รายงานวิจัยฉบับสมบูรณ์

โครงการการวางแผนชีวิตของเกษตรกรไทยผู้ประยุกต์ใช้ "ทฤษฎีใหม่"

โดย

ศาสตราจารย์ ดร.อัญญา ขันธวิทย์

กรกฎาคม 2554

สัญญาเลขที่ RTA/11/2543

รายงานวิจัยฉบับสมบูรณ์

โครงการการวางแผนชีวิตของเกษตรกรไทยผู้ประยุกต์ใช้ "ทฤษฎีใหม่"

ศาสตราจารย์ ดร.อัญญา ขันธวิทย์
คณะพาณิชยศาสตร์และการบัญชี
มหาวิทยาลัยธรรมศาสตร์

สนับสนุนโดยสำนักงานกองทุนสนับสนุนการวิจัย

กิตติกรรมประกาศ

คณะผู้วิจัยขอขอบคุณสำนักงานกองทุนสนับสนุนการวิจัย (สกว.) ที่ได้สนับสนุนเมธีวิจัยอาวุโส สกว. พ.ศ. 2543 คณะผู้เขียนขอบคุณคณะพาณิชยศาสตร์และการบัญชี มหาวิทยาลัยธรรมศาสตร์ ที่ร่วมให้ทุนสนับสนุนโครงการวิจัยเรื่อง **World and Regional Factors in Stock Market Returns** และขอบคุณตลาดหลักทรัพย์แห่งประเทศไทย ธนาคาร CITIBANK ศูนย์ซื้อขายตราสารหนี้ไทย ธนาคารแห่งประเทศไทย ธนาคารเพื่อการเกษตรและสหกรณ์การเกษตร กระทรวงเกษตรและสหกรณ์การเกษตร และสำนักงานนายกรัฐมนตรี ซึ่งได้อนุเคราะห์ข้อมูล และผู้วิจัยขอขอบคุณผู้เข้าร่วมฟังการนำเสนอผลงานของเมธีวิจัยอาวุโส สกว. ทุกท่านที่ได้ให้ข้อเสนอแนะซึ่งเป็นประโยชน์ต่อการปรับปรุงผลงานวิจัย

บทคัดย่อ

Abstracts

บทคัดย่อ

ตัวแบบจำลองเพื่ออธิบายพฤติกรรมซึ่งอาจไม่สมเหตุสมผลของเกษตรกร

การศึกษาเสนอตัวแบบจำลองเพื่ออธิบายพฤติกรรมของเกษตรกรที่ยังคงยึดมั่นการผลิตพืชผลทางการเกษตรเพียงชนิดดั้งเดิม และปฏิเสธการผลิตแบบกระจายออกไปให้ครอบคลุมพืชผลหลายชนิด ซึ่งพฤติกรรมนี้ดูเหมือนจะไม่สมเหตุสมผล การศึกษาอธิบายว่าพฤติกรรมนี้สามารถเป็นพฤติกรรมซึ่งสมเหตุสมผลได้อย่างยิ่ง โดยการใช้ตัวแบบจำลองซึ่งพัฒนาจากทฤษฎีบทของเบย์ กล่าวคือ พืชผลดั้งเดิมที่เกษตรกรผลิตเป็นพืชผลซึ่งเกษตรกรมีความรู้และประสบการณ์ในการผลิตเป็นอย่างดี ในสายตาของเกษตรกร พืชผลเหล่านี้มีความเสี่ยงต่ำมาก เกษตรกรจึงกระจุกตัวการผลิตเฉพาะพืชผลชนิดดั้งเดิมนั้น และปฏิเสธพืชผลชนิดใหม่ซึ่งในสายตาของเกษตรกรเป็นพืชผลที่มีความเสี่ยงสูงกว่า จากนั้นการศึกษาได้ประยุกต์ใช้ตัวแบบจำลองไปตรวจสอบความเหมาะสมของนโยบายและมาตรการการส่งเสริมการเกษตรของภาครัฐ

ABSTRACT

Knowledge, Experience and Farmers' Seemingly Irrational Behavior

This study proposes that rational farmers can concentrate the production on traditional, familiar crops. Farmers are risk averse and Bayesian. They use the predictive densities they develop on their own to form the expectations and make decisions. From their perspectives, familiar crops are less risky. So, the risk-averse farmers concentrate on the less-risky, familiar crops and avoid the more-risky, unfamiliar crops.

The impact of the government's farmers assistance programs are examined. Training seems to be the most efficient because it can improve the prior knowledge and reduce return volatility so that farmers practice more diversification. The mean-enhancement programs must be administered with the volatility-reduction programs to achieve the true optima.

Finally, we demonstrate that forced diversification constraints can be useful even though they are wrong ones. The constraints help to lessen concentration on the familiar crops that results from the improper predictive densities. The findings enable us to understand the success of certain production plans, such as the "New Theory", being introduced to farmers.

คำหลัก Irrational Behavior, the "New Theory", Risk Aversion

บทคัดย่อ

การระบุฟังก์ชั่นอรรถประโยชน์ของเกษตรกรไทย

การศึกษาเสนอการใช้ทฤษฎีข่าวสารข้อมูลเพื่อระบุรูปแบบฟังก์ชั่นอรรถประโยชน์ และแสดงความสามารถของวิธีที่เสนอในเชิงประจักษ์โดยการประยุกต์ใช้กับการระบุฟังก์ชั่นอรรถประโยชน์ของเกษตรกรไทย 10 ราย และพบว่าวิธีการนี้สามารถระบุรูปแบบฟังก์ชั่นได้ดี และพบต่อไปอีกว่าเกษตรกรไทยส่วนใหญ่มีฟังก์ชั่นรูปล็อค (log utility) ผลการศึกษานี้สามารถอธิบายพฤติกรรมของเกษตรกรไทยได้บางส่วนว่าเหตุใดจึงมีเกษตรกรไทยเพียงน้อยรายที่นำ "ทฤษฎีใหม่" ของพระบาทสมเด็จพระเจ้าอยู่หัวไปประยุกต์ใช้

ABSTRACT

An Information-Theoretic Approach for Identifying Utility Functional Form With An Application in Describing Risk Behavior of Thai Farmers

Previous studies rely on revealed economic behavior for identifying the exact utility functions for farmers. The approach is not practical because the data are difficult to obtain or are inexistent. This study proposes an application of the information-theoretic test as an alternative for the identification purpose. It is convenient, quick and inexpensive because the test employs the data readily available from the popular Ramsey interview. The study demonstrates its application, using the interview data of ten small Thai farmers. It is found that the test can discriminate the competing utility functions and successfully identify the dominant ones.

In recent years, the "New Theory" of H.M. the King is regarded as being a more profitable, less risky production strategy for small farmers. The sample farmers participate in a free-irrigation-pond program, which applies the Theory in a smaller-scale production. It is interesting to find that almost all the sample farmers possess log utility, implying their myopic behavior. This finding helps to explain in part the reason why the "New Theory" is not so well accepted among farmers before they receive free ponds. The Theory leads to higher and less risky returns in a long run, while farmers with a log utility consider only the returns in the current period. The study suggests "forced" acceptance or behavior-modification program for widespread adoption of the Theory.

คำหลัก: Utility Function Estimation, Farmer's Economic Behavior

บทคัดย่อ

ปัจจัยที่มีผลต่อการตัดสินใจในการทำการเกษตรแบบผสมผสาน

แนวความคิดการทำการเกษตรแบบผสมผสานเป็นแนวความคิดในการวางแผนการผลิตพืช ปศุสัตว์ และ การประมง ในเวลาเดียวกัน รวมถึงกระบวนการจัดสรรทรัพยากรการผลิต ได้แก่ ที่ดิน แรงงาน เงินทุน การพิจารณาปัจจัยที่มีผลต่อการตัดสินใจของเกษตรกรในการเลือกทำการเกษตรแบบผสมผสานจึงมีความจำเป็นในฐานะเป็นเครื่องมือเพื่อกำหนดนโยบายทั้งภาครัฐและเอกชนในการให้การสนับสนุนหรือเลือกเกษตรกรที่จะเข้าร่วมโครงการ การศึกษาใช้ปัจจัยในสามลักษณะ คือ ปัจจัยที่เป็นคุณลักษณะของเกษตร ปัจจัยที่เกี่ยวกับพื้นที่ทำการเกษตร และปัจจัยทางการเงิน โดยใช้ตัวแบบ Logit และ Probit เพื่อตรวจสอบปัจจัยเหล่านี้ว่าปัจจัยใดส่งผลกระทบในทิศทางใด และมีนัยสำคัญหรือไม่ทางสถิติ ซึ่งผลการศึกษาที่ได้รับ พบว่า ปัจจัยที่มีผลทำให้เกษตรกรมีการตัดสินใจในการทำการเกษตรผสมผสาน คือ การมีที่ดินเป็นของตนเอง และคมนาคมที่สะดวก ซึ่งทั้งสองปัจจัยนี้เป็นปัจจัยที่ส่งเสริมให้เกษตรกรตัดสินใจทำการเกษตรแบบผสมผสาน ในขณะที่ประสบการณ์ในการปลูกพืชเชิงเดี่ยวแสดงความสัมพันธ์ในทางตรงกันข้าม คือ การที่เกษตรกรมีการทำการปลูกพืชเชิงเดี่ยวเป็นเวลายาวนานก็จะมีโอกาสที่น้อยในการตัดสินใจทำการเกษตรแบบผสมผสาน ดังนั้นแนวนโยบายที่รัฐควรให้การสนับสนุนหากต้องการให้เกษตรกรเปลี่ยนพฤติกรรมมาทำการเกษตรแบบผสมผสาน คือ การสร้างความสะดวกในการคมนาคมและการส่งเสริมให้เกษตรกรมีที่ทำกินเป็นของตนเอง

ABSTRACT

Determinants of Farmers' Decision to Adopt Multi-Crop Production

The study attempts to identify the determinants of farmers' decision to switch from a mono-crop production to a multi-crop production. The determinants are tested for significance, using survey data from farmers in Nakorn Nayok Province. The study finds that significant factors include land ownership, convenient transportation, and experiences.

คำหลัก: การเกษตรแบบผสมผสาน, การจัดสรรทรัพยากรการผลิต, ปัจจัยกำหนดการตัดสินใจ

บทคัดย่อ

การระบุเพดานเงินกู้ของเกษตรกรในประเทศไทย

การศึกษาชี้ว่าสถาบันการเงินซึ่งให้เงินกู้แก่เกษตรกรไทยสามารถใช้ข้อมูลพฤติกรรมของอัตราผลตอบแทนของพืชผลทางการเกษตรที่เกษตรกรผลิตไป เพื่อระบุขนาดความสามารถของเกษตรกรที่จะใช้รายได้จากการผลิตพืชผลนั้นๆ มาชำระคืนเงินกู้ จากนั้นการศึกษาจึงใช้วิธีการของ Ramirez เพื่อระบุรูปแบบการแจกแจงของอัตราผลตอบแทนของพืชผล แล้วใช้ผลลัพธ์นี้ตรวจสอบถึงความสำเร็จของการใช้ข้อมูลในการกำหนดเพดานเงินกู้ การศึกษาพบว่าวิธีการนี้สามารถระบุเพดานเงินกู้ได้อย่างถูกต้องเหมาะสม และยังพบต่อไปอีกว่าเพดานเงินกู้ที่การศึกษาระบุได้มีขนาดใกล้เคียงกับเพดานเงินกู้ที่ธนาคารเพื่อการเกษตรและสหกรณ์การเกษตรระบุ

ABSTRACT

MAXIMUM FEASIBLE FARM CREDITS: CASES FOR THAILAND

We show how banks can use the information on statistical distributions of crop returns to set limits for farm loans so that borrowing farmers are able to repay their loans by the crop income with an accepted default probability. We then apply the technique proposed by Ramirez (1997, 2000) to estimate the return distribution. Its resulting credit limits are tested against the ones under the normality assumption. The Ramirez limits can pass the in-sample and out-of-sample tests. And, they outperform the normality limits. We apply the resulting limits to evaluate the limits set by the Bank of Agriculture and Agricultural Co-operatives--Thailand's largest provider of farm loans. Those limits can be justified by the revealed behavior of the crop returns.

คำหลัก: Default Probability, Maximum Farm Credits, Revealed Behavior

บทคัดย่อ

การวัดขนาดความเสี่ยงซึ่งพิจารณาพฤติกรรม “การกระโดด” ของราคาหลักทรัพย์

การศึกษาเสนอการแจกแจงซึ่งมีสามโหนกเพื่อพรรณนาพฤติกรรมความเสี่ยงของหลักทรัพย์ซึ่งอาจมีราคาปรับตัวสูงขึ้นหรือลดลงอย่างรุนแรงบางครั้งในลักษณะกระโดด จากนั้นจึงใช้การแจกแจงนี้ไปพยากรณ์ขนาดของมูลค่าความเสี่ยงของดัชนี S&P 500 เพื่อเปรียบเทียบกับการพยากรณ์ของการแจกแจงรูปแบบอื่น การศึกษาพบว่า การแจกแจงแบบสามโหนกนี้สามารถให้ผลการพยากรณ์ซึ่งแม่นยำกว่าการแจกแจงรูปแบบอื่นอย่างมีนัยสำคัญ

ABSTRACT

MEASURING RISK WITH STOCHASTIC JUMPS

We propose a trimodal distribution of returns which combines normal distribution and stochastic jumps, where both the positive and negative jumps are allowed for the presence of asymmetry. We apply the proposed distribution in a Value at Risk (VaR) analysis. The model is compared with the four competing models including the normal distribution, the student's *t* distribution, the extreme value theory, and the bimodal distribution. Using daily returns on S&P500 index, we find that the trimodal distribution gives a better VaR forecast in all performance measures.

คำหลัก: Risk management, Stochastic jumps, Trimodal distribution, Value at Risk

บทคัดย่อ

การวัดขนาดความเสี่ยงซึ่งพิจารณาพฤติกรรมการกระโดด
และความผันผวนอย่างมีเงื่อนไขของราคาหลักทรัพย์

การศึกษาขยายผลการพัฒนาตัวแบบจำลองเพื่อพรรณนาพฤติกรรมของราคาหลักทรัพย์โดยใช้การแจกแจงแบบสามโหนกที่เกิดจากการปรับตัวลดลงและเพิ่มขึ้นของราคาอย่างรุนแรง ให้พิจารณาเพิ่มเติมถึงความผันผวนอย่างมีเงื่อนไขของราคา แล้วนำการแจกแจงที่ได้เป็นผลลัพธ์ไปเปรียบเทียบความสามารถกับการแจกแจงอื่น โดยการเปรียบเทียบใช้ข้อมูลดัชนี S&P 500 การศึกษาพบว่า แม้การแจกแจงที่พัฒนาขึ้นนี้จะมีลักษณะยืดหยุ่นที่สุดสำหรับการพรรณนาพฤติกรรมความเสี่ยงของราคาหลักทรัพย์ แต่ความสามารถในการพยากรณ์มูลค่าความเสี่ยงกลับไม่ต่างอย่างมีนัยสำคัญจากการแจกแจงรูปแบบอื่นทั่วไป

Abstract

Measuring Risk with Stochastic Jumps and Conditional Heteroskedasticity

We extend previously proposed trimodal model which combines normal distribution and stochastic jump process where both the positive and negative jumps are allowed for the presence of asymmetry to incorporate the conditional heteroskedasticity. Both the GARCH and the asymmetric EGARCH processes are considered. We propose the conditional trimodal distribution for the returns on S&P500 index and apply it with the estimation of the Value at Risk (VaR). The model is compared with the three competing models including the conditional normal distribution, the conditional student's *t* distribution, and the conditional bimodal distribution. The issue of the unconditional and conditional models is still inconclusive since the more complicated conditional models do not grant better performance in some cases.

คำหลัก*:* Conditional heteroskedasticity; Risk management; Stochastic jumps; Trimodal distribution; Value at Risk

บทคัดย่อ

การพัฒนาความแม่นยำของการพยากรณ์มูลค่าความเสี่ยง
โดยใช้ข้อมูลเพิ่มเติมจากราคาของหลักทรัพย์อนุพันธ์

การศึกษาพัฒนาเทคนิคเพื่อปรับปรุงความแม่นยำของการพยากรณ์มูลค่าความเสี่ยง โดยใช้ข้อมูลเพิ่มเติมจากราคาของหลักทรัพย์อนุพันธ์ ตามแนวทางการประสานข้อมูลจากแหล่งต่างๆ ภายใต้ทฤษฎีบทของเบย์ ทั้งนี้เทคนิคที่พัฒนาขึ้นได้ใช้การแจกแจงที่เกิดจากการพยากรณ์ผลตอบแทนของการลงทุนในคาบถัดไป แล้วใช้การแจกแจงที่พยากรณ์นี้ไปพยากรณ์มูลค่าความเสี่ยงอีกต่อหนึ่ง การศึกษาใช้เทคนิคไปในการพยากรณ์มูลค่าความเสี่ยงของอัตราแลกเปลี่ยนระหว่างเงินบาทกับเงินดอลลาร์สหรัฐอมริกา โดยข้อมูลส่วนเพิ่มเป็นค่าความผันผวนของอัตราแลกเปลี่ยนที่ชี้โดยนัยจากราคาออปชัน การศึกษาพบว่า เทคนิคที่พัฒนาขึ้นได้ให้ผลการพยากรณ์ที่แม่นยำขึ้นอย่างมีนัยสำคัญ

ABSTRACT

Improving VaR Forecasts, Using Information in Derivatives Prices

A VaR forecast is developed in a Bayesian framework to improve the performance over that of traditional ones. As opposed to the traditional forecasts, which assume risk manager knows the return distribution and that distribution is the same for the realized returns and next period's return, our return distribution is predictive and is derived for the next period's return in particular. Moreover, we are able to incorporate information in the volatilities implied by option prices, in addition to that in the return samples, into the estimation of the predictive distribution. We demonstrate its out-of-sample performance in the risk measurement of daily baht/dollar exchange rate from December 24, 2001 to January 15, 2003. Our Bayesian VaR forecast can outperform those from the traditional ones, which rely on historical or implied volatilities alone.

