0.332***	(0.000)	-0.314***	(0.000)			-0.066	(0.227)	-0.024	(0.626)
RH(t)					0.067	(0.639)	0.052	(0.717)			0.040	(0.739)	-0.032	(0.781)
Macroeconomic news														
ARS(t)							0.001	(0.943)					0.006	(0.604)
BI(t)							0.011	(0.255)					0.007	(0.353)
CNP(t)							0.005	(0.563)					0.009	(0.267)
CS(t)							0.012*	(0.050)					0.008	(0.988)
HS(t)							0.010	(0.310)					0.018*	(0.058)
IP(t)							-0.015	(0.152)					-0.016*	(0.057)

Note: P-values are reported in parentheses. *, **, *** denoted statistically significant at 10%, 5%, and 1%. HQ(20) and $HQ^s(20)$ are Hosking's multivariate portmanteau *Q*-statistics on the standardized residuals and the standardized squared residuals, respectively.

Table 6 (Continued)

Variables	Model [1]		Model [2]		Model [3]		Model [4]		Model [5]		Model [6]		Model [7]	
	Base model		Base model with storage in conditional mean equation		Base model with storage and weather factors in conditional mean equation		Base model with storage, weather factors and macroeconomic news in conditional mean equation		Base model with storage in conditional mean and variance equations		Base model with storage and weather factors in conditional mean and variance equations		Base model with storage, weather factors and macroeconomic news in conditional mean and variance equations	
Panel B. Conditional variance-covariance equation														
GARCH=M+A1*RESID(t-1)*RESID(t-1)'+B1*GARCH(t-1)+E1*(STORAGE SURPRISES)(t)+E2*CC(t)+E3*CDD(t)+E4*HDD(t)+E5*RH(t) +E6*ARS(t)+E7*BI(t)+E8*CNP(t)+E9*CS(t)+E10*HS(t)+E11*IP(t)														
M(Futures,Futures)	0.052***	(0.000)	0.057***	(0.000)	0.053***	(0.000)	0.050***	(0.000)	0.041***	(0.000)	0.012	(0.655)	0.010	(0.834)
M(Futures,Spot)	0.044***	(0.000)	0.054***	(0.000)	0.053***	(0.000)	0.053***	(0.000)	0.048***	(0.000)	0.006	(0.985)	-0.087	(0.533)
M(Spot,Spot)	0.041***	(0.000)	0.056***	(0.000)	0.054***	(0.000)	0.055***	(0.000)	0.062***	(0.000)	0.052	(0.894)	-0.055	(0.160)
A1(Futures, Futures)	0.454***	(0.000)	0.486***	(0.000)	0.386***	(0.000)	0.383***	(0.000)	0.395***	(0.000)	0.249***	(0.000)	0.324***	(0.000)
A1(Spot, Spot)	0.595***	(0.000)	0.609***	(0.000)	0.582***	(0.000)	0.583***	(0.000)	0.528***	(0.000)	0.452***	(0.000)	0.334***	(0.000)
B1(Futures, Futures)	0.846***	(0.000)	0.836***	(0.000)	0.866***	(0.000)	0.869***	(0.000)	0.878***	(0.000)	0.920***	(0.000)	0.832***	(0.000)