คำหลัก: Bayesian VaR Forecast, Option Prices, Predictive Distribution

บทคัดย่อ

โครงสร้างของคณะกรรมการตรวจสอบกับความสำเร็จ

ของบริษัทจดทะเบียนไทย

การศึกษาตรวจสอบลักษณะของโครงสร้างของคณะกรรมการตรวจสอบในด้านความเป็นอิสระอย่างแท้จริงที่จะมีผลต่อความสำเร็จในการดำเนินงานของบริษัทจดทะเบียนไทย โดยการศึกษาได้พิจารณามาตรการอื่นด้านบรรษัทภิบาลร่วมด้วย การศึกษาพบว่า สำหรับปี พ.ศ. 2543 บริษัทที่มีผลการดำเนินงานดี มีความสำเร็จ มักมีโครงสร้างของคณะกรรมการตรวจสอบที่เป็นอิสระจริง และมักระดมทุนโดยการก่อหนี้ ลักษณะกลุ่มนี้ได้รับการกำหนดร่วมกันในดุลยภาพและโครงสร้างของคณะกรรมการตรวจสอบไม่ใช้ตัวแปรซึ่งกำหนดความสำเร็จของบริษัท

ABSTRACT

Outside Directors, Audit Committee Structure, and Firm Performance:

Evidence from Thailand

We examine the relationship of the firm's performance with the independence structure of audit committee and other corporate governance mechanisms of Thai firms listed on the Stock Exchange of Thailand in the year 2000. We apply the simultaneous-equations approach to acknowledge the possible endogeneity relationship among the variables in order to avoid inconsistency problems. We test for exogeneity and endogeneity of the firm's performance and governance mechanisms, so that the relationship is interpreted correctly. This test has never been conducted by any other study and we consider it as our contribution.

We find that the independence structure of audit committee and the level of debt financing are determined simultaneously with the firm's performance. As opposed to previous studies, we find that the firm's performance, debt financing and audit committee independence are exogenous to and are determinants of certain corporate governance mechanisms.

คำหลัก: Audit committee, Corporate governance, Firm performance, Outside directors

บทคัดย่อ

การประเมินระดับการควบคุมบริษัทจดทะเบียนในประเทศไทย โดยบุคคลในครอบครัวผู้ก่อตั้ง ภายหลังจากวิกฤตการเงินเอเซีย

การศึกษาตรวจสอบและประเมินระดับของการควบคุมบริษัทจดทะเบียนในประเทศไทยโดยบุคคลในครอบครัวผู้ก่อตั้ง เพื่อเปรียบเทียบระดับการควบคุมในช่วงก่อนและหลังจากวิกฤตการเงินเอเซีย การศึกษาพบว่า ภายหลังวิกฤตการเงิน บุคคลในครอบครัวผู้ก่อตั้งยังคงเป็นผู้ถือหุ้นใหญ่ของบริษัทและมีอำนาจในการออกเสียง แต่บุคคลเหล่านี้กลับมีบทบาทลดลงในฐานะผู้ถือหุ้นใหญ่

Abstract

Did Families Lose or Gain Control?: Thai Firms after the East Asian Financial Crisis

This paper investigates the ownership and control of Thai public firms in the period after the East Asian financial crisis, compared to those in the pre-crisis period. Using the comprehensive unique database of ownership and board structures, we find that the ownership and control appear to be more concentrated in the hands of controlling shareholders subsequent to the crisis. Interestingly, even though families remain the most prevalent owners of Thai firms and are still actively involved in the management after the financial crisis, their role as the controlling shareholder becomes less significant. In addition, our results show that direct shareholdings are most frequently used as a means of control in both periods. Pyramids and cross-shareholdings, however, are employed to the lesser extent following the crisis.

คำหลัก: Ownership; Controlling Shareholder; Corporate Governance; East Asian Financial Crisis; Thailand

บทคัดย่อ

การทดสอบถึงอิทธิพลของตลาดหลักทรัพย์สหรัฐอเมริกา

การศึกษาทดสอบในเชิงลึกถึงสาเหตุที่ตลาดหลักทรัพย์สหรัฐอเมริกามีอิทธิพลซึ่งทำให้เกิดการเคลื่อนไหวของราคาหลักทรัพย์ในตลาดอื่นทั่วโลก ว่าจะเกิดจากต้นเหตุที่เป็นข่าวสารข้อมูลในสหรัฐอเมริกา หรือเกิดจากการที่ตลาดหลักทรัพย์สหรัฐอเมริกาเป็นตลาดที่มีประสิทธิภาพสูงมาก จึงรับข่าวสารข้อมูลก่อนแล้วจึงกระจายไปสู่ตลาดอื่น การศึกษาทดสอบโดยใช้ข้อมูลจากตลาดในสหรัฐอเมริกาควบคู่กับคานาดา สหราชอาณาจักร เยอรมันนี และญี่ปุ่น พบว่า ตลาดหลักทรัพย์ในประเทศทั้งห้ามีการเคลื่อนไหวไปพร้อมกันจากข่าวสารข้อมูลที่ใช้ร่วมกัน และตลาดหลักทรัพย์ในสหรัฐอเมริกาไม่ได้เป็นตลาดที่มีอิทธิพลจริงในการทำให้เกิดการเคลื่อนไหวของราคาในตลาดอื่น

Abstract

No, the U.S. Market is not the World Factor

Returns in national stock markets exhibit strong interdependence. Among these markets, the U.S. market has ability to explain and predict the movement of other markets. In this study, we examine the mechanism that constitutes this ability. We propose two competing hypotheses. Under the first hypothesis, the U.S. return is a common or world factor that drives returns in all national markets. Hence, all the national market returns must be explained by the U.S. return by the construction. The predictive ability results from the delayed reaction of markets to the U.S. returns on earlier dates. Under the second hypothesis, the U.S. return and other national market returns are driven by a common factor and by the idiosyncratic factors of their own. The explanatory ability is from the common factor that moves all the returns together; the predictive ability is from the delayed reaction of markets to the common factor, which has already acknowledged by the U.S. market on earlier dates.

We use daily return data on the U.S., Canadian, U.K., German and Japanese markets from January 5, 1987 to December 22, 2000 (2,646 observations) for the tests. Our results support the second hypothesis. The U.S. market is not the world factor.

คำหลัก: Common factor, Kalman filter, Stock returns, Market efficiency

บทคัดย่อ

การสำรวจคุณภาพชีวิตของคนไทยซึ่งป่วยเป็นโรคตับชนิดเรื้อรัง

การศึกษาใช้แบบสำรวจเพื่อวัดระดับคุณภาพชีวิตของคนไทยซึ่งป่วยเป็นโรคตับชนิดเรื้อรัง และตรวจสอบปัจจัยที่มีผลกระทบต่อระดับคุณภาพชีวิต ทั้งปัจจัยที่เกี่ยวกับความรุนแรงของโรค ปัจจัยด้านสภาพบุคคล ปัจจัยด้านเศรษฐกิจและสังคม และปัจจัยด้านทัศนคติของผู้ป่วยต่อโรค การศึกษาพบว่าปัจจัยเหล่านี้มีผลกระทบต่อคุณภาพชีวิตอย่างมีนัยสำคัญและยังพบต่อไปว่าทัศนคติของผู้ป่วยต่อโรคมีผลกระทบต่อตัวชี้ค่าคุณภาพชีวิตทุกตัว การศึกษาสรุปว่าการปรับเปลี่ยนทัศนคติของผู้ป่วย เช่น การจัดกลุ่มแลกเปลี่ยนประสบการณ์ของผู้ป่วยและการให้กำลังใจไปพร้อมกับการรักษาทางกายภาพจะทำให้คุณภาพชีวิตของผู้ป่วยดีขึ้นมาก

ABSTRACT

The Quality of Life in Thai Patients with Chronic Liver Diseases

Health-related quality of life (HRQOL) is a concept that incorporates many aspects of life beyond “health”. HRQOL is important for measuring the impact of chronic disease on patients. The research for QOL in chronic liver disease (CLD) has hardly been received attention in Southeast Asian countries. We compare the QOL in Thai patients having CLD with that in normal people and to investigate for factors relating to the QOL. We find that the CLDQ, a western originated questionnaire, is valid and applicable in Thai patients with CLD. Generic and liver disease-specific health measurement reveals that QOL in these patients is lower than that in normal people. QOL is more impaired in advanced stage of CLD. Other factors, such as age, sex, education level, career, financial problem and etiology of liver disease may individually influence HRQOL in Thais with CLD.

คำหลัก: Quality of life, chronic hepatitis, cirrhosis, chronic liver diseases

บทคัดย่อ

หลักฐานเชิงประจักษ์ด้านการกำหนดมูลค่าของบริษัทจดทะเบียน ในตลาดหลักทรัพย์แห่งประเทศไทย

การศึกษาเปรียบเทียบตัวแบบจำลองเพื่อกำหนดมูลค่าของบริษัทจำนวน 2 ตัวแบบ คือ (1) ตัวแบบ Dividend Discount Model (DDM) และ (2) ตัวแบบ Residual Income Model (RIM) โดยใช้ตัวอย่างจากบริษัทจดทะเบียนในตลาดหลักทรัพย์แห่งประเทศไทยช่วงปี 2538 ถึงปี 2547 การศึกษาพบว่า ทั้งตัวแบบ DDM และ RIM ให้มูลค่าที่ต่ำกว่าระดับที่ควรจะเป็นจริง แต่เมื่อเปรียบเทียบตัวแบบทั้งสองระหว่างกันแล้ว การศึกษาพบว่า ตัวแบบ RIM ให้ค่าที่กำหนดได้ที่คลาดเคลื่อนน้อยกว่าที่ตัวแบบ DDM ให้ การศึกษาโดยใช้สมการถดถอยสำหรับบริษัทที่ใช้เป็นตัวอย่าง พบว่า ตัวแปรราคาตามบัญชีของส่วนของทุนสามารถอธิบายมูลค่าที่พบโดยตัวแบบ DDM และ RIM ได้ดี ผลการศึกษานี้ชี้โดยนัยว่าความคลาดเคลื่อนของมูลค่าที่รายงานผ่านมูลค่าทางบัญชีมีระดับที่ไม่มากนักและต่ำกว่าที่หลายฝ่ายเข้าใจไปเองแต่แรก

ABSTRACT

Empirical Evidence on Equity Valuation of Thai Firms

This study aims at providing empirical evidence on a comparison of two equity valuation models: (1) the dividend discount model (DDM) and (2) the residual income model (RIM), in estimating equity values of Thai firms during 1995-2004. Results suggest that DDM and RIM underestimate equity values of Thai firms and that RIM outperforms DDM in predicting cross-sectional stock prices. Results on regression of cross-sectional stock prices on the decomposed DDM and RIM equity values indicate that book value of equity provides the greatest incremental explanatory power, relative to other components in DDM and RIM terminal values, suggesting that book value distortions resulting from accounting procedures and choices are less severe than forecast and measurement errors in discount rates and growth rates.

We also document that the incremental explanatory power of book value of equity during 1998-2004, representing the information environment under Thai Accounting Standards reformed after the 1997 economic crisis to conform to International Accounting Standards, is significantly greater than that during 1995-1996, representing the information environment under the pre-reformed Thai Accounting Standards. This implies that the book value distortions are less severe under the 1997 Reformed Thai Accounting Standards than the pre-reformed Thai Accounting Standards.

คำหลัก: Dividend Discount Model, Residual Income Model, Thai Stock Market

บทคัดย่อ

ปัจจัยโลกและปัจจัยภูมิภาคซึ่งผลักดันพฤติกรรม
ของอัตราผลตอบแทนในตลาดหลักทรัพย์

การศึกษาทดสอบสมมติฐานว่า การเคลื่อนไหวของอัตราผลตอบแทนในตลาดหลักทรัพย์ในประเทศต่าง ๆ ทั่วโลกจะได้รับผลกระทบหรือไม่และเป็นจำนวนมากหรือน้อยเพียงใดจากปัจจัยโลก (World Factor) และปัจจัยภูมิภาค (Regional Factor) การศึกษาใช้ตัวแบบจำลอง State-Space Model ร่วมกับเทคนิค Kalman Filter ซึ่งสามารถระบุปัจจัยคู่นี้ได้จากข้อมูลอัตราผลตอบแทนในประเทศต่าง ๆ ซึ่งการศึกษาใช้เป็นตัวอย่าง ข้อมูลที่ใช้เป็นข้อมูลอัตราผลตอบแทนรายวันและรายสัปดาห์ในช่วงเดือนมกราคม 2531 ถึงเดือน ธันวาคม 2547 ของประเทศต่าง ๆ จำนวน 11 ประเทศ ใน 4 ทวีป การทดสอบพบว่า อัตราผลตอบแทนของประเทศในกลุ่มตัวอย่างสามารถอธิบายได้โดยปัจจัยโลกและปัจจัยภูมิภาค ในขณะที่ส่วนที่เหลือเป็นปัจจัยเฉพาะตัวของประเทศนั้น การศึกษาพบต่อไปว่า ปัจจัยโลกมีบทบาทค่อนข้างน้อยในการอธิบายพฤติกรรมการเคลื่อนไหวของอัตราผลตอบแทน ส่วนปัจจัยภูมิภาคและปัจจัยเฉพาะตัวเป็นปัจจัยที่มีความสำคัญมากกว่า นอกจากนั้น การตอบสนองของอัตราผลตอบแทนของแต่ละประเทศยังรวดเร็วกว่าสำหรับปัจจัยภูมิภาค เมื่อเปรียบเทียบกับปัจจัยโลก

ABSTRACT

World and Regional Factors in Stock Market Returns

This paper aims to test the hypothesis that the national stock market returns are driven by a world factor, regional factors and idiosyncratic factors, and to measure the importance of each factor. The state-space model is applied to describe the sample returns and estimate a world factor, regional factors and idiosyncratic factors by Kalman filtering. Weekly and daily returns calculated from MSCI country indexes from January 1988 to December 2004 of 11 national stock markets in four regions, i.e. North America (the USA and Canada), South America (Brazil, Mexico and Chile), Europe (the UK, Germany and France), and Asia (Japan, Hong Kong, and Singapore) are used. The results support the hypothesis that national market returns are driven by a world factor, regional factors and idiosyncratic factors. National markets do not always respond mainly to the world factor; regional factors and idiosyncratic factors play important roles as well. They also respond to world news at a slower rate than regional news.

คำหลัก: Stock Markets, Stock Returns, World Economy, Factor Analysis

ABSTRACT

The Influence of Viral Hepatitis C Infection on Quality of Life

Aim: Chronic liver disease creates a reduction in health-related quality of life (HRQL). Disease severity, demographic, alcohol and comorbidity can affect HRQL. A reducing HRQL in chronic hepatitis C may be associated with comorbid medical illness, response to antiviral treatment, psychogenic disorder and diagnosis awareness. The influence of chronic hepatitis B on HRQL is not known. We aimed to compare HRQL in chronic hepatitis B and C, and to study for factors that affected the HRQL in Thai patients with chronic viral hepatitis.

Materials and methods: Normal subjects, subjects with chronic hepatitis B and C performed HRQL questionnaires: the Short-Form (SF) 36 and the Chronic Liver Disease Questionnaire (CLDQ), and the Hospital Anxiety Depression Scale (HADS) questionnaire. Demographic, socioeconomic and clinical data were collected. One-way ANOVA was used to compare mean differences among groups. Stepwise multiple regression analysis was used to assess the independent influence of variables on HRQL. P-value <0.05 was considered statistically significant.

Results: Up to now, 146 subjects were enrolled. Mean ages (range) were 42.8 (20-73) years. The number (%) of male to female ratio was 85: 61 (58.2%: 41.8%). There were 50, 59 and 37 subjects in normal, in chronic hepatitis B and in chronic hepatitis C groups. The greatest number of anxiety disorder was seen in chronic hepatitis C group. Hepatitis C viral infection impaired emotional function and worry subscales of the CLDQ significantly. Female, single status, low socioeconomic factor, viral load, anxiety and depressive disorders, but not the type of viral hepatitis, caused a reduction in HRQL.

Conclusions: HRQL in chronic viral hepatitis are affected by anxiety, depression, female gender, single status, socioeconomic factors and viral load. We do not have enough evidence to conclude that HBV and HCV infection affect HRQL in Thai patients, or if there is any difference of HRQL in chronic hepatitis B and C.