B1(Spot, Spot)	0.828***	(0.000)	0.801***	(0.000)	0.803***	(0.000)	0.801***	(0.000)	0.822***	(0.000)	0.797***	(0.000)	0.867***	(0.000)
Storages of natural gas														
E1(Futures, Futures)									-0.026	(0.781)	-0.080	(0.508)	0.018	(0.407)
E1(Futures, Spot)									-0.227**	(0.040)	-0.017	(0.908)	0.064	(0.428)
E1(Spot, Spot)									-0.539***	(0.000)	-0.125	(0.474)	0.030	(0.225)
Weather factors														
E2(Futures, Futures)											0.108*	(0.060)	-0.041	(0.951)
E2(Futures, Spot)											0.132**	(0.011)	-0.122	(0.620)
E2(Spot, Spot)											0.163***	(0.001)	-0.158	(0.645)
E3(Futures, Futures)											0.110	(0.534)	0.017	(0.498)
E3(Futures, Spot)											0.230	(0.283)	0.007	(0.346)
E3(Spot, Spot)											0.146	(0.590)	0.028	(0.227)
E4(Futures, Futures)											-0.106	(0.149)	0.096	(0.420)
E4(Futures, Spot)											-0.066	(0.475)	0.382	(0.333)
E4(Spot, Spot)											-0.121	(0.322)	0.016	(0.163)
E5(Futures, Futures)											0.188	(0.380)	0.027	(0.944)
E5(Futures, Spot)											0.487	(0.110)	0.336	(0.755)
E5(Spot, Spot)											0.753*	(0.071)	0.018	(0.575)
Macroeconomic news														
E6(Futures, Futures)													0.032	(0.646)
E6(Futures, Spot)													0.037	(0.866)
E6(Spot, Spot)													0.238	(0.426)
E7(Futures, Futures)													-0.031	(0.957)
E7(Futures, Spot)													-0.070	(0.728)
E7(Spot, Spot)													-0.105*	(0.058)
E8(Futures, Futures)													-0.010	(0.980)
E8(Futures, Spot)													0.017	(0.903)
E8(Spot, Spot)													-0.125	(0.769)
E9(Futures, Futures)													0.016	(0.680)
E9(Futures, Spot)													0.042	(0.722)
E9(Spot, Spot)													0.654**	(0.036)
E10(Futures, Futures)													0.089	(0.863)
E10(Futures, Spot)													0.106	(0.553)
E10(Spot, Spot)													0.871	(0.101)
E11(Futures, Futures)													0.034	(0.525)
E11(Futures, Spot)													0.303*	(0.072)
E11(Spot, Spot)													2.160***	(0.000)
Log-likelihood	2,535		2,534		2,575		2,582		2,568		2,569		2,536	
Observations	725		725		725		725		725		725		725	
HQ(20)	90.175	(0.205)	87.529	(0.264)	88.394	(0.244)	84.515	(0.344)	86.022	(0.303)	92.723	(0.157)	75.372	(0.389)
$HQ^S(20)$	88.699	(0.237)	87.086	(0.275)	85.495	(0.317)	83.341	(0.377)	86.916	(0.280)	89.621	(0.216)	79.168	(0.416)