คำหลัก: Health-related Quality of life, chronic hepatitis B, chronic hepatitis C, SF-36, CLDQ

ผลงานที่ได้จากโครงการ

1. ผลงานตีพิมพ์ในวารสารวิชาการนานาชาติ หนังสือ และสิทธิบัตร

Khanthavit, Anya, Piruna Polsiri, and Yupana Wiwattanakantang, 2003, Did Families Lose or Gain Control?: Thai Firms after the East Asian Financial Crisis, in **Designing Financial Systems in East Asia and Japan: Toward a Twenty-First Century Paradigm**, J. Fan, M. Hanazaki, and J. Teranishi (eds.), Routledge, New York.

Pattarathammas, Suluck and Anya Khanthavit, 2009, **World and Regional Factors in Stock Market Returns,** International Journal of Managerial Finance **5, 222-241.**

Sobhonslidsuk, Abhasnee, Chatchawan Silpakit, Patchareeya Satitpornkul, Chaleaw Sripetch, Anya Khanthavit, 2006, Factors Influencing Health-Related Quality of Life in Chronic Liver Disease, **World Journal of Gastroenterology** 12, 7786-7791.

2. ความก้าวหน้าในการสร้างทีมวิจัย การสำเร็จการศึกษาของนักศึกษาปริญญาเอกและโท

2.1 หัวหน้าโครงการ (ศาสตราจารย์ ดร.อัญญา ขันธวิทย์)

ก. ศาสตราจารย์ในสาขาวิชาการเงินและการธนาคาร ระดับ 11

ข. กีรตยาจารย์แห่งมหาวิทยาลัยธรรมศาสตร์ (Thammasat Distinguished Professor)

ค. ศาสตรเมธาจารย์ *บริษัทหลักทรัพย์จัดการกองทุน เอ็มเอฟซี จำกัด (มหาชน)* (*MFC Asset Management* Professor of Finance and Banking)

2.2 การสำเร็จการศึกษาระดับปริญญาเอก

ก. นายสุลักษมณ์ ภัทธรรมมาศ
จากคณะพาณิชยศาสตร์และการบัญชี มหาวิทยาลัยธรรมศาสตร์

ข. นางสาวปริยดา ศรีโสภิตสวัสดิ์
จากคณะพาณิชยศาสตร์และการบัญชี มหาวิทยาลัยธรรมศาสตร์

ค. นายสรศาสตร์ สุขเจริญสิน
จากคณะพาณิชยศาสตร์และการบัญชี มหาวิทยาลัยธรรมศาสตร์

ง. นายศุภชัย ศรีสุชาติ
จาก University of Hawaii

2.3 การสำเร็จการศึกษาระดับปริญญาโท

ก. นายธีรวุฒิ ศรีพินิจ
จากคณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์

ข. นางสาววรนุช คงธนาคมธัญกิจ
จากคณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์

ค. นายณัฐชัย บุณยประภัศร

จากคณะพาณิชยศาสตร์และการบัญชี มหาวิทยาลัยธรรมศาสตร์

3. การนำผลจากโครงการไปใช้ประโยชน์

3.1 การนำไปใช้อ้างอิงเพื่อการเขียนหนังสือ

ก. ผลงานวิจัยเรื่อง An Information-Theoretic Approach for Identifying Utility Functional Form With An Application in Describing Risk Behavior of Thai Farmers เรื่อง Measuring Risk with Stochastic Junps และเรื่อง World and Regional Factors in Stock Market Returns ได้ถูกอ้างอิงในหนังสือ อัญญา ขันธวิทย์. 2554. **วิศวกรรมการเงินในตลาดการเงินไทย**. สำนักพิมพ์มหาวิทยาลัยธรรมศาสตร์.

ข. ผลงานวิจัยเรื่อง Outside Directors, Audit Committee Structure, and Firm Performance--Evidence from Thailand และเรื่อง Did Families Lose or Gain Control? Thai Firms after the East Asian Financial Crisis ได้ถูกอ้างอิงในหนังสือ อัญญา ขันธวิทย์. ศิลปพร ศรีจั่นเพชร. และ เดือนเพ็ญ จันทร์ศิริศรี. 2552. การกำกับดูแลเพื่อสร้างมูลค่ากิจการ. ตลาดหลักทรัพย์แห่งประเทศไทย. กรุงเทพฯ

3.2 การนำไปใช้เพื่อปรับปรุงประสิทธิภาพและประสิทธิผลการปฏิบัติงาน

ก. ผลงานวิจัยเรื่อง Factors influencing health-related quality of life in chronic liver disease ได้นำไปประยุกต์ใช้ประกอบการรักษาโดยรองศาสตราจารย์ พญ.อาภัสณี โสภณสฤษฎ์สุข คณะแพทย์ศษสตร์ โรงพยาบาลรมาธิบดี ผู้เชี่ยวชาญโรคตับ พร้อมขยายผลไปสู่แพทย์คนอื่นในสาขาเดียวกันหรือสาขาใกล้เคียง

ข. ผลงานวิจัยเรื่อง Maximum Feasible Farm Credits: Cases for Thailand ได้นำไปประยุกต์ใช้ประกอบการออกแบบและพิจารณา Portfolio ของสินเชื่อแก่เกษตรกรของธนาคารเพื่อการเกษตรและสหกรณ์การเกษตร

กิจกรรมอื่นที่เกี่ยวข้อง

1. การได้รับทุนอื่นทั้งจากในและต่างประเทศ

ก. ทุนแห่งความเป็นเลิศทางวิชาการ มหาวิทยาลัยธรรมศาสตร์ แก่ศาสตราจารย์ ดร.อัญญา ขันธวิทย์

ข. ทุนร่วมสนับสนุนการวิจัย แก่งานวิจัยเรื่อง World and Regional Factors in Stock Market Returns แก่ผู้ช่วยศาสตราจารย์ ดร.สุลักษมณ์ ภัทรธรรมมาศ

2. ผลงานที่ได้รับรางวัล

ก. รางวัลชมเชยวิทยานิพนธ์ จากสำนักงานคณะกรรมการ วิจัยแห่งชาติ ประจำปี 2547 แก่นางสาวปริยดา ศรีโสภิตสวัสดิ์

ข. รางวัลชมเชยวิทยานิพนธ์ จากสำนักงานคณะกรรมการ วิจัยแห่งชาติ ประจำปี 2547 แก่นายสรศาสตร์ สุขเจริญสิน

Manuscripts และ Reprints

Knowledge, Experience and Farmers' Seemingly Irrational Behavior

Anya Khanthavit, *Ph.D.* *

Professor of Finance and Banking

Faculty of Commerce and Accountancy

Thammasat University

Chaiyuth Punyasavatsut, *Ph.D.*

Assistant Professor of Economics

Faculty of Economics

Thammasat University

and

Supachai Srisuchart

Lecturer of Economics

Faculty of Economics

Thammasat University

Date: August 2003

---

* Corresponding author. Faculty of Commerce and Accountancy, Thammasat University, Bangkok 10200, Thailand. Phone: (662) 613-2223, Fax: (662) 225-2109, E-mail: akhantha@tu.ac.th. The authors would like to thank Thailand Research Fund for the financial supports.

ABSTRACT

Knowledge, Experience and Farmers' Seemingly Irrational Behavior

This study proposes that rational farmers can concentrate the production on traditional, familiar crops. Farmers are risk averse and Bayesian. They use the predictive densities they develop on their own to form the expectations and make decisions. From their perspectives, familiar crops are less risky. So, the risk-averse farmers concentrate on the less-risky, familiar crops and avoid the more-risky, unfamiliar crops.

The impact of the government's farmers assistance programs are examined. Training seems to be the most efficient because it can improve the prior knowledge and reduce return volatility so that farmers practice more diversification. The mean-enhancement programs must be administered with the volatility-reduction programs to achieve the true optima.

Finally, we demonstrate that forced diversification constraints can be useful even though they are wrong ones. The constraints help to lessen concentration on the familiar crops that results from the improper predictive densities. The findings enable us to understand the success of certain production plans, such as the "New Theory", being introduced to farmers.

บทคัดย่อ

ตัวแบบจำลองเพื่ออธิบายพฤติกรรมซึ่งอาจไม่สมเหตุสมผลของเกษตรกร

การศึกษาเสนอตัวแบบจำลองเพื่ออธิบายพฤติกรรมของเกษตรกรที่ยังคงยึดมั่นการผลิตพืชผลทางการเกษตรเพียงชนิดดั้งเดิม และปฏิเสธการผลิตแบบกระจายออกไปให้ครอบคลุมพืชผลหลายชนิด ซึ่งพฤติกรรมนี้ดูเหมือนจะไม่สมเหตุสมผล การศึกษาอธิบายว่าพฤติกรรมนี้สามารถเป็นพฤติกรรมซึ่งสมเหตุสมผลได้อย่างยิ่ง โดยการใช้ตัวแบบจำลองซึ่งพัฒนาจากทฤษฎีบทของเบย์ กล่าวคือ พืชผลดั้งเดิมที่เกษตรกรผลิตเป็นพืชผลซึ่งเกษตรกรมีความรู้และประสบการณ์ในการผลิตเป็นอย่างดี ในสายตาของเกษตรกร พืชผลเหล่านี้มีความเสี่ยงต่ำมาก เกษตรกรจึงกระจุกตัวการผลิตเฉพาะพืชผลชนิดดั้งเดิมนั้น และปฏิเสธพืชผลชนิดใหม่ซึ่งในสายตาของเกษตรกรเป็นพืชผลที่มีความเสี่ยงสูงกว่า จากนั้นการศึกษาได้ประยุกต์ใช้ตัวแบบจำลองไปตรวจสอบความเหมาะสมของนโยบายและมาตรการการส่งเสริมการเกษตรของภาครัฐ

I. Introduction

Agricultural diversification has now been recognized as an important alternative to improve farm incomes for most countries at farm, regional and national levels. Its success comes from increased land and labor utilization, crop complement, and reduced risk. Despite the proven success of diversification theoretically and empirically, individual farmers tend to specialize in a single crop--their traditional and familiar ones. For Thailand, Siamwalla et al. (1992) reports that only half of Thai farmers grow more than one crop. And, Wang et al. (1975) admits that Taiwanese farmers do not diversify their production very well.

Factors that prohibit individual farmers from diversification have been proposed in the literature. Wang and Yu (1975) summarize that the factors include soil quality, weather, irrigation, production factors, crop choices, technological progress, and culture. Poapongsakorn et al. (1995) add that the availability of non-farm employment, which offers higher and more stable wages, induces farmers to concentrate on less labor-intensive crops such as rice and cassava and that certain commodity prices are positively correlated, hence limiting the benefits of a multiple crop production. Timmer (1998) and the World Bank (1990) point out that government policies may discriminate against the crops with high but volatile prices in favor of the ones with more stable prices, thereby resulting in farmers' concentration in the latter crops. Finally, Petit and Barghouti (1992) summarize that on-farm constraints, extension services, contract farming, and possible assistance or promotion programs can also drive farmers toward concentration.

Today, the influences of these prohibiting factors are lower and less relevant. Crops are engineered to withstand harsh weather and poor soil quality. Irrigation improves. Farmers have increasing opportunities to access credits, technologies, and markets. Yet, concentration on a single, traditional and familiar crop continues. If these factors are not important, does concentration reflect irrational behavior of the farmers?

In this paper, we propose that even if these factors are irrelevant, rational farmers can concentrate on their traditional, familiar crops. As in Ellis (1988), we assume that the farmer is risk-averse and maximize the expected utility of future farm income. Diversification can be interpreted as the case in which the farmer considers to add a new crop to the next period's production. In this setting, the farmer tends to avoid new crops as he does the new technology in Ellis (1988).

In our model, the farmer has two crops--traditional, familiar crop and unfamiliar crop, in the menu. We classify the crops in a natural way, where the traditional, familiar crop is the one the farmer knows very well and has long experience in growing it. The unfamiliar crop is the one new to him. So, he knows little about it and has never grown it. We examine the farmer's production decision in a Bayesian framework. The risk behavior of crop returns is described by their joint distribution. The farmer knows only the form of the distribution, but he does not know the governing parameters. So, he must choose the optimal production of the crops, using the Bayesian predictive distribution. This distribution is not the true distribution. It is derived from the form of the true distribution, the prior knowledge the farmer has about the return on familiar and unfamiliar crops, and the realized returns the farmer has the experience in these crops over the years.

It is this resulting predictive return distribution that drives concentration on the traditional, familiar crop. In our model, the unfamiliar crop is risky because the farmer has limited knowledge and experience about it. So, it is avoided and concentration becomes rational.

The finding is important because it helps us to understand the farmers' seemingly irrational behavior better. The model being proposed can also be used as a framework to understand the roles of the government's farmers assistance programs that drive the production toward its optima. Finally, we apply the model to examine how a force diversification measure, such as the "New Theory" of His Majesty the King of Thailand, can be useful.

II. The Model

In our model, it is assumed, as are suggested by the literature (e.g., Young (1979)), that the farmer maximizes his expected utility of uncertain future income from crop production. There are $N > 1$ interesting crops. It is assumed that crops 1 to n are traditional and familiar to the farmer. He and his ancestor have been growing these crops for years. The remaining $N-n$ crops from crops $n+1$ to N are new and unfamiliar.

The farmer has limited knowledge about and little experiences in growing them. Yet, he considers these crops for possible production diversification, and income and utility improvements.

Let $\tilde{\mathbf{Y}}_{T+1} = \begin{bmatrix} \tilde{\mathbf{Y}}^1_{T+1} \\ \tilde{\mathbf{Y}}^2_{T+1} \end{bmatrix}$, an (N×1) vector, denote the uncertain future returns from the familiar crops $\tilde{\mathbf{Y}}^1_{T+1}$ and unfamiliar crops $\tilde{\mathbf{Y}}^2_{T+1}$ per one unit of land. The farmer's expected utility maximization problem is

$$\underset{\mathbf{w}}{Max} \quad E_i \left\{ \mathrm{U_i} \left(\mathbf{w}' \tilde{\mathbf{Y}}_{T+1} \right) \right\} \tag{1.1}$$

subject to

$$\mathbf{w}' \boldsymbol{\iota} \quad = \quad 1.00. \tag{1.2}$$

$\mathbf{w}$ --an (N×1) vector, is the percentage weights of the farmer's land being allocated to the crops. $\boldsymbol{\iota}$ is an (N×1) vector of ones. $\mathrm{U_i}\left(\mathbf{w}' \tilde{\mathbf{Y}}_{T+1} \right)$ is the farmer's utility of the next period's income. Equation (1.2) imposes the constraint on full utilization of the land.[1]

We assume that the true distribution of $\tilde{\mathbf{Y}}_{T+1}$ is mutivariate normal, with a mean vector $\boldsymbol{\mu} = \begin{bmatrix} \boldsymbol{\mu}_1 \\ \boldsymbol{\mu}_2 \end{bmatrix}$ and a covariance matrix $\mathrm{V} = \begin{bmatrix} \mathrm{V}_{11} & 0 \\ 0' & \mathrm{V}_{22} \end{bmatrix}$. In reality, crop income can be correlated. Yet, we assume uncorrelated income on the familiar and unfamiliar crops for tractability. This assumption will not affect our result very much because we are interested in the farmer's production concentration on the familiar crops. If the income is correlated, the farmer's realized production choice will be less diversified.

We assume that the farmer knows only the form of the distribution. But he does not know the governing parameters $\{\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, \mathrm{V}_{11}, \mathrm{V}_{22}\}$. Hence, the expectation in equation (1.1) must be formed under the subjective belief about $\tilde{\mathbf{Y}}_{T+1}$.

---

[1] Each crop may require different levels of investment money per unit of land. In that more realistic case, we can assume that the farmer has sufficient fund to grow the most costly crop. The unused money from the decision to grow less costly crops can be put in the bank and earn interest income for the season.

II.1 A Bayesian Model of the Crop Income

The farmer forms his belief of $\tilde{\mathbf{Y}}_{T+1}$ in a Bayesian framework. In this framework, familiarity and unfamiliarity of the crops can be modeled quite naturally. To form the expectations, the farmer applies his prior knowledge about the crops with his experiences from growing these crops for some time to predict how the crop return will behave in the next period. Then he makes the production decision $\mathbf{w}$ to maximize the expected utility.

II.2 Description of the Familiar and Unfamiliar Crops

We describe familiar and unfamiliar crops by the extent of the knowledge and the experiences the farmer possesses about the crops. The familiar crop is the one crop that the farmer knows about its nature very well and he has the experiences from growing its for a quite few seasons. The less familiar crop is the one crop that the farmer knows less well. He has never grown this crop before. So, he has no experiences.