Note: P-values are reported in parentheses. *, **, *** denoted statistically significant at 10%, 5%, and 1%. HQ(20) and $HQ^s(20)$ are Hosking's multivariate portmanteau *Q*-statistics on the standardized residuals and the standardized squared residuals, respectively.

Table 7
Descriptive statistics on time-varying hedge ratios estimated by different specifications

Statistics	Model Specifications							Test in		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	Mean	Median	Variance
Panel A. VAR-VECH-GARCH model										
Mean	0.9769	0.9583	0.9828	0.9804	0.9719	0.9385	0.9349	7.285***	93.207***	85.458***
Median	0.9500	0.9465	0.9473	0.9453	0.9509	0.9232	0.9045	(0.000)	(0.000)	(0.000)
Maximum	2.3108	2.3035	2.7261	2.7710	2.3026	2.7443	2.5797			
Minimum	0.0092	-0.0814	0.1868	0.1709	0.1704	0.3629	0.3869			
Std. Dev.	0.2166	0.2037	0.2105	0.2122	0.1952	0.1852	0.1616			
Skewness	1.1701	0.5621	1.7021	1.7558	1.1165	3.1006	3.3537			
Kurtosis	10.8990	11.5398	14.6881	15.6880	11.4603	27.7298	30.4785			
Jarque-Bera	2,050***	2,241***	4,477***	5,236***	2,313***	19,636***	24,168***			
(Probability)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)			
Observations	725	725	725	725	725	725	725			
Panel B. VAR-BEKK-GARCH model										
Mean	0.9324	0.9583	0.9828	0.9804	0.9719	0.9385	0.9405	7.028***	21.062***	35.722***
Median	0.9050	0.9465	0.9473	0.9453	0.9509	0.9232	0.9207	(0.000)	(0.001)	(0.000)
Maximum	2.4631	2.3035	2.7261	2.7710	2.3026	2.7443	1.7706			
Minimum	0.3144	-0.0814	0.1868	0.1709	0.1704	0.3629	0.5216			
Std. Dev.	0.1685	0.2037	0.2105	0.2122	0.1952	0.1852	0.1781			
Skewness	2.6769	0.5621	1.7021	1.7558	1.1165	3.1006	0.9765			
Kurtosis	23.6470	11.5398	14.6881	15.6880	11.4603	27.7298	4.7946			
Jarque-Bera	13,744***	2,241***	4,477***	5,236***	2,313***	19,636***	213***			
(Probability)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000	(0.0000)	(0.0000)			
Observations	725	725	725	725	725	725	725			

Note: Model [1]: Base model. Model [2]: Base model with storages in conditional mean equation. Model [3]: Base model with storages and weather factors in conditional mean equation. Model [4]: Base model with storages, weather factors and macroeconomic news in conditional mean equation. Model [5]: Base model with storages in conditional mean and variance equation. Model [6]: Base model with storages and weather factors in conditional mean and variance equation. Model [7]: Base model with storages, weather factors and macroeconomic news in conditional mean and variance equation. *** denoted statistically significant at 1%.

Table 8

Structural breaks in the time-series hedging ratios using Bai and Perron (2003) approach

Panel A. VAR-VECH-BGARCH model

Estimation models	Specifications: z=1, q=1, p=0, h=72.5, M=5						
	Test statistics						
	SupF_t(1)	SupF_t (2)	SupF_t (3)	SupF_t (4)	SupF_t (5)	*UDmax*	*WDmax*
1	9.667	5.866	4.337	3.300	2.959	9.667	9.667
2	20.909	14.128	11.752	9.003	7.851	20.909	20.909
3	21.356	14.250	13.378	10.626	9.352	21.356	21.356
4	19.731	13.711	9.953	9.664	8.723	19.731	19.731
5	2.523	2.585	2.869	2.407	1.991	2.869	2.869
6	3.313	2.533	2.295	1.922	2.326	3.313	3.313
7	19.418	10.809	8.145	6.383	6.701	19.418	19.418
	SupF_t(1|0)	SupF_t (2|1)	SupF_t (3|2)	SupF_t (4|3)	SupF_t (5|4)		
1	9.667	3.594	1.006	1.238	0.000		
2	20.909	13.150	5.378	0.186	0.000		
3	21.356	15.193	3.375	0.000	0.000		
4	19.731	16.008	2.543	0.346	0.000		
5	2.523	4.686	2.570	0.000	0.000		
6	3.313	4.056	1.429	0.934	0.000		
7	19.418	10.695	2.140	5.141	0.000		
	Number of breaks selected						
	Sequential		LWZ (Modified Schwarz criterion)		BIC (Bayesian information criterion)		
1	1		1		1		
2	1		1		1		
3	1		1		1		
4	2		2		2		
5	2		2		2		
6	2		2		2		
7	2		2		2		
	Break dates according to BIC						
	Date [1]		Date [2]		Date [3]		
1	10/13/2006						
2	10/06/2006						
3	10/13/2006						
4	2/28/2003		10/13/2006				
5	9/27/2002		2/17/2006				
6	3/07/2003		2/10/2006				
7	3/07/2003		10/06/2006				
	Mean hedging ratio according to subsamples proposed by break dates given above						
	Subsample 1 (*t*-statistics)		Subsample 2 (*t*-statistics)		Subsample 3 (*t*-statistics)		
1	1.027***(37.353)		0.931***(65.499)				
2	0.994***(80.516)		0.925***(106.213)				
3	1.020***(76.918)		0.948***(113.908)				
4	0.962***(35.600)		1.064***(26.670)		0.947***(68.811)		
5	0.939***(35.510)		1.043***(25.769)		0.952***(66.934)		
6	0.920***(42.972)		1.018***(23.004)		0.916***(72.522)		
7	0.927***(88.290)		0.994***(54.651)		0.909***(163.588)		

Note: Based on Bai and Perron (2003) the Bayesian information criterion (BIC) has to be preferred under the presence of multiple breaks, the modified Schwarz criterion (LWZ) by contrast under H_0: No breaks. M: Maximum number of breaks allowed. h: Minimum length of a segment (0.1*sample size). z: Matrix of regressors whose coefficients are allowed to change. q: Number of regressors z. x: Matrix of regressors with coefficients fixed across regimes. p: Number of regressors x. Sup$F_t(l)$: F statistic for H_0: No structural breaks vs. H_1: Arbitrary number of breaks. Sup$F_t(l+1|l)$: Sequential test, H_0: No breaks vs. H_1: l+1 breaks. *UDmax*: Double maximum statistic ($max_{1\leq l\leq M}$sup$F_T(l)$). *WDmax*: Weighted double maximum statistic ($max_{1\leq l\leq M}\ w_l$sup$F_T(l)$). Newey-West (1987) corrected *t*-statistics appear in parentheses. *, **, *** denoted statistically significant at 10%, 5%, and 1%, respectively.

Table 8 (Continued)

Panel B. VAR-BEKK-BGARCH model							
Estimation models	Specifications: z=1, q=1, p=0, h=72.5, M=5						
	Test statistics						
	SupF_t(1)	SupF_t (2)	SupF_t (3)	SupF_t (4)	SupF_t (5)	*UDmax*	*WDmax*
1	9.667	5.866	4.337	3.300	2.959	9.667	9.667
2	20.909	14.128	11.752	9.003	7.851	20.909	20.909
3	21.356	14.250	13.378	10.626	9.352	21.356	21.356
4	19.731	13.711	9.953	9.664	8.723	19.731	19.731
5	10.409	10.133	9.866	7.940	6.918	10.409	10.409
6	12.501	8.869	7.765	6.458	7.351	12.501	12.501
7	7.613	13.943	17.171	16.297	17.214	17.214	17.214
	SupF_t(1|0)	SupF_t (2|1)	SupF_t (3|2)	SupF_t (4|3)	SupF_t (5|4)		
1	9.667	3.594	1.006	1.238	0.000		
2	20.909	13.150	5.378	0.186	0.000		
3	21.356	15.193	3.375	0.000	0.000		
4	19.731	16.008	2.543	0.346	0.000		
5	10.409	17.547	7.949	0.000	0.000		
6	12.501	13.961	4.513	3.006	0.000		
7	7.613	26.301	24.807	10.686	0.000		

	Number of breaks selected		
	Sequential	LWZ (Modified Schwarz criterion)	BIC (Bayesian information criterion)
1	1	1	1
2	2	2	2
3	2	2	2
4	2	2	2
5	2	2	2
6	2	2	2
7	2	2	2
	Break dates according to BIC		
	Date [1]	Date [2]	Date [3]
1	10/13/2006		
2	3/07/2003	10/06/2006	
3	2/21/2003	10/13/2006	
4	2/28/2003	10/13/2006	
5	9/27/2002	2/17/2006	
6	3/07/2003	2/10/2006	
7	12/06/2002	5/13/2005	
	Mean hedging ratio according to subsamples proposed by break dates given above		
	Subsample 1 (*t*-statistics)	Subsample 2 (*t*-statistics)	Subsample 3 (*t*-statistics)
1	1.027***(37.353)	0.931***(65.499)	
2	0.948***(63.626)	1.035***(53.897)	0.925***(106.140)
3	0.967***(64.420)	1.066***(50.874)	0.948***(113.829)
4	0.962***(64.823)	1.064***(49.967)	0.947***(112.351)
5	0.939***(65.269)	1.043***(50.643)	0.952***(123.008)
6	0.920***(77.579)	1.018***(42.523)	0.916***(137.432)
7	0.905***(66.357)	1.038***(45.103)	0.925***(133.169)