II.2.1 Knowledge as the Prior Belief

Case 1 A Diffuse Prior

Firstly, we assume that the farmer has no knowledge about either familiar or unfamiliar crop. Although this assumption is not very realistic, it serves as the foundation to separate the effects of the prior knowledge and the experience on diversification. When the farmer knows nothing about the governing parameters, the prior density becomes vague or diffuse. The invariance theory of Jeffreys dictates that it is proportional to

$$p\left(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\right) \quad \propto \quad \left|V_{11}^{-1}\right|^{-\left(\frac{N+1}{2}\right)} \left|V_{22}^{-1}\right|^{-\left(\frac{N+1}{2}\right)} \qquad (2)$$

Case 2 An Informative Prior

Secondly, however, at the least the farmer has to know some things about the interesting crops. This knowledge can come from his previous study, training and observation, weather reports, technology updates, market price and trend, etc. Although he is uncertain about the exact parameter values $\{\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\}$, he uses the knowledge to form their prior. We assume the parameters $\boldsymbol{\mu}_1$, $\boldsymbol{\mu}_2$, V_{11} and V_{22} are independent. Furthermore, we assume ($\boldsymbol{\mu}_1, \boldsymbol{\mu}_2$) are distributed normally with means ($\boldsymbol{\mu}_1^*$, $\boldsymbol{\mu}_2^*$) and co-variances ($\sigma^2 \mathrm{I}_n$, $\mathrm{k}\,\sigma^2 \mathrm{I}_{N-n}$), where I_m is the identity matrix of size m = n and N-n. $\mathrm{k} \geq 1$ and σ^2 > 0 are constant. Under this structure, because the farmer has little knowledge and information about the unfamiliar crop, he is less certain about the mean of $\boldsymbol{\mu}_2$ than of $\boldsymbol{\mu}_1$. The uncertainty grows with the proportionality factor $\mathrm{k} \geq 1$. We assume vague priors for V_{11} and V_{22}. In all, the prior for the parameters is

$$p\left(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, \mathrm{V}_{11}, \mathrm{V}_{22}\right) \quad \propto \quad \left|\mathrm{V}_{11}^{-1}\right|^{-\left(\frac{N+1}{2}\right)} exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)'\left(\sigma^2 \mathrm{I}_n\right)^{-1}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)\right\}$$

$$\times \left|\mathrm{V}_{22}^{-1}\right|^{-\left(\frac{N+1}{2}\right)} exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)'\left(\mathrm{k}\sigma^2 \mathrm{I}_{N-n}\right)^{-1}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)\right\} \qquad (3)$$

II.2.2 The Experiences as the Likelihood

The farmer can have experiences from growing the crops and actually earn from them during the past years. These experiences help the farmer to understand the nature of these crops better. Let $\mathbf{Y}_T^1$ and $\mathbf{Y}_S^2$ be the (T×n) and (S×(N-n)) vectors of the realized income from the familiar and unfamiliar crops over the past T and S seasons, respectively. The condition T > S indicates the fact the farmer has more experiences in growing the familiar crops than the unfamiliar crops. We impose S > n+2 so that the likelihood of $\mathbf{Y}_S^2$ exists and the predictive density is meaningful in the limit. The likelihood for $\mathbf{Y}_T^1$ and $\mathbf{Y}_S^2$ is

$$\ell\left(\mathbf{Y}_T^1, \mathbf{Y}_T^2 \mid \boldsymbol{\mu}_1, \boldsymbol{\mu}_2, \mathrm{V}_{11}, \mathrm{V}_{22}\right) \propto \left|\mathrm{V}_{11}^{-1}\right|^{\frac{T}{2}} exp\left\{-\frac{1}{2} tr\left(\mathbf{Y}_T^1 - \boldsymbol{\iota}_T\boldsymbol{\mu}_1'\right)'\left(\mathbf{Y}_T^1 - \boldsymbol{\iota}_T\boldsymbol{\mu}_1'\right)\mathbf{V}_{11}^{-1}\right\}$$

$$\times \left|\mathrm{V}_{22}^{-1}\right|^{\frac{S}{2}} exp\left\{-\frac{1}{2} tr\left(\mathbf{Y}_S^2 - \boldsymbol{\iota}_S\boldsymbol{\mu}_2'\right)'\left(\mathbf{Y}_S^2 - \boldsymbol{\iota}_S\boldsymbol{\mu}_2'\right)\mathbf{V}_{22}^{-1}\right\} \qquad (4)$$

II.2.3 The Predictive Distribution

Having the prior and the likelihood as well as the assumption on the distribution of $\tilde{\mathbf{Y}}_{T+1}$, we can write the joint distribution of the unknown parameters $\left\{\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, \mathrm{V}_{11}, \mathrm{V}_{22}\right\}$ and the future income $\tilde{\mathbf{Y}}_{T+1}$.

Case 1 A Diffuse Prior

When the prior is diffuse, the joint density becomes

$$p\left(\tilde{\mathbf{Y}}_{T+1} \mid \boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\right) p\left(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)$$

$$= \quad p\left(\tilde{\mathbf{Y}}_{T+1}\ \boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right) \tag{5.1}$$

$$\propto \quad \left|V_{11}^{-1}\right|^{\frac{T-(N+1)}{2}} exp\left\{-\frac{1}{2} tr\ A_1\ V_{11}^{-1}\right\} \times \left|V_{22}^{-1}\right|^{\frac{S-(N+1)}{2}} exp\left\{-\frac{1}{2} tr\ A_2\ V_{22}^{-1}\right\} \tag{5.2}$$

where

$$A_1 = \left(\mathbf{Y}_T^1 - \boldsymbol{\iota}_T \boldsymbol{\mu}_1^{'}\right)'\left(\mathbf{Y}_T^1 - \boldsymbol{\iota}_T \boldsymbol{\mu}_1^{'}\right) + \left(\tilde{\mathbf{Y}}_T^1 - \boldsymbol{\mu}_1^{'}\right)'\left(\tilde{\mathbf{Y}}_T^1 - \boldsymbol{\mu}_1^{'}\right)$$

$$A_2 = \left(\mathbf{Y}_S^2 - \boldsymbol{\iota}_S \boldsymbol{\mu}_1^{'}\right)'\left(\mathbf{Y}_S^2 - \boldsymbol{\iota}_S \boldsymbol{\mu}_2^{'}\right) + \left(\tilde{\mathbf{Y}}_S^2 - \boldsymbol{\mu}_2^{'}\right)'\left(\tilde{\mathbf{Y}}_S^2 - \boldsymbol{\mu}_2^{'}\right).$$

In making his decision, the farmer is interested in the behavior of the next period's income $\tilde{\mathbf{Y}}_{T+1}$. Because he does not know the true parameters $\{\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\}$, he has to rely on his prior knowledge and experiences. From equation (5.2), the behavior $p\left(\tilde{\mathbf{Y}}_{T+1} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)$ conditioned on the prior knowledge and experience can be obtained by integrating $\{\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\}$ out of $p\left(\tilde{\mathbf{Y}}_{T+1}\ \boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)$. Following Zellner (1971, p. 233-236), we integrate out $(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22})$ to obtain the predictive density as in equation (6).[2]

---

[2] Equation (2) is a form of the multivariate Student's *t* distribution. To show, note that

$$p\left(\tilde{\mathbf{Y}}_{T+1} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right) \propto \left|H_1 + \frac{T}{T+1}\left(\mathbf{Y}_{T+1}^1 - \hat{\boldsymbol{\mu}}_1{}'\right)'\left(\mathbf{Y}_{T+1}^1 - \hat{\boldsymbol{\mu}}_1{}'\right)\right|^{-\left(\frac{T-(N-n)-2}{2}\right)}$$

$$\times \left|H_2 + \frac{S}{S+1}\left(\mathbf{Y}_{T+1}^2 - \hat{\boldsymbol{\mu}}_2{}'\right)'\left(\mathbf{Y}_{T+1}^2 - \hat{\boldsymbol{\mu}}_2{}'\right)\right|^{-\left(\frac{S-n-2}{2}\right)}$$

$$= \left\{1 + \frac{T}{T+1}\left(\mathbf{Y}_{T+1}^1 - \hat{\boldsymbol{\mu}}_1{}'\right) H_1^{-1}\left(\mathbf{Y}_{T+1}^1 - \hat{\boldsymbol{\mu}}_1{}'\right)'\right\}^{-\left(\frac{T-(N-n)-2}{2}\right)}$$

$$p\left(\tilde{\mathbf{Y}}_{T+1} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)$$

$$\propto \left| \mathbf{Y}_T^1{}'\mathbf{Y}_T^1 + \tilde{\mathbf{Y}}^1_{T+1}{}'\tilde{\mathbf{Y}}^1_{T+1} - (T+1)\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)' \right|^{-\left(\frac{T-(N-n)-2}{2}\right)}$$

$$\times \left| \mathbf{Y}_S^2{}'\mathbf{Y}_S^2 + \tilde{\mathbf{Y}}^2_{S+1}{}'\tilde{\mathbf{Y}}^2_{S+1} - (S+1)\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)' \right|^{-\left(\frac{S-n-2}{2}\right)} \qquad (6)$$

Case 2 An Informative Prior

If the prior is informative, the information about $(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2)$ must enter into the prediction equation. The joint density becomes

$$p\left(\tilde{\mathbf{Y}}_{T+1} \mid \boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\right) p\left(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)$$

$$= \quad p\left(\tilde{\mathbf{Y}}_{T+1}\ \boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right) \qquad (7.1)$$

$$\propto \left|V_{11}^{-1}\right|^{\frac{T-(N+1)}{2}} exp\left\{-\frac{1}{2} tr\ A_1 V_{11}^{-1}\right\} exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)'\left(\sigma^2 I_n\right)^{-1}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)\right\}$$

$$\times \left|V_{22}^{-1}\right|^{\frac{S-(N+1)}{2}} exp\left\{-\frac{1}{2} tr\ A_2 V_{22}^{-1}\right\} exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)'\left(k\sigma^2 I_{N-n}\right)^{-1}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)\right\} \quad (7.2)$$

We integrate out $\left(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2, V_{11}, V_{22}\right)$ to obtain the predictive density. We perform this procedure in two steps. In the first step, we Follow Zellner (1971, p. 240) to integrate out V_{11} and V_{22} to obtain

---

$$\times \left\{1 + \frac{S}{S+1}\left(\mathbf{Y}_{T+1}^2 - \hat{\boldsymbol{\mu}}_2{}'\right)' H_2^{-1}\left(\mathbf{Y}_{T+1}^2 - \hat{\boldsymbol{\mu}}_2{}'\right)'\right\}^{-\left(\frac{S-n-2}{2}\right)}$$

where $H_1 = \left(\mathbf{Y}_T^1 - \boldsymbol{\iota}_T\hat{\boldsymbol{\mu}}_1{}'\right)'\left(\mathbf{Y}_T^1 - \boldsymbol{\iota}_T\hat{\boldsymbol{\mu}}_1{}'\right)$ and $H_2 = \left(\mathbf{Y}_S^2 - \boldsymbol{\iota}_S\hat{\boldsymbol{\mu}}_2{}'\right)'\left(\mathbf{Y}_S^2 - \boldsymbol{\iota}_S\hat{\boldsymbol{\mu}}_2{}'\right)$. In addition, $\hat{\boldsymbol{\mu}}_1 = \frac{1}{T}\boldsymbol{\iota}_T{}'\mathbf{Y}_T^1$ and $\hat{\boldsymbol{\mu}}_2 = \frac{1}{S}\boldsymbol{\iota}_S{}'\mathbf{Y}_S^2$. The second equation follows the first as in Zellner (1971, p. 236, footnote 23). It is clear that the second equation is the kernal of a multivariate Student's *t* distribution for independent $\tilde{\mathbf{Y}}^1_{T+1}$ and $\tilde{\mathbf{Y}}^2_{T+1}$ with T-N and S-N degrees of freedom, respectively.

$$p\left(\tilde{\mathbf{Y}}_{T+1}, \boldsymbol{\mu}_1, \boldsymbol{\mu}_2 \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right) \quad \propto$$

$$\left|\mathbf{Y}_T^1{}'\mathbf{Y}_T^1 + \tilde{\mathbf{Y}}^1_{T+1}{}'\tilde{\mathbf{Y}}^1_{T+1} - (T+1)\left(\tilde{\boldsymbol{\mu}}_1 \tilde{\boldsymbol{\mu}}_1'\right) + (T+1)\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)'\right|^{-\frac{T-(N-n)}{2}}$$

$$\times \; exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)'\left(\sigma^2 I_n\right)^{-1}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)\right\}$$

$$\times \; \left|\mathbf{Y}_S^2{}'\mathbf{Y}_S^2 + \tilde{\mathbf{Y}}^2_{S+1}{}'\tilde{\mathbf{Y}}^2_{S+1} - (S+1)\left(\tilde{\boldsymbol{\mu}}_2 \tilde{\boldsymbol{\mu}}_2'\right) + (S+1)\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)'\right|^{-\frac{S-n}{2}}$$

$$\times \; exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)'\left(k\sigma^2 I_{N-n}\right)^{-1}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)\right\}, \qquad (8.1)$$

where $\tilde{\boldsymbol{\mu}}_1' = \frac{1}{T+1}\left(\boldsymbol{\iota}_T{}'\mathbf{Y}_T^1 + \tilde{\mathbf{Y}}^1_{T+1}\right)$ and $\tilde{\boldsymbol{\mu}}_2' = \frac{1}{S+1}\left(\boldsymbol{\iota}_S{}'\mathbf{Y}_S^2 + \tilde{\mathbf{Y}}^2_{S+1}\right)$. Next define matrices Ω_1 and Ω_2 by

$$\Omega_1 = \mathbf{Y}_T^1{}'\mathbf{Y}_T^1 + \tilde{\mathbf{Y}}^1_{T+1}{}'\tilde{\mathbf{Y}}^1_{T+1} - (T+1)\left(\tilde{\boldsymbol{\mu}}_1 \tilde{\boldsymbol{\mu}}_1'\right) \qquad (8.2)$$

$$\Omega_2 = \mathbf{Y}_S^2{}'\mathbf{Y}_S^2 + \tilde{\mathbf{Y}}^2_{S+1}{}'\tilde{\mathbf{Y}}^2_{S+1} - (S+1)\left(\tilde{\boldsymbol{\mu}}_2 \tilde{\boldsymbol{\mu}}_2'\right) \qquad (8.3)$$

From Zellner (1971, p. 240), it can be shown the density $p\left(\tilde{\mathbf{Y}}_{T+1}, \boldsymbol{\mu}_1, \boldsymbol{\mu}_2 \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)$ is approximately proportional to

$$p\left(\tilde{\mathbf{Y}}_{T+1}, \boldsymbol{\mu}_1, \boldsymbol{\mu}_2 \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right) \quad \propto \bullet$$

$$exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)'\left(\frac{\Omega_1}{(T+1)(T-(N-n)-2)}\right)^{-1}\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)\right\}$$

$$\times \; exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)'\left(\sigma^2 I_n\right)^{-1}\left(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_1^*\right)\right\}$$

$$\times \; exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)'\left(\frac{\Omega_2}{(S+1)(S-n-2)}\right)^{-1}\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)\right\}$$

$$\times \; exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)'\left(k\sigma^2 I_{N-n}\right)^{-1}\left(\boldsymbol{\mu}_2 - \boldsymbol{\mu}_2^*\right)\right\} \qquad (9.1)$$

$$= exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_1 - \mathbf{U}_1\right)'F_1\left(\boldsymbol{\mu}_1 - \mathbf{U}_1\right)\right\} \; exp\left\{-\frac{1}{2}\left(\boldsymbol{\mu}_2 - \mathbf{U}_2\right)'F_2\left(\boldsymbol{\mu}_2 - \mathbf{U}_2\right)\right\}, \qquad (9.2)$$

where

$$F_1 = \left\{ \left(\sigma^2 I_n\right)^{-1} + \left(\frac{\Omega_1}{(T+1)(T-(N-n)-2)} \right)^{-1} \right\},$$

$$F_2 = \left\{ \left(k\sigma^2 I_{(N-n)}\right)^{-1} + \left(\frac{\Omega_2}{(S+1)(S-N-2)} \right)^{-1} \right\},$$

$$\mathbf{U}_1 = \left\{ \left(\sigma^2 I_n\right)^{-1} + \left(\frac{\Omega_1}{(T+1)(T-(N-n)-2)} \right)^{-1} \right\}^{-1} \left\{ \left(\sigma^2 I_n\right)^{-1} \boldsymbol{\mu}_1^* + \left(\frac{\Omega_1}{(T+1)(T-(N-n)-2)} \right)^{-1} \tilde{\boldsymbol{\mu}}_1 \right\}$$

$$\mathbf{U}_2 = \left\{ \left(k\sigma^2 I_{(N-n)}\right)^{-1} + \left(\frac{\Omega_2}{(S+1)(S-n-2)} \right)^{-1} \right\}^{-1} \left\{ \left(k\sigma^2 I_{(N-n)}\right)^{-1} \boldsymbol{\mu}_2^* + \left(\frac{\Omega_2}{(S+1)(S-n-2)} \right)^{-1} \tilde{\boldsymbol{\mu}}_2 \right\}.$$

The approximation helps so much to simplify the integration of $\boldsymbol{\mu}_1$ and $\boldsymbol{\mu}_2$ from the density $p\left(\tilde{\mathbf{Y}}_{\mathbf{T+1}}, \boldsymbol{\mu}_1, \boldsymbol{\mu}_2 \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2 \right)$. In the second step, we notice that equation (9.2) is the kernal of a multivariate normal density. Hence, direct integration of $\boldsymbol{\mu}_1$ and $\boldsymbol{\mu}_2$ in equation (9.2) gives the predictive density

$$p\left(\tilde{\mathbf{Y}}_{\mathbf{T+1}} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2 \right) \quad \propto \bullet \quad \left| F_1 \right|^{-\frac{1}{2}} \left| F_2 \right|^{-\frac{1}{2}}. \tag{10.1}$$

Although the approximation enables us to obtain an analytical solution for the predictive density as in equation (10.1), it introduces at least two approximation errors. One, it is interesting to note that the means ($\boldsymbol{\mu}_1^*$, $\boldsymbol{\mu}_2^*$) of the prior belief do not enter into the predictive density (10.1). So, it does not matter at all as to how high the farmer believes the mean returns are. Only the volatilities σ^2 and $k\sigma^2$ affect the farmer's expectations.