Note: Based on Bai and Perron (2003) the Bayesian information criterion (BIC) has to be preferred under the presence of multiple breaks, the modified Schwarz criterion (LWZ) by contrast under H_0: No breaks. M: Maximum number of breaks allowed. h: Minimum length of a segment (0.1*sample size). z: Matrix of regressors whose coefficients are allowed to change. q: Number of regressors z. x: Matrix of regressors with coefficients fixed across regimes. p: Number of regressors x. Sup$F_t(l)$: F statistic for H_0: No structural breaks vs. H_1: Arbitrary number of breaks. Sup$F_t(l+1|l)$: Sequential test, H_0: No breaks vs. H_1: l+1 breaks. *UDmax*: Double maximum statistic ($max_{1\leq l\leq M}\text{sup}F_T(l)$). *WDmax*: Weighted double maximum statistic ($max_{1\leq l\leq M}\, w_l\text{sup}F_T(l)$). Newey-West (1987) corrected t-statistics appear in parentheses. *, **, *** denoted statistically significant at 10%, 5%, and 1%, respectively.

Table 9

Hedging effectiveness under difference model specifications

Model Specifications	Mean of Hedge Ratio	Variance of Unhedged Portfolio (%)	Variance of Hedge Portfolio (%)	HE (Hedging Effectiveness)(%)
Panel A. VAR-VECH-BGARCH model				
Model [1]	0.9769	0.5665	0.2039	64.0038
Model [2]	0.9583	0.5665	0.2006	64.5870
Model [3]	0.9828	0.5665	0.2020	64.3383
Model [4]	0.9804	0.5665	0.2019	64.3526
Model [5]	0.9719	0.5665	0.1898	66.5007
Model [6]	0.9385	0.5665	0.1967	65.2794
Model [7]	0.9349	0.5665	0.1937	65.8004
Panel B. VAR-BEKK-BGARCH model				
Model [1]	0.9324	0.5665	0.1941	65.7454
Model [2]	0.9583	0.5665	0.2006	64.5870
Model [3]	0.9828	0.5665	0.2020	64.3383
Model [4]	0.9804	0.5665	0.2019	64.3526
Model [5]	0.9719	0.5665	0.1898	66.5007
Model [6]	0.9385	0.5665	0.1967	65.2794
Model [7]	0.9405	0.5665	0.1683	70.2991

Note: Model [1]:Base model; Model [2]: Base model with storage in conditional mean equation; Model [3]:Base model with storage and weather factors in conditional mean equation; Model [4]: Base model with storage, weather factors and macroeconomic news in conditional mean equation; Model [5]: Base model with storage in conditional mean and variance equations; Model [6]: Base model with storage and weather factors in conditional mean and variance equations; Model [7]: Base model with storage, weather factors and macroeconomic news in conditional mean and variance equations.