Two, it should be noted that in the limiting case, in which $\sigma^2 \to \infty$ and the prior becomes diffuse, the predictive density under an informative prior must converge to the one under the diffuse prior. A careful examination suggests that this is not the case. The predictive density in equation (10.1) converges to

$$p\left(\tilde{\mathbf{Y}}_{T+1} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right) \propto \bullet \left|\mathbf{Y}_T^{1\,\prime}\mathbf{Y}_T^1 + \tilde{\mathbf{Y}}_{T+1}^{1\,\prime}\tilde{\mathbf{Y}}_{T+1}^{1} - (T+1)\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)\left(\boldsymbol{\mu}_1 - \tilde{\boldsymbol{\mu}}_1\right)'\right|^{\frac{1}{2}}$$

$$\times \left|\mathbf{Y}_S^{2\,\prime}\mathbf{Y}_S^2 + \tilde{\mathbf{Y}}_{S+1}^{2\,\prime}\tilde{\mathbf{Y}}_{S+1}^{2} - (S+1)\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)\left(\boldsymbol{\mu}_2 - \tilde{\boldsymbol{\mu}}_2\right)'\right|^{\frac{1}{2}}, \qquad (10.2)$$

not the correct one in equation (6). It is not clear how large these approximation errors are.

The farmer will apply the predictive densities in equations (6) and (10.1), depending on the assumption on the prior belief, to form the expectation and decide how he will allocate his land for the production of familiar and unfamiliar crops. The farmer's land allocation problem becomes

$$\underset{\mathbf{w}}{Max} \quad E_i\left\{U_i\left(\mathbf{w}'\tilde{\mathbf{Y}}_{T+1}\right)\right\} = \int \frac{U_i\left(\mathbf{w}'\tilde{\mathbf{Y}}_{T+1}\right)p\left(\tilde{\mathbf{Y}}_{T+1} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)}{\int p\left(\tilde{\mathbf{Y}}_{T+1} \mid \mathbf{Y}_T^1, \mathbf{Y}_S^2\right)d\mathbf{Y}_{T+1}}\, d\mathbf{Y}_{T+1} \qquad (11.1)$$

subject to

$$\mathbf{w}'\boldsymbol{\iota} = 1.00. \qquad (11.2)$$

We will use the solution to the farmer's problem (11) to demonstrate that production concentration in the familiar crop is the farmer's optimum choice, therefore explaining the seemingly irrational behavior.

III. Empirical Investigation

III.1 The Farmer, His Knowledge and Experience, and Crop Returns

We empirically investigate the farmer's behavior under problem (11). We assume the farmer is risk-averse and has a power utility.

$$U_i(W) = \frac{W^\gamma}{\gamma}, \qquad (9)$$

where W is the final wealth and 1-γ > 0 is the coefficient of relative risk aversion. We assume this utility because of two reasons. Firstly, to obtain the solution for a representative farmer, all the optimum solutions will have to be averaged across farmers in the group. Power utility ensures that the solution $\mathbf{w}$ will not vary with wealth (Elton and Gruber (1995, p. 218)). Hence, we can consider the average $\mathbf{w}$ to be the solution of the farmers in the group. Secondly, the literature suggests that the power utility can describe the farmers' behavior quite well. For example, Khanthavit et al. (2002) reports that most of Thai farmers has log utility, which is a limiting case of the power utility when $\gamma \rightarrow 0$.

The farmer considers two crops for production in the next period. The first crop is familiar and the second crop is unfamiliar. The returns on these two crops are distributed bivariate normally with a mean vector $\boldsymbol{\mu} = \begin{bmatrix} 0.05 \\ 0.05 \end{bmatrix}$ and a covariance matrix $\mathrm{V} = \begin{bmatrix} 0.15^2 & 0 \\ 0 & 0.15^2 \end{bmatrix}$. The return structure approximates the maize and soybean matched-pair samples for Thailand's north-eastern provinces during 1999 to 2003. See the appendix. If the farmer knows this structure and the parameter values, it is easy to show that the optimal allocation is 50%.

We examine the farmer's behavior under both the diffuse and the informative prior assumptions. The information in the preceding paragraph is sufficient to construct a model under the diffuse prior. For an information-prior specification, the farmer believes the mean parameter $\boldsymbol{\mu}$ is distributed normally with a mean vector $\begin{bmatrix} 0.05 \\ 0.05 \end{bmatrix}$ and a co-variance matrix $\begin{bmatrix} \frac{0.15^2}{35} & 0 \\ 0 & \mathrm{k}\frac{0.15^2}{35} \end{bmatrix}$. The prior for V is diffuse. Because there are two interesting crops, we set S = 4 and T $\geq$ S.

We consider the cases in which γ = -1.00, -0.50, 0.00, +0.50 and +0.99. The log- utility farmer has γ = 0.00. γ = -1.00 and -0.50 represents a more risk-averse farmer and γ = 0.50 and 0.99 does a less risk-averse farmer. We consider different degrees of prior knowledge for $\sqrt{\mathbf{k}}$ = 1, 10, 20, ..., 50 and years of experience for T = 4, 20, 40, 60.

Although the farmers have the same risk aversion (γ), knowledge (k) and experiences (T, S), their allocation $\mathbf{w}$ can differ depending on the individual's experience of realized $\mathbf{Y}_{T}^{1}$ and $\mathbf{Y}_{S}^{2}$. In order to determine the allocation $\mathbf{w}$ for the average farmer in a group, we consider the average allocation $\mathbf{w}$ of 1,000 farmers in that group. $\mathbf{Y}_{T}^{1}$ and $\mathbf{Y}_{S}^{2}$--being drawn randomly from the true distribution, identify the individual farmers. For each farmer i, we evaluate the expected utility and identify his optimum allocation, using Kloek and van Dijk's (1978) numerical integration with 5,000 simulations.

III.2 Empirical Results

The simulation results are summarized in Table 1. Turn first to Panel 1.1 for the log-utility farmer. For the diffuse-prior case, when the farmer has more years of experience in growing the familiar crop, he tend to allocate more of the production to that crop. A farmer with 60 years of experience allocates about 80 percent of his land to grow the familiar crop, as opposed to about 50 percent when he has four years of experience as he does for the unfamiliar crop.

TABLE 1

The Optimal Land Allocation Decision of an Average Farmer

The table reports the optimal land allocation of an average farmer in familiar crops. For the diffuse prior, the expected utility is evaluated, assuming the farmer has no prior knowledge about the familiar and unfamiliar crops. For the informative prior, the expected utility is evaluated, assuming the farmer has some information about the expected returns. The information about the expected return on the unfamiliar crop falls with the factor k. As k goes to infinity, the prior about the unfamiliar crop becomes vague. Five thousand simulations are conducted for each farmer and the results are the average allocation of 1,000 farmers.

Panel 1.1

A Log-Utility Farmer

Experience (T)	Diffuse Prior	Informative Prior $\left(\sqrt{k}\right)$					
		1	10	20	30	40	50
4	50.90	52.02	56.30	57.91	59.01	57.54	59.21
20	79.56	48.89	55.88	58.60	57.80	57.20	57.36
40	81.63	49.28	54.52	57.48	58.94	58.86	59.10
60	82.38	49.82	56.66	57.99	59.74	57.92	58.42

Panel 1.2

A Power-Utility Farmer whose γ = -1.00

Experience (T)	Diffuse Prior	Informative Prior $\left(\sqrt{k}\right)$					
		1	10	20	30	40	50
4	50.41	50.86	56.26	56.98	58.73	57.35	58.19
20	84.25	49.54	54.41	58.43	57.30	58.39	57.91
40	85.63	50.99	55.71	56.66	55.52	57.81	58.07
60	85.53	50.19	54.15	57.19	59.01	57.96	58.27

Panel 1.3

A Power-Utility Farmer whose γ = -0.50

Experience (T)	Diffuse Prior	Informative Prior $\left(\sqrt{k}\right)$					
		1	10	20	30	40	50
4	49.25	50.32	54.91	58.22	58.91	57.81	60.13
20	81.95	49.62	55.92	56.32	56.58	57.38	57.35
40	84.12	49.43	55.85	56.79	55.66	58.03	57.91
60	84.64	48.75	53.23	56.99	58.85	58.22	57.26

Panel 1.4

A Power-Utility Farmer whose γ = 0.50

Experience (T)	Diffuse Prior	Informative Prior $\left(\sqrt{k}\right)$					
		1	10	20	30	40	50
4	50.45	49.25	52.28	56.79	57.56	58.63	58.50
20	75.10	49.56	53.57	55.91	58.49	58.95	57.37
40	71.78	48.64	55.53	55.07	56.81	56.27	56.22
60	74.25	47.15	54.77	51.90	57.91	56.44	58.09

Panel 1.5

A Power-Utility Farmer whose γ = 0.99

Experience (T)	Diffuse Prior	Informative Prior $\left(\sqrt{k}\right)$					
		1	10	20	30	40	50
4	51.36	50.21	52.48	56.10	57.80	54.33	57.27
20	60.43	45.64	55.25	54.53	52.36	53.47	54.24
40	60.92	47.39	52.07	55.79	55.00	56.39	54.77
60	64.56	52.96	52.80	54.70	56.75	56.16	56.01

We describe the familiar crop by the more experience and knowledge the farmer has for that crop. The relative knowledge about the familiar crop *vis-a-vis* the unfamiliar crop grow with factor k. We find that for $\sqrt{\mathbf{k}}$ = 50, when the farmer knows little about the unfamiliar crop, the farmer chooses to grow the familiar crop about 60% and does the unfamiliar crop about 40%. The proportion gradually reduces to 50%--the optimal value, as the farmer knows the unfamiliar crop better and $\sqrt{\mathbf{k}}$ falls to 1.

As we pointed out earlier, the predictive density under the informative prior is approximate. It can induce approximation errors. Even though it offers the insightful results that the farmer is less averse to the unfamiliar crop with a better knowledge as our intuition suggests, the proportion is not very sensitive with the years of experience (T). So, we limit the use of the informative-prior predictive density to the examination of the improved prior knowledge.

Panels 1.2 and 1.3 report the allocation results for more risk-averse farmers, while panels 1.4 and 1.5 does for the less risk-averse farmers. In each panel, the results are qualitatively similar to those in Panel 1.1. As the farmer has more years of experience in the familiar crop, he tends to concentrate on that crop. He grows more of the unfamiliar crop, when he has more prior knowledge about it.

It is important to note that, for a given experience (T) and a prior knowledge (k), a more risk-averse farmer (with a smaller γ) concentrate even more on the familiar crop. For example, with a 60-year experience and a diffuse prior, a farmer with a -1.00 γ will have an 85% allocation in the familiar crop, as opposed to a 65% allocation of a farmer with a 0.99 γ.

The different levels of production allocation can be explained as follows. From the farmer's perspective, the familiar crop is less risky than the unfamiliar crop because the farmer knows more about it from the prior belief and the previous experience. So, the risk-averse farmer concentrates on the more-familiar, less-risky crop. Concentration becomes more intense for a more risk-averse farmer. For that farmer, the concentration can be higher than 85%.

This finding is very important. It helps to explain the seemingly irrational behavior of the farmers being observed in reality. If the farmers know the true behavior of crop returns, then a 50-50 diversification is optimal. The observed concentration in reality and here is irrational. However, it is difficult for the farmer to know the truth. The expectations must always be formed from the prior knowledge and experience. After all, the seemingly irrational behavior is perfectly rational in this framework.

IV. Policy Implications

IV.1 Design of the Government's Farmers Assistance Programs

The methodology developed in this study can be applied in the design of farmer assistance programs to improve the quality of life of the farmers. From the exercise, we find that it is rational for the farmers to concentrate his production in the familiar crop. Although it is rational, this decision is unhealthy. A successful assistance program should be able to shape the behavior toward the best allocation choice. Over the years, the principal programs being implemented are training programs, subsidies, insurance and guarantees.

Training programs can be in many areas. The introduction of new crops enables the farmers to raise the knowledge and understanding of the unfamiliar crop. It therefore leads to a falling k factor. As k falls, the results in Table 1 suggest that the farmer will grow the unfamiliar crop more and diversification improves. The training programs on how the unfamiliar crop can be marketed reduce the price volatility and those on how it is cultivated properly reduce the output volatility. Together, these training programs lower the return volatility σ_2^2. It seems training programs are the most effective measures because they can raise the prior knowledge and lessen the return volatility at the same time.

Certain assistance programs can lower the return volatility σ_2^2 directly. For example, a minimum-price guarantee scheme limits the lowest possible selling price at the guaranteed price so that the price is less fluctuating. A weather insurance scheme compensates the farmer for the loss of outputs due to catastrophic weather such as flood, drought or wild fire.

Other assistance programs raise the mean return. These programs include soft loans, low priced fertilizer and insecticide, or even direct subsidies. These programs reduce the effective costs of production. Because the costs are known today, the programs cannot the return volatility.

Successful assistance must raise the quality of life of the farmers. In the meantime, it must shape the decision toward the best allocation choice--50% in this exercise. We use a model with a diffuse prior to investigate the impacts of these assistance programs. We vary the distribution of $\mathbf{Y}_S^2$ with respect to that of $\mathbf{Y}_T^1$ to reflect the impacts of the programs on the mean and variance. We set $\mu_2 = \mu_1$ (1+m) to describe the mean-enhancement programs and set $\sigma_2^2 = \left(\frac{\sigma_1}{v}\right)^2$ to describe the volatility-reduction programs. Our farmer in this experiment has a log utility and a vague prior. The experience in the unfamiliar crop is set to its minimum level of 4 years. The results are reported in Table 2.

TABLE 2

Impacts of Farmers Assistance Programs

The table reports the optimal land allocation with respect to the government's farmers assistance programs. The return-enhancement programs raise the mean return of the unfamiliar crops to $\mu_2 = \mu_1$ (1+m), while the volatility-reduction programs lower the return volatility of the unfamiliar crop to $\sigma_2^2 = \left(\frac{\sigma_1}{v}\right)^2$. The farmer has a log utility, a diffuse prior and four-year experience on the unfamiliar crop.

Panel 2.1

The Farmer has a 20-year Experience in the Familiar Crop.

Volatility-Reduction Programs (v)	Return-Enhancement Programs (m)		
	0.00	0.50	1.00
1	81.01	77.48	72.31
2	69.25	61.18	53.56
4	61.29	52.99	43.90

Panel 2.2

The Farmer has a 40-year Experience in the Familiar Crop.

Volatility-Reduction Measures (v)	Return-Enhancement Measures (m)		
	0.00	0.50	1.00
1	81.64	77.91	75.32
2	71.96	62.72	56.00
4	68.33	53.26	44.50

Panel 2.3

The Farmer has a 60-year Experience in the Familiar Crop.

Volatility-Reduction Measures (v)	Return-Enhancement Measures (m)		
	0.00	0.50	1.00
1	82.34	76.47	76.48
2	74.46	62.81	59.11
4	69.54	56.43	47.18

Turn first to Panel 2.1, which are the results for a farmer with a 20-year experience. At the current state, this farmer will choose to grow 81% of the familiar crop. He turns to the unfamiliar crop more and more when the return-enhancement programs or volatility reduction programs are administered for the familiar crop. The best allocation choice can be achieved. But both programs must be administered together. The results change a little for the farmers with more experience in Panels 2.2 and 2.3. The finding suggests that the programs need not be designed for particular farmer groups.

IV.2 Forced Diversification

In a perfect world where the farmer knows all the information, he will choose the true optimal allocation and the utility is maximized *ex ante* and *ex post*. Allocation constraints can never improve his utility. However, when the farmer has limited information and expectations are formed with errors, certain constraints--such as maximum and minimum weight constraints to force diversification, can be useful although they are improper ones. Recently, Jaganathan and Ma (2003) show that forced diversification constraints can improve portfolio performance by diversifying errors in the estimation of a covariance matrix. Khanthavit (2003) show that the same constraints can reduce the errors in the estimation of mean returns.

The forced diversification constraints have been proposed to improve farm income. For example, in Thailand the "New Theory" of his majesty the King can be considered as being, among others, a form of forced diversification. It basically recommends how farmers allocate their land to attain self-sufficiency.

In this study, we will utilize our model to explore whether and how the forced diversification constraints are successful in helping the farmers to achieve better allocation. If it is successful, in our exercise our farmer's choice must be closer to 50% when the constraint is imposed. Our representative farmer is a log-utility farmer with a diffuse prior and 4, 20, 40 and 60 years of experience in the familiar crop as opposed to 4 years in the unfamiliar crop. The cases with minimum weight constraints of 10%, 20% and 30% are examined against the one without constraints. The results are reported in Table 3.

TABLE 3

Forced Diversification Measures

The table reports the production allocation of the familiar crop, when the constraints $w_i \geq C$--i = 1, 2, are assumed. The farmer has a log utility and a vague prior knowledge.

Experience (T)	Constraint (C)				
	None	5%	10%	20%	30%
4	49.16	51.02	49.00	50.31	49.59
20	79.48	77.77	74.38	69.11	63.35
40	79.78	78.58	76.98	70.94	64.16
60	81.15	78.95	75.40	70.55	64.32

From the table, when the farmer has more experience in the familiar crop, he tend to concentrate more in it as the percentage grows from about 50% for a 4-year experience to about 80% for a 60-year experience. But when the constraint is imposed, the farmer is less concentrating. The concentration reduces with the level of the constraint. At a 30% constraint, the percentage is about 64% and apparently closer to the optimal 50% level than in the unconstrained case.

This finding leads us to conclude that the forced diversification constraints are useful in the agricultural production problem as in the financial asset allocation problem. The success comes from the fact that they help farmers to concentrate less on the familiar product than what they incorrectly do in an unconstrained case.

V. Conclusion

Agricultural diversification has been accepted as a means of improving farm income and its stability. Diversification can be at farm, regional and national levels. Despite its benefits, diversification is practiced less at a farm level. Although factors that prohibit diversification have been proposed in the literature, these factors are less influential today. Yet, concentration continues, hence raising a question whether or not farmers are rational for not practicing diversification.

This study proposes that rational farmers can concentrate the production of traditional, familiar crops. We show in a Bayesian framework that the farmers have to use the predictive densities they develop on their own to form the expectations and make decisions. These densities are not the true one that describes crop returns. From their perspective, familiar crops are less risky because the farmers knows them better and have longer years of experience in producing them. So, the risk-averse farmers concentrate on the less-risky, familiar crops and avoid the more-risky, unfamiliar crops.

We move forward to apply the framework to explore the impact of the government's farmers assistance programs, including training, price guarantee, crop insurance and direct as well as indirect subsidies, in shaping the farmers' allocation toward the true optimal level. We find that training seems to be the most efficient because it can improve the prior knowledge as well as reduce return volatility. The mean-enhancement programs must be administered with the volatility-reduction programs to achieve the true optima.

Finally, we demonstrate that forced diversification constraints can be useful even though they are wrong ones. The constraints help to lessen concentration in the familiar crops, resulting in the improper predictive densities. The results enable us to understand the success of certain production plans, such as the "New Theory", being introduced to farmers.

APPENDIX

Statistics for Sample Crop Production

The farmer's optimum allocation must be determined for particular familiar and unfamiliar crops. We study the statistics for the production of maize and soybean in the north-eastern provinces of Thailand. Maize and soybean can be grown successfully in arid areas. These two crops in that part of the country are similar in terms of production costs and returns. Table A reports important return statistics for the matched-pair samples across provinces and seasons from 1999 to 2003. The data are collected from the Office of Agricultural Economics, Ministry of Agriculture and Agricultural Co-operatives.

TABLE A

Statistics for Corn and Soybean Production in Thailand's North-Eastern Provinces

Statistics	Crop Production	
	Corn	Soybean
Average	0.0380	0.0581
Standard Deviation	0.1713	0.1194
Skewness	-0.3351	-0.5427
Excess Kurtosis	0.9558	1.0004
Minimum	-0.3873	-0.2569
Maximum	0.4476	0.2890
Normality Test	2.8958 (0.2351)	4.6302 (0.0988)
Average Investment	1937.38	1858.60
Return Correlation	0.0461 (0.7922)	
Matched Observations	35	

From the table, in each season both the maize and soybean production costs about 1,900 baht per rai. The average return for maize is 3.8 percent, while the return for soybean is 5.8 percent. Their standard deviations are 17.1 and 11.9 percent, respectively. The tests for normality distribution of the two return series cannot be rejected at any conventional confidence level. We also check for the return correlation. We find that it is small of 0.05 and is not significant.

References

Ellis, Frank, 1988, **Peasant Economics: Farm Households and Agrarian Development**, Cambridge University Press, Cambridge.

Elton, Edwin J., and Martin J. Gruber, 1995, **Modern Portfolio Theory and Investment Analysis**, 5th ed., John Wiley and Sons, New York.

Jagnathan, Ravi, and Tongshu Ma, 2003, Risk Reduction in Large Portfolios: Why Imposing the Wrong Constraints Helps, **Journal of Finance** 58, 1651-1683.

Khanthavit, Anya, 2003, A Design of Optimum Investment-policy Constraints, A Research Report, Thammasat University and the Bank of Thailand Foundation, Bangkok.

Khanthavit, Anya, Arunee Punyasavatsut, Chaiyuth Punyasavatsut, and Poonjai Nacaskul, 2002, An Information-Theoretic Approach for Identifying Utility Functional form, Faculty of Commerce and Accountancy, Thammasat University And Thailand Research Fund, Bangkok, being presented at The 2002 10 th Annual Conference on Pacific Basin Finance, Economics Accounting, Singapore.

Kloek, T., and K. van Dijk, 1978, Bayesian Estimates of Equation System Parameters: An Application of integration by Monte Carlo, **Econometrica** 46, 1-19.

Petit, Michel and Shawki Barghouti, 1992, Diversification: Challenges and Opportunities, in **Trends in Agricultural Diversification: Regional Perspectives**, Shawki Barghouti, Lisa Garbus, and Dina Umali (eds.), World Bank Technical Paper, Washington D.C.

Poapongsakorn, Nipon, Ammar Siamwalla, Boonjit Titapiwatnakun, Prayong Netayarak, Patamawade Suzuki, Aphipun Pookpakdi, and Paradorn Preedasak, 1995, Agricultural Diversification/ Restructuring of Agricultural Production System in Thailand, Thailand Development Research Institute, Bangkok.

Timmer, Peter C., 1992, Agricultural Diversification in Asia: Lessons from the 1980s and Issues for the 1990s, in **Trends in Agricultural Diversification: Regional Perspectives**, Shawki Barghouti, Lisa Garbus, Dina Umali (eds.), World Bank Technical Paper, Washington D.C.

Siamwalla, Ammar, Direk Patamasiriwat, and Suthad Setboonsarng, 1992, Public

Policies toward Agricultural Diversification in Thailand, **Trends in Agricultural Diversification: Regional Perspectives**, Shawki Barghouti, Lisa Garbus, Dina Umali (eds.), World Bank Technical Paper, Washington D.C.

Timmer, Peter C., 1988, Crop Diversification in Rice-Based Agricultural Economies: Conceptual and Policy Issues, in **Research in Domestic and International Agribusiness Management**, vol. 8, Ray Goldberg (ed.), JAI Press, Greenwich.

Wang, Y.T., and Terry Yu, 1975, Historical Evolution and Future Prospect of Multiple-Crop diversification in Taiwan, **Philippine Economic Journal** 14, 26-46.

World Bank, 1990, Agricultural Diversification, Policies and Issues from East Asian Experience, Policy and Research Report 11, Washington, D.C.

Young, Douglas L., 1979, Risk Preferences of Agricultural Producers: Their Use in Extension and Research, **American Journal of Agricultural Economics** 61, 1063-1077.

Zellner, Arnold, 1971, **An Introduction to Bayesian Inference in Econometrics**, John Wiley and Sons, New York.

An Information-Theoretic Approach for Identifying Utility Functional Form With An Application in Describing Risk Behavior of Thai Farmers

Anya Khanthavit, *Ph.D.*

Professor of Finance and TRF Senior Researcher

Faculty of Commerce and Accountancy

Thammasat University, Bangkok

Arunee Punyasavatsut[*], *Ph.D.*

Lecturer of Economics

Faculty of Economics

Kasetsart University, Bangkok

Chaiyuth Punyasavatsut, *Ph.D.*

Assistant Professor of Economics

Faculty of Economics

Thammasat University, Bangkok

Poomjai Nacaskul, *Ph.D.*

Analyst

International Affairs Team, Monetarry Policy Group

Bank of Thailand, Bangkok

---

[*] Correspondence to Arunee Punyasavatsut, Tel: (662) 924-8084 Ex. 106, Fax: (662) 561-3474 or E-mail: fecoand@nontri.ku.ac.th.

The authors would like to thank Thailand Research Fund of the grant and Supachai Srisuchart and Woranoot Kongtanakomtunyakit for their research assistance.

ABSTRACT

An Information-Theoretic Approach for Identifying Utility Functional Form With An Application in Describing Risk Behavior of Thai Farmers

Previous studies rely on revealed economic behavior for identifying the exact utility functions for farmers. The approach is not practical because the data are difficult to obtain or are inexistent. This study proposes an application of the information-theoretic test as an alternative for the identification purpose. It is convenient, quick and inexpensive because the test employs the data readily available from the popular Ramsey interview. The study demonstrates its application, using the interview data of ten small Thai farmers. It is found that the test can discriminate the competing utility functions and successfully identify the dominant ones.

In recent years, the "New Theory" of H.M. the King is regarded as being a more profitable, less risky production strategy for small farmers. The sample farmers participate in a free-irrigation-pond program, which applies the Theory in a smaller-scale production. It is interesting to find that almost all the sample farmers possess log utility, implying their myopic behavior. This finding helps to explain in part the reason why the "New Theory" is not so well accepted among farmers before they receive free ponds. The Theory leads to higher and less risky returns in a long run, while farmers with a log utility consider only the returns in the current period. The study suggests "forced" acceptance or behavior-modification program for widespread adoption of the Theory.

บทคัดย่อ

การระบุฟังก์ชั่นอรรถประโยชน์ของเกษตรกรไทย

การศึกษาเสนอการใช้ทฤษฎีข่าวสารข้อมูลเพื่อระบุรูปแบบฟังก์ชั่นอรรถประโยชน์ และแสดงความสามารถของวิธีที่เสนอในเชิงประจักษ์โดยการประยุกต์ใช้กับการระบุฟังก์ชั่นอรรถประโยชน์ของเกษตรกรไทย 10 ราย และพบว่าวิธีการนี้สามารถระบุรูปแบบฟังก์ชั่นได้ดี และพบต่อไปอีกว่าเกษตรกรไทยส่วนใหญ่มีฟังก์ชั่นรูปล็อค (log utility) ผลการศึกษานี้สามารถอธิบายพฤติกรรมของเกษตรกรไทยได้บางส่วนว่าเหตุใดจึงมีเกษตรกรไทยเพียงน้อยรายที่นำ “ทฤษฎีใหม่” ของพระบาทสมเด็จพระเจ้าอยู่หัวไปประยุกต์ใช้

I. INTRODUCTION

Farmers' attitude toward risk has important implications on the adoption of new technologies, the success of rural development programs, and the understanding and designs of their production-consumption plans. According to Young (1979), three approaches to estimate this risk behavior have been proposed in the literature. The first approach--the Ramsey approach, is the direct elicitation of utility function. This approach recovers the relationship of the utility with income or wealth from interview data. It is prone to biasedness of interviewers. Moreover, answers under hypothetical situations in a brief interview may not reflect the behavior in reality. However, because it is straightforward, inexpensive, and less time-consuming, this approach is followed quite extensively in the literature by, for example, Lin *et al* (1974) and Zuhair *et al* (1992).

The second approach is the experimental method, which allows participating farmers to choose among possible choices and subsequently to receive actual, resulting financial compensations. This approach is more reflexive of the true behavior because the experiment is real. But each experiment can be very expensive. Hence, it cannot be conducted in a large scale.

The third approach recovers the utility from observed economic behavior. This approach is interesting because the risk behavior is based on the behavior that has been revealed. Yet, it is quite difficult to obtain the data on revealed behavior. Moreover, to recover the risk behavior, a restrictive set of assumptions must be made. This approach is followed, for example, by Moscardi and de Janvry (1977).

Although the second and third approaches can infer risk behavior of sample farmers, the inference is descriptive. For this matter, the first approach is superior because it reports data on income levels and corresponding utility, which researchers can infer their exact functional relationship.

In principle, utility should be increasing with wealth at a decreasing rate. Moreover, a rational farmer should be risk averse at all levels of wealth. Officer and Halter (1968) argue that the farmer may be risk-loving or risk-neutral with certain wealth. This argument is supported by empirical findings such as Lin *et al* (1974). These research studies point to competing utility functions for describing the farmer's risk attitude.

It is important that a utility function is exactly and correctly identified for the representative farmer because an incorrect identification will lead to a sub-optimal production-consumption plan (Bied *et al* (2001)). Previous studies that employ the Ramsey approach recognize the need for correct identification of utility functional forms. These studies consider competing utility functions and verify the better utility function by revealed behavior of farmers in the sample. For example, Lin *et al* (1974) considers the linear, quadratic, and cubic utility functions and identifies the better function by comparing actual allocation of land with theoretically optimal allocation. Zuhair *et al* (1992) considers the quadratic, cubic and exponential functions. That study identifies the better function by comparing the chosen harvesting strategies with the optimal ones predicted by the competing utilities.

Although identification of the utility functional forms by revealed economic behavior is more reflexive of farmers' true risk behavior, the process is time-consuming and costly because it requires data on revealed behavior which are not readily available. Moreover, the revealed behavior may be the interesting behavior those studies try to improve toward the optimum.

This study proposes an alternative approach for identifying the utility functional forms that can best describe the framer's risk behavior. It notices that the correct utility function cannot be observed, but it must correspond with wealth. Among the competing functions, a better function must lie closer to the correct function than does a poorer one. The test is based on Khanthavit's (1992) information test for non-nested models because competing utility functional forms are not all nested.[1] It compensates the weaknesses from not using revealed behavior by its quick speed and low cost. And, most importantly, when the data on reveled behavior are difficult to obtain or when the behavior is the interesting behavior of the optimization problem, this approach is probably the only means of identifying the correct utility function.

---

[1] A model is defined as nesting its competing model if the competing model can be obtained by restricting certain parameters of the nesting model.

The study considers an extensive set of competing utility functions--linear, quadratic, cubic, semi-log, semi-exponential and semi-power functions. The study examines risk behavior of 10 sample Thai farmers in Sukothai and Prae provinces to demonstrate the application of the test.

It is found that the information test can differentiate the competing utility functions successfully. Among the ten farmers, the utility of seven farmers can be best described by the semi-log utility. This finding has important policy implications on the promotion of the "New Theory" program. It is well known in the literature, e.g. Ingersoll (1987, pp. 235-240), that a farmer with a semi-log utility is myopic, meaning that his expected production-consumption plan will not affect his decision about production and consumption in the current period. This fact implies that the farmer will not consider the investment whose payoff is realized beyond the current investment horizon.

The organization of the study is the following. Section II discusses competing utility functional forms. Section III briefly explains how these utility functions can be inferred from the Ramsey interview data. Section IV discusses the Khanthavit (1992) information test. Section V describes the ten sample farmers and Section VI reports and discusses the test results. Section VII concludes.

II. COMPETING UTILITY FUNCTIONS

Risk behavior of framers can be described by utility functions. In the theory, the utility must be increasing with wealth or income at a degreasing rate. Officer and Halter (1968) argue that farmers may be risk-loving, risk-neutral or risk-averse with respect to their levels of wealth and income. This study considers an extensive set of utility functions that have been examined in the literature. These functions include the linear, quadratic, cubic, semi-log, semi-exponential, and semi-power forms.

The linear utility implies that the farmer is risk neutral at all levels of wealth. The quadratic utility is popular in the literature because its expectation can be conveniently represented by the mean and variance of the risky returns. The cubic utility nests the linear and quadratic utility. Hence it is more general and can describe different risk behavior of the same farmer at different income ranges. The semi-log utility is usually considered in textbooks but not by applied research studies, because it implies the farmer's hardly plausible, myopic behavior. The semi-exponential utility is another popular functional form because its expectation can be written as an expectation of the moment generating function of random return. If the return assumes a traditional distribution such as normal or Student's t, this expectation is readily available and is a function of the return's moments. Finally, the semi-power utility is considered because it possesses various desirable properties. The competing utility functions are summarized in Table 1 below.

TABLE 1

COMPETING UTILITY FUNCTIONS

The table describes the forms of competing utility functions and their corresponding coefficients of absolute risk aversion. U is the utility level, which correspond with the monetary payoff M. c_1, c_2, c_3 and c_4 are the function's governing parameters.