科技部補助計畫衍生研發成果推廣資料表

日期:2017/04/12

<table>
<tr><td rowspan="3">科技部補助計畫</td><td>計畫名稱: 銀行競爭對銀行系統性風險影響的全球銀行實證研究:公司治理、內部風險管理、國家治理、金融監理的角色</td></tr>
<tr><td>計畫主持人: 陳昇鴻</td></tr>
<tr><td>計畫編號: 104-2410-H-343-001- 學門領域: 產業組織與政策</td></tr>
<tr><td colspan="2">無研發成果推廣資料</td></tr>
</table>

104年度專題研究計畫成果彙整表

計畫主持人：陳昇鴻				計畫編號：104-2410-H-343-001-		
計畫名稱：銀行競爭對銀行系統性風險影響的全球銀行實證研究:公司治理、內部風險管理、國家治理、金融監理的角色						
成果項目				量化	單位	質化 （說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）
國內	學術性論文	期刊論文		0	篇	
		研討會論文		0		
		專書		0	本	
		專書論文		0	章	
		技術報告		1	篇	
		其他		0	篇	
	智慧財產權及成果	專利權	發明專利 申請中	0	件	
			發明專利 已獲得	0		
			新型/設計專利	0		
		商標權		0		
		營業秘密		0		
		積體電路電路布局權		0		
		著作權		0		
		品種權		0		
		其他		0		
	技術移轉	件數		0	件	
		收入		0	千元	
國外	學術性論文	期刊論文		0	篇	
		研討會論文		0		
		專書		0	本	
		專書論文		0	章	
		技術報告		1	篇	
		其他		0	篇	
	智慧財產權及成果	專利權	發明專利 申請中	0	件	
			發明專利 已獲得	0		
			新型/設計專利	0		
		商標權		0		
		營業秘密		0		
		積體電路電路布局權		0		
		著作權		0		
		品種權		0		

		其他	0		
	技術移轉	件數	0	件	
		收入	0	千元	
參與計畫人力	本國籍	大專生	4	人次	
		碩士生	2		
		博士生	0		
		博士後研究員	0		
		專任助理	0		
	非本國籍	大專生	0		
		碩士生	2		
		博士生	0		
		博士後研究員	0		
		專任助理	0		
其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）					

科技部補助專題研究計畫成果自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現（簡要敘述成果是否具有政策應用參考價值及具影響公共利益之重大發現）或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估
   ■達成目標
   □未達成目標（請說明，以100字為限）
   　□實驗失敗
   　□因故實驗中斷
   　□其他原因
   說明：

2. 研究成果在學術期刊發表或申請專利等情形（請於其他欄註明專利及技轉之證號、合約、申請及洽談等詳細資訊）
   論文：□已發表　■未發表之文稿　□撰寫中　□無
   專利：□已獲得　□申請中　■無
   技轉：□已技轉　□洽談中　■無
   其他：（以200字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性，以500字為限）
   本研究計畫針對2007年至2011 年間全球上市商業銀行為研究對象，進行實證檢驗銀行競爭與系統性風險的關係，不同於過去多數研究僅考慮銀行個別風險指標，本研究則特別考量銀行系統性風險具共同相依性的特性以反映出銀行的脆弱性。再者，本研究計畫擬進一步探討公司治理品質與內部風險管理機制對系統風險的影響角色，同時也探討跨國間國家治理品質與金融監理對銀行系統性風險的影響，尤其是驗證銀行競爭透過國家治理與金融監理的管道如何交互影響銀行系統性風險。本計畫發現銀行競爭程度愈大、風險管理品質愈好、公司治理品質愈佳者，則會顯著地降低其系統性風險。再者，在銀行競爭程度愈高下，風險管理品質愈好、公司治理品質愈佳、以及金融監理要求較嚴格國家的銀行，則表現出較低的系統性風險。

4. 主要發現
   本研究具有政策應用參考價值：□否　■是，建議提供機關<u>金融管理委員會</u>
   （勾選「是」者，請列舉建議可提供施政參考之業務主管機關）
   本研究具影響公共利益之重大發現：□否　■是
   說明：（以150字為限）
   1.銀行競爭程度愈大、風險管理品質愈好、公司治理品質愈佳者，則可以顯著地降低其系統性風險。

2. 在銀行競爭程度愈高下，風險管理品質愈好、公司治理品質愈佳、以及金融監理要求較嚴格國家的銀行，則表現出較低的系統性風險。