Function	Form	Coefficient of Absolute Risk Aversion
Linear	$U = c_1 + c_2 M$	0
Quadratic	$U = c_1 + c_2 M + c_3 M^2$	$-\left(\frac{2c_3}{c_2 + 2c_3 M}\right)$
Cubic	$U = c_1 + c_2 M + c_3 M^2 + c_4 M^3$	$-\left(\frac{2c_3 + 6c_4 M}{c_2 + 2c_3 M + 3c_4 M^2}\right)$
Semi-Exponential	$U = c_1 - c_2 e^{-c_3 M}$	c_3
Semi-Logarithm	$U = c_1 + c_2 \ln M$	$\frac{1}{M}$
Semi-Power	$U = c_1 + c_2 \frac{M^{c_3}}{c_3}$	$-\left(\frac{c_3 - 1}{M}\right)$

III. THE DIRECT ELICITATION APPROACH

This study needs the data on income levels and their corresponding utility in order to infer their functional relationship. To obtain the data, it follows previous literature, e.g. Lin *et al* (1974) and Zuhair *et al* (1992), in applying the direct elicitation

(Ramsey) approach. Although this approach suffers from certain weaknesses, it is easy to be conducted with relatively low costs and quick speed.

This study asks sample farmers ten successive questions as to which of two competing crops they would prefer under different payoffs of equal chance. The payoffs are limited from 15,000 baht to 100,000 baht because this range is the lowest and highest annual income, reported by the Office of Prime Minister Affairs for the Program's participating farmers. See Lin *et al* (1974), for example, for a details.[2] The 10 questions allow this study to infer eleven utility-payoff pairs for the farmers. These data will be used in parameter estimation for competing utility functions by the maximum likelihood technique.

IV. ESTIMATION AND TEST

This study estimates utility in its semi-functional forms because implied risk behavior is invariant to the utility's linear transformation. This practice is also consistent with the interview data, which are in a linear transformation format of the true but unobserved utility levels. Let $U_k^i(M_s|\Phi_k)$ be the utility of functional form k of farmer i at an income level M_s. And, let $U^i(M_s)$ be the utility level being inferred from the interview. Φ_k is the vector of governing parameters of the interesting function. The MLE choose Φ_k to maximize the likelihood of $e_k^i(M_s)$ defined by $U^i(M_s) - U_k^i(M_s|\Phi)$, where e_k^i is normally distributed by the assumption.

If a utility function nests others, one can test for a better performing function by restricting certain parameters and comparing the values of log likelihood. For example, one can restrict the coefficient of the cubed income of a cubic utility to zero to yield a quadratic utility. However, problems arise when competing models are non-nesting. For example, one cannot restrict the cube utility in any way to obtain an exponential or power utility. In this case, the classical test is not helpful. In noticing these problems, this study will apply the information test for non-nested models, proposed by Khanthavit (1992), to compare the competing utility functions.

[2] In the first question, the less risky crop pays 90,000 baht in the good state and pays 15,000 baht in the bad state. The more risky crop pays 100,000 baht in the good state. And, the sample farmers are asked to identify the income in the bad state so that the two crops are indifferent.

Define ΔL_{is} as the difference of the log likelihood of $e^{i}_{k1}(M_s)$ and $e^{i}_{k2}(M_s)$ for utility functions k1 and k2. Khanthavit (1992, pp. 107-116) shows that

$$z \quad = \quad \frac{1}{S}\sum_{s=1}^{S}\Delta L_{is} - 0.5\frac{1}{S}(p1\text{-}p0)$$

is distributed normally with a zero mean and a σ standard deviation if functions k1 and k2 can describe the risk behavior of farmer i equally well. p1 and p0 are numbers for governing parameters of functions k1 and k2, respectively. σ can be estimated by

$$\hat{\sigma} \quad = \quad \sqrt{\frac{1}{S}\sum_{s=1}^{S}\Delta L^{2}_{is}}\ .$$

This study concludes that function k1 is better (worse) than function k2 if z > 0 (z < 0) and it is significantly different from zero

V. THE SAMPLE

This study interviewed ten farmers in Sukothai and Prae provinces, who joined the program devised by the Office of Prime Minister Affairs. These sample farmers are very interesting. The program they are participating applies His Majesty the King's "New Theory" to promote the farmer's sufficiency living standard by appropriately allocate his land under a multiple/simultaneous-cropping strategy. The program gives an irrigation pond to the participating farmer for free.[3] The pond serves two important purposes. First, it forces the farmer to diversify his production by adding fish cropping to the production set. Second, because the participating farmer does not have access to an irrigation canal, the pond enables the farmer to grow certain grains and/or vegetables in the dry season. The "New Theory" can be considered as being new technology for small farmers who traditionally practice bullet-cropping strategies. Knowledge about the exact risk behavior of these farmers in the program will help to explain at least partly why small farmers do not adopt this seemingly more profitable, less risky strategy.

[3] The ten ponds delivered to these sample farmers are supported financially by Thailand Research Fund.

These ten farmers are small ones. They work in a small piece of land between 2-5 rais and earn on average less than 100,000 baht per family per year. Among these sample farmers, eight are male and two are female.

VI. THE RESULTS

Table 2 reports the dominance utility functions for the ten sample farmers, based on the Khanthavit (1992) information test.[4] The reported utility functions are the ones that perform significantly better than their competing functions. Farmer 6 is an exception, however. For farmer 6, his linear utility gives the highest likelihood value. The likelihood is significantly higher than those of the others, except for the log utility.

TABLE 2

EXACT UTILITY FUNCTIONS

IDENTIFIED BY THE INFORMATION-THEORETIC TEST

The table reports the utility functions that are identified by the information-theoretic test as best describing the farmers' risk behavior. The test uses the data from the Ramsey interviews. The range of the payoffs is from 15,000 baht and 100,000 baht.

Farmer	Utility	Farmer	Utility
1	Log	6	Linear/Log
2	Log	7	Log
3	Linear	8	Log
4	Log	9	Linear
5	Log	10	Log

Unlike the tests in previous literature that rely on revealed economic behavior, the test applied by this study is convenient, inexpensive, and quick. It employs the data that readily available from the interview. This finding suggests that the test is powerful enough to discriminate the competing utility functions, although the number of observations for each farmer is quite small of only eleven. Once the exact utility function is identified, it can be applied immediately in its corresponding research study.

[4] Interesting readers may obtain details of the tests and the estimated parameters for the competing functions directly from the corresponding author.

Table 2 reports that almost all of the sample farmers have log utility. This finding has at least two important policy implications. First, it helps us to better understand at least in part why the "New Theory" is not so widely accepted as it should be, despite its seemingly profitable results and government agencies' full supports and promotion. A log utility indicates that the farmer is myopic. His current production-consumption plan depends on the risk and return behavior of the assets in his investment set in the present. His expectations of future events are irrelevant. Suppose an investment project requires more than one period for the realization of the return. This project will be interpreted as being money-losing in the current period and it will be refused, although it can give a large gain in the future. The "New Theory" and its applied versions are long-termed because farmers must dig irrigation ponds and grow orchards, whose payoffs are several years away. Hence, they are hardly accepted by the farmers who share this type of utility. Second, for the Theory to be accepted, one has two approaches--not necessarily mutually exclusive. The first approach is to "force" the acceptance. The free-irrigation-pond program is a very good example. This program effectively forces the participating farmers to hold the ponds in their land. So, a part of the land is converted for fish farming. The program also promotes fruit orchard areas and/or herb, spice and vegetable gardens around the ponds. This approach gives immediate results. But it can be very expensive because only free ponds from the government can do. These farmers will not invest.

The second approach is to change the risk behavior. This approach is much less expensive from the government's perspective. But it will take a much longer time. And, its success is very difficult to measure.

VI. CONCLUSION

This study proposes an application the Khanthavit (1992) information test in identifying the exact utility function of a farmer. This test is an alternative to the ones proposed in previous studies, which must rely on the farmer's revealed economic behavior. The test is quick, inexpensive and employs the data readily available from the interview. The identified utility can be used immediately in its corresponding research study. To demonstrate the application, the study interviews ten farmers in Sukothai and Prae provinces, who participate in the Office of Prime Minister Affairs' free-irrigation-pond program. This program aims at promoting the application of H.M. the King's "New Theory" by small farmers.

It is found that the test can discriminate the performance of competing utility functions for the sample farmers, using data obtained from the popular Ramsey interview. It is interesting to find that almost all of the sample farmers have log utility, implying their myopic behavior. This finding helps to explain why the "New Theory" is not so widely accepted as it should be. The benefit from applying the "New Theory" is long-termed, while farmers with log utility disregard the outcome of more than one period hence. This interpretation has important policy implications in that the acceptance of the Theory must be "forced" or that the acceptance is from the modification of farmers' risk behavior.

REFERENCES

Bied, Sina El, Lionel Martellini and Philippe Priaulet, 2001, Measuring the costs of ineficient portfolio strategies, Working Paper, University of Southern California.

Ingersoll, J., Jr., 1987, *Theory of Financial Decision Making*, Rowman and Littlefield, New Jersey.

Khanthavit, Anya, 1992, Three Essay on Asset Pricing, An Unpublished Doctoral Thesis, New York University.

Lin, W., and H. Chang. “Specification of Bernoullian Utility Functions in Decision Analysis.” *Agricultural Economics Research*. 30(1978): 30-36.

Lin, W., G. Dean, and C. Moore, 1974, An empirical test of utility vs. profit maximization in agricultural production, *American Journal of Agricultural Economics* 56, 497-508.

Moscardi, Edgards, and Alain de Janvry, 1977, Attitudes toward risk among peasants: An econometric approach, *American Journal of Agricultural Economics* 59, 710-716.

Officer, R., and A. Halter, 1968, Utility analysis in a practical setting, *American Journal of Agricultural Economics* 50, 257-277.

Young, D., 1974, Risk preferences of agricultural producers: Their use in extension and research, *American Journal of Agricultural Economics* 61, 1063-1070.

Zuhair, S., D. Taylor, and R. Kramer, 1992, Choice of utility function form: Its effect on classification of risk preferences and the prediction of farmer Decision, *Agricultural Economics* 6, 333-344.

ปัจจัยที่มีผลต่อการตัดสินใจ
ในการทำการเกษตรแบบผสมผสาน

ศุภชัย ศรีสุชาติ*

คณะเศรษฐศาสตร์

มหาวิทยาลัยธรรมศาสตร์

มโนชัย สุดจิตร

ฝ่ายการเงิน

ธนาคารเพื่อการเกษตรและสหกรณ์การเกษตร

---

* ผู้วิจัยขอบพระคุณศาสตราจารย์ ดร.อัญญา ขันธวิทย์ และ ผู้ช่วยศาสตราจารย์ ดร.ชัยยุทธ์ ปัญญสวัสดิ์สุทธิ์ ที่ได้ให้แนวทางและข้อเสนอแนะอันเป็นประโยชน์อย่างยิ่งในการทำวิจัย และคุณไชยพร หวังเจริญรุ่ง ผู้อำนวยการฝ่ายการเงิน และเจ้าหน้าที่ของธนาคารเพื่อการเกษตรและสหกรณ์การเกษตรในพื้นที่ ที่อำนวยความสะดวกในการเก็บข้อมูล และผู้ช่วยงานวิจัย คือ ศุภสินธุ์ บุญเรือง นราธิป วงศ์ศิวรางกูร และนักศึกษาช่วยเก็บข้อมูลทุกคน งานวิจัยเป็นส่วนหนึ่งของโครงการเมธีวิจัยอาวุโส สกว. (ศาสตราจารย์ ดร.อัญญา ขันธวิทย์) สำนักงานกองทุนสนับสนุนการวิจัย

บทคัดย่อ

ปัจจัยที่มีผลต่อการตัดสินใจในการทำการเกษตรแบบผสมผสาน

แนวความคิดการทำการเกษตรแบบผสมผสานเป็นแนวความคิดในการวางแผนการผลิตพืช ปศุสัตว์ และ การประมง ในเวลาเดียวกัน รวมถึงกระบวนการจัดสรรทรัพยากรการผลิต ได้แก่ ที่ดิน แรงงาน เงินทุน การพิจารณาปัจจัยที่มีผลต่อการตัดสินใจของเกษตรกรในการเลือกทำการเกษตรแบบผสมผสานจึงมีความจำเป็นในฐานะเป็นเครื่องมือเพื่อกำหนดนโยบายทั้งภาครัฐและเอกชนในการให้การสนับสนุนหรือเลือกเกษตรกรที่จะเข้าร่วมโครงการ การศึกษาใช้ปัจจัยในสามลักษณะ คือ ปัจจัยที่เป็นคุณลักษณะของเกษตร ปัจจัยที่เกี่ยวกับพื้นที่ทำการเกษตร และปัจจัยทางการเงิน โดยใช้ตัวแบบ Logit และ Probit เพื่อตรวจสอบปัจจัยเหล่านี้ว่าปัจจัยใดส่งผลกระทบในทิศทางใด และมีนัยสำคัญหรือไม่ทางสถิติ ซึ่งผลการศึกษาที่ได้รับ พบว่า ปัจจัยที่มีผลทำให้เกษตรกรมีการตัดสินใจในการทำการเกษตรผสมผสาน คือ การมีที่ดินเป็นของตนเอง และคมนาคมที่สะดวก ซึ่งทั้งสองปัจจัยนี้เป็นปัจจัยที่ส่งเสริมให้เกษตรกรตัดสินใจทำการเกษตรแบบผสมผสาน ในขณะที่ประสบการณ์ในการปลูกพืชเชิงเดี่ยวแสดงความสัมพันธ์ในทางตรงกันข้าม คือ การที่เกษตรกรมีการทำการปลูกพืชเชิงเดี่ยวเป็นเวลายาวนานก็จะมีโอกาสที่น้อยในการตัดสินใจทำการเกษตรแบบผสมผสาน ดังนั้นแนวนโยบายที่รัฐควรให้การสนับสนุนหากต้องการให้เกษตรกรเปลี่ยนพฤติกรรมมาทำการเกษตรแบบผสมผสาน คือ การสร้างความสะดวกในการคมนาคมและการส่งเสริมให้เกษตรกรมีที่ทำกินเป็นของตนเอง

ABSTRACT

Determinants of Farmers' Decision to Adopt Multi-Crop Production

The study attempts to identify the determinants of farmers' decision to switch from a mono-crop production to a multi-crop production. The determinants are tested for significance, using survey data from farmers in Nakorn Nayok Province. The study finds that significant factors include land ownership, convenient transportation, and experiences.

ปัจจัยที่มีผลต่อการตัดสินใจ
ในการทำการเกษตรแบบผสมผสาน

ความสำคัญของปัญหา

เกษตรผสมผสาน (Intercropping)[1] เป็นการจัดการกิจกรรมการผลิตในไร่นา คือ การปลูกพืช เลี้ยงสัตว์ และการประมง ให้มีการผสมผสานเกื้อกูลและใช้ประโยชน์จากทรัพยากรการผลิตร่วมกัน ได้แก่ การใช้ดิน น้ำ แรงงาน ทุน อย่างเหมาะสม เพื่อการทำการเพาะปลูกพืชหลายชนิดหรือการเพาะปลูกร่วมกับการทำปศุสัตว์ ในช่วงเวลาใดเวลาหนึ่ง ซึ่งเป็นแนวทางหนึ่งในการทำการเกษตรที่มีการพัฒนามาตั้งแต่ช่วงสงครามโลกครั้งที่สองในประเทศญี่ปุ่น และไต้หวัน และมีการเผยแพร่สู่ประเทศในแถบเอเซีย (Oshima 1975) เพื่อเป็นแนวทางในการใช้ทรัพยากรการผลิตให้มีประสิทธิภาพสูงสุด และมีการขยายแนวความคิดเพื่อเป็นการทำการเกษตรรูปแบบอื่นๆ อาทิเช่น เกษตรทฤษฎีใหม่ วนเกษตร เป็นต้น

ในการทำการเกษตรผสมผสานอาจพิจารณาได้ว่าเป็นการดำเนินการกระจายความเสี่ยงอันเกิดจากการผลิต การตลาด และทางการเงินของเกษตรกร เมื่อเทียบกับการปลุกพืชเชิงเดี่ยว (Monocropping) รวมถึงการสร้างการประสิทธิภาพให้กับการผลิต การใช้ทรัพยากรพื้นที่ และแรงงาน และการเพิ่มรายได้ให้กับระบบการผลิต (Lee *et al*. 1975) และการศึกษาในประเทศไทยได้มีการนำทฤษฎีที่เกี่ยวข้องกับการกระจายความเสี่ยงมาประยุกต์ใช้กับการเกษตร โดยประดิษฐ์ วิธิศุภกร และคณะ (2542) ซึ่งจากการพิจารณาถึงประโยชน์ต่างๆแล้วเกษตรผสมผสานจึงน่าจะเป็นแนวทางที่เกษตรไทยจะเลือกกำหนดรูปแบบในการทำการเกษตรของตน แต่สิ่งที่เป็นประเด็นปัญหา ได้แก่

ประเด็นปัญหาที่หนึ่ง คือ มีการนำเสนอจากภาครัฐและเอกชนอย่างมากเพื่อสนับสนุนให้เกษตรกรทำการเกษตรแบบผสมผสาน และทุกฝ่ายได้แสดงถึงผลประโยชน์ที่ดีกว่าในการทำการเกษตรแบบผสมผสาน ดังนั้นเมื่อเกษตรกรรับทราบข้อมูลข่าวสารเหล่านั้นก็ควรเปลี่ยนพฤติกรรมในการประกอบอาชีพ แต่ในความเป็นจริงเกษตรกรส่วนใหญ่ยังคงมีการทำการเกษตรเชิงเดี่ยว ซึ่งน่าจะเกิดจากปัจจัยบางประการที่เป็นตัวแปรสำคัญที่มีผลต่อการตัดสินใจของเกษตรกร

---

[1] อาจมีการใช้ในความหมายของการกระจายการผลิต (Diversification) หรือการปลูกพืชหมุนเวียน (Multi-cropping)

ประเด็นปัญหาที่สองที่คือในพื้นที่ทางกายภาพที่มีลักษณะเดียวกันซึ่งเกษตรกรควรมีลักษณะหรือวิธีทำการเกษตรในลักษณะเดียวกันแต่กลับมีความแตกต่างกันในเรื่องรูปแบบของการทำการเกษตร ซึ่งน่าจะต้องมีปัจจัยบางประการที่ทำให้การตัดสินใจของเกษตรกรเหล่านั้นมีความแตกต่างกัน ซึ่งประโยชน์ของงานศึกษานี้จะเป็นเครื่องมือในการรับรู้ถึงปัจจัยที่จะมีผลต่อการตัดสินใจของเกษตรกรในการเลือกทำการเกษตรแบบผสมผสาน และสามารถกำหนดเป็นแนวนโยบายต่อไปในอนาคตว่าจะเริ่มสนับสนุนให้เกษตรกรที่มีลักษณะหนึ่งลักษณะใดเป็นการเฉพาะ

ดังนั้นในงานศึกษานี้จึงมีวัตถุประสงค์เพื่อตอบคำถามที่สองว่า ปัจจัยใดบ้างที่มีผลต่อการตัดสินใจทำการเกษตรแบบผสมผสานของเกษตรกร โดยมีกลุ่มตัวอย่างเป็นเกษตรกรในจังหวัดนครนายก จำนวน 4 อำเภอ และเป็นลูกค้าของธนาคารเพื่อการเกษตรและสหกรณ์การเกษตร (ธกส.) เพื่อเป็นการตัดปัจจัยด้านการเข้าถึงตลาดสินเชื่อ (Access to credit markets) เพราะในการทำการเกษตรแบบผสมผสานในขั้นเริ่มแรกมีการเสนอว่าเกษตรกรควรมีแหล่งน้ำเป็นของตนเอง และการปลูกพืชยืนต้นบางชนิดจำเป็นต้องใช้ช่วงระยะเวลาจึงจะสามารถเก็บเกี่ยวผลผลิตได้ ดังนั้นเงินทุนเริ่มต้นจึงมีความจำเป็นสำหรับเกษตรกรที่จะดำเนินการทำการเกษตรแบบผสมผสาน

ตัวแปรที่มีการเลือกใช้ในการศึกษา ได้แก่ คุณลักษณะทั่วไปของเกษตรกร สภาพทางการเงินของเกษตร ปัจจัยทางกายภาพของพื้นที่ทำการเพาะปลูก ซึ่งการศึกษาใช้วิธีการทางเศรษฐมิติในการอธิบายความสัมพันธ์ในลักษณะที่เป็น Binary – Choice Model เพราะเป็นเครื่องมือเพื่อบ่งชี้ว่าตัวแปรอิสระที่มีการกำหนดส่งผลต่อการตัดสินใจในการทำการเกษตรของเกษตรกรที่มีสองลักษณะคือ การทำการเกษตรผสมผสาน และการปลูกพืชเชิงเดี่ยว ในทิศทางและขนาดเท่าไรภายใต้สมมติฐานของตัวแบบบางประการคือ การกระจายตัวของค่าความผิดพลาด ซึ่งได้มีการทดสอบในสองรูปแบบ คือ ตัวแบบ Probit และตัวแบบ Logit และมีการทดสอบโดยสุ่มแบ่งกลุ่มตัวอย่างในการทดสอบถึงผลลัพธ์เพื่อระบุตัวแปรที่มีผลอีกครั้งหนึ่ง

ผลการศึกษาสามารถบ่งชี้ได้ว่ามีปัจจัยสามประการ ได้แก่ ประสบการณ์ในการปลูกพืชเชิงเดี่ยวของเกษตรกร การเข้าถึงพื้นที่ทำการเกษตร และ การมีที่ดินเป็นของตนเอง ที่ส่งผลต่อการตัดสินใจทำการเกษตรผสมผสานของเกษตรกรที่เป็นกลุ่มตัวอย่าง

วิธีการศึกษาและตัวแบบ

ในการศึกษาใช้ตัวแบบที่มีลักษณะเป็น Binary Model โดยที่ตัวแปรตามมีค่าที่เป็นไปได้สองทางตามการเลือกของเกษตรกร คือ การทำการเกษตรแบบผสมผสานและการเกษตรเชิงเดี่ยว

โดยที่ Y_i เป็นตัวแปรที่แทนการตัดสินใจของเกษตรกรในการทำการเกษตรแบบผสมผสาน และ X_i เป็นกลุ่มตัวแปรที่ใช้แสดงลักษณะของปัจจัยที่นำมาทดสอบซึ่งปรากฏในตารางที่ 2 เมื่อกำหนดตัวแปรตามที่มีลักษณะเป็นค่าที่ไม่ต่อเนื่องและมีการแสดงค่าเพียง 2 รูปแบบ คือ 1 และ 0 การศึกษาจึงใช้รูปแบบของการประมาณของค่าความผิดพลาด (Error Term) ใน 2 ลักษณะคือ Logit Model, Probit Model เพื่อเป็นการทดสอบผลการประมาณค่าที่ได้ว่าแนวโน้มส่วนใหญ่แล้วมีความเหมือนหรือต่างกันหรือไม่ ในการประมาณค่าใช้วิธีการหาค่ามากที่สุด (Maximum Likelihood Process) ในการกำหนดค่าสัมประสิทธ์ที่ต้องการ การพิจารณารูปแบบของค่าความผิดพลาดของทั้งสามวิธีมีความแตกต่างกันในเรื่องรูปแบบของการกระจายตัว ซึ่งในแต่ละรูปแบบสามารถสรุปได้ดังตารางที่ 1

ตารางที่ 1

รูปแบบของการกระจายตัวของค่าความผิดพลาดในแต่ละตัวแบบ

ตัวแบบ	รูปแบบ
Logit Model	$\Pr(Y_i=1/X_i,\beta)=1-\frac{e^{-X_i'\beta}}{1+e^{-X_i'\beta}}=\frac{e^{X_i'\beta}}{1+e^{X_i'\beta}}$ ซึ่งอยู่บนพื้นฐานของ Cumulative distribution function for logistic distribution
Probit Model	$\Pr(Y_i=1/X_i,\beta)=1-\Phi(-X_i'\beta)=\Phi(X_i'\beta)$ เมื่อ $\Phi(.)$ เป็นฟังก์ชันการกระจายสะสมของการแจกแจงปกติ (Cumulative distribution function of standard normal)

สำหรับการศึกษานี้ การตีความค่าสัมประสิทธ์ในเบื้องต้นที่ได้จากตัวแบบทั้งสองเป็นการพิจารณาทิศทางและความมีนัยสำคัญว่าการเปลี่ยนแปลงของตัวแปรอิสระจะส่งผลต่อโอกาสที่จะทำให้ตัวแปรตามมีค่าเป็น 1 (ในกรณีนี้คือ เกษตรกรทำการเกษตรแบบผสมผสาน) มากขึ้น (ในกรณีที่ค่าสัมประสิทธ์มีค่ามากกว่าศูนย์) หรือมีโอกาสที่ลดลง (ในกรณีที่ค่าสัมประสิทธ์มีค่าน้อยกว่าศูนย์) ดังนั้นในกรณีที่ค่าสัมประสิทธ์มีค่ามากกว่าศูนย์อย่างมีนัยสำคัญ ก็อาจสามารถระบุได้ว่าตัวแปรอิสระนั้นมีผลต่อการทำการเกษตรแบบผสมผสาน และตัวแปรอิสระนั้นทำให้โอกาสที่เกษตรกรจะทำการเกษตรแบบผสมผสานเพิ่มมากขึ้น ในทางกลับกันหากค่าสัมประสิทธ์มีค่าน้อยกว่าศูนย์อย่างมีนัยสำคัญ ก็สามารถระบุได้ว่าตัวแปรอิสระนั้นมีผลต่อการทำการเกษตรแบบผสมผสานและทำให้โอกาสที่เกษตรกรจะทำการเกษตรแบบผสมผสานลดน้อยลง

ดังนั้น ในการตีความค่าสัมประสิทธิ์ที่ได้จากการประมาณค่าในแต่ละตัวแบบไม่สามารถตีความค่าโดยตรงได้เหมือนกับกรณีการใช้ตัวแบบเชิงเส้นตรงที่ระบุว่าค่าสัมประสิทธ์คือค่าส่วนเพิ่ม

จากการตัวแปรนั้นมีการเปลี่ยนแปลงในขณะที่ตัวแปรอื่นๆคงที่ แต่ในการใช้ตัวแบบทั้งสองจำเป็นต้องหาค่าส่วนเพิ่มหรือ Marginal effect ที่เกิดขึ้นจากการที่ตัวแปร X_j ใดๆมีการปรับเปลี่ยนระดับหรือพฤติกรรม และการศึกษาจะนำผลลัพธ์ที่ได้ไปออกแบบนโยบาย ซึ่งจะทำการนำเสนอในส่วนต่อไป ทั้งนี้การคำนวณค่า Marginal Effect สามารถคำนวณได้จากสมการที่ (1)

$$\frac{\partial E(Y_i/X_i,\beta)}{\partial X_{ij}} = f(-X_i^{'}\beta)\beta_j \qquad (1)$$

โดยที่ $f(y)=\frac{dF(y)}{dy}$ หรือแนวทางหนึ่งในการพิจารณาค่าส่วนเพิ่มอาจทำได้โดยการหาค่าเปรียบเทียบเพื่อระบุการเปลี่ยนแปลงความน่าจะเป็นที่เกษตรกรจะตัดสินใจทำการเกษตรแบบผสมผสาน โดยคำนวณจากสมการที่ (2)

$$\frac{\beta_j}{\beta_k} = \frac{\partial E(Y_i/X_i,\beta)/\partial X_{ij}}{\partial E(Y_i/X_i,\beta)/\partial X_{ik}} \qquad (2)$$

การตีความผลการศึกษาในลำดับต่อมา คือ การตีความถึงผลกระทบในลักษณะ Marginal effect ว่าการเปลี่ยนแปลงในตัวแปรหนึ่งตัวแปรใดในขณะที่ตัวแปรอื่นๆคงที่ (พิจารณาที่ค่ากลางของแต่ละตัวแปร) จะทำให้โอกาสที่เกษตรจะตัดสินใจทำการเกษตรแบบผสมผสานเพิ่มมากขึ้นหรือลดลงเท่าไร และมีนัยสำคัญหรือไม่ ซึ่งก็จะตรงตามวัตถุประสงค์ในการศึกษา คือ เพื่อที่จะระบุความสัมพันธ์ของปัจจัยที่จะมีผลต่อการทำการเกษตรผสมผสานทั้งในด้านขนาดและทิศทางของความสัมพันธ์

สำหรับการวัดความน่าเชื่อถือของตัวแบบที่สร้างขึ้น สามารถพิจารณาจากค่าทางสถิติ คือ McFadden R-squared[2] ที่สามารถเทียบเคียงได้กับกรณีการใช้ค่า R-squared ในตัวแบบเชิงเส้นด้วยเหตุผลที่ว่า การกำหนดค่าตัวแปรตามเป็น 1 และ 0 จึงทำให้ค่า R-squared แบบปกติไม่สามารถได้ค่าที่นำไปใช้งานประเมินความน่าเชื่อถือของตัวแบบได้ จึงจำเป็นต้องใช้ McFadden R-squared โดยที่ค่าที่ได้มีค่าอยู่ระหว่าง ศูนย์ถึงหนึ่ง ทั้งนี้ค่าที่สูงย่อมแสดงถึงความน่าเชื่อถือที่สูงกว่าของตัวแบบเมื่อเทียบกับค่า McFadden R-squared ที่ต่ำกว่า

---

[2] ค่า McFadden R-squared สามารถคำนวณได้จากสูตร $1-\frac{l(\hat{\beta})}{l(\tilde{\beta})}$ เมื่อ $l(\hat{\beta})$ เป็นค่าสูงสุดของฟังก์ชันล็อคไลค์ลิฮูด และ $l(\tilde{\beta})$ เป็นค่าสูงสุดของฟังก์ชันล็อคไลค์ลิฮูดเมื่อมีการกำหนดให้ค่าสัมประสิทธิ์ของทุกตัวแปรอิสระมีค่าเป็นศูนย์ (Restricted Value)

ข้อมูลและการกำหนดตัวแปร

สำหรับข้อมูลเป็นข้อมูลเชิงคุณภาพและปริมาณที่เกี่ยวข้องกับเกษตรกรโดยใช้การสัมภาษณ์สอบถามเกษตรกรในพื้นที่[3] ซึ่งสามารถแบ่งตัวแปรเป็นสามกลุ่มหลัก (ตัวแปรทั้งหมดและการกำหนดค่าตัวแปร พิจารณาได้ตามตารางที่ 2) ได้แก่ กลุ่มที่เกี่ยวกับคุณลักษณะของเกษตร ทางกายภาพของพื้นที่ทำการเกษตร สถานะทางการเงินของเกษตรกร

กลุ่มที่เกี่ยวกับคุณลักษณะของเกษตร ได้แก่ ระดับการศึกษา (EDU) ประสบการณ์ (EXPER) และการมีพื้นที่ทำการเกษตรเป็นของตนเอง (LAND) ในส่วนนี้เป็นผลจากการศึกษาในเรื่องที่เกี่ยวกับการรับรู้และการถ่ายทอดเทคโนโลยีของเกษตรกร โดยที่ขึ้นกับระดับการศึกษาของเกษตร ดังนั้นข้อสมมติฐานที่สำคัญ คือ หากเกษตรกรมีระดับการศึกษาที่สูงก็สามารถที่จะรับเทคโนโลยี ซึ่งส่งผลต่อการตัดสินใจเลือกทำเกษตรแบบผสมผสาน ซึ่งในการกำหนดตัวแปร มีการกำหนดให้ หากเกษตรกรมีระดับการศึกษาที่สูงกว่าประถม 4 ให้มีค่าเป็น 1 และหากต่ำกว่าประถม 4 ให้มีค่าเป็นศูนย์ การกำหนดระดับประถมศึกษา 4 เป็นเกณฑ์ เพราะเป็นการศึกษาขั้นต่ำในช่วงอายุของเกษตรกร และมีข้อสมมติฐานว่าเกษตรกรที่มีความรู้ตั้งแต่ประถม 4 ขึ้นไปสามารถที่อ่านเขียน และเรียนรู้ ข้อมูลข่าวสารต่างๆได้โดยความสัมพันธ์ที่คาดหวัง ควรมีทิศทางที่ไปในทิศทางเดียวกัน นั่น คือ เมื่อเกษตรกรมีระดับการศึกษาที่สูงกว่าประถม 4 ก็จะเลือกทำการเกษตรแบบผสมผสาน เพราะสามารถรับรู้ข้อมูลข่าวสารและเทคโนโลยีในการผลิตได้อย่างรวดเร็วกว่าเกษตรกรที่ไม่มีความรู้หรือมีความรู้ต่ำกว่าประถม 4

ตัวแปรต่อมา คือ ประสบการณ์ของเกษตรกรในการทำการเกษตรในลักษณะเชิงเดี่ยว เพราะ ข้อมูลของเกษตรกรได้รับ บ่งชี้ว่า ในช่วงต้นเกษตรกรได้มีการทำการเกษตรเชิงเดี่ยวแล้วจึงมีการปรับเปลี่ยนการผลิตมาเป็นการเกษตรแบบผสมผสาน ดังนั้นในเงื่อนไขที่เกษตรกรที่มีประสบการณ์และความรู้ในสิ่งใดสิ่งหนึ่งที่ดีอยู่แล้ว จะมีโอกาสที่น้อยในการเปลี่ยนมาทำการเกษตรแบบผสมผสานเพราะตนมีประสบการณ์และความชำนาญในด้านนั้นเป็นอย่างดี ดังนั้นความสัมพันธ์คาดหวังระว่างประสบการณ์ของเกษตรกรกับการตัดสินใจในการทำการเกษตรผสมผสาน ควรมีความสัมพันธ์ในทิศทางตรงกันข้าม

ตัวแปรคุณลักษณะของเกษตรกรประการสุดท้าย คือ การมีที่ทำกินเป็นของตนเอง (กำหนดให้ค่า 1 แทนการที่เกษตรกรมีที่ดินทำกินเป็นของตัวเอง และเป็น 0 เมื่อเกษตรกรไม่ได้มีที่ทำกินเป็นของตัวเอง) การเลือกตัวแปรที่เกี่ยวข้องกับการมีที่ดินเป็นของตนเอง เสนอว่า ใน

[3] รายละเอียดของข้อมูลนำเสนอในภาคผนวกที่ 1 รายงานเบื้องต้นเกี่ยวกับเกษตรกรกลุ่มตัวอย่าง

เบื้องต้นเกษตรกรควรมีที่ดินเป็นของตนเอง เพราะพืชที่เพาะปลูกจำเป็นต้องใช้เวลาบางช่วงก่อนที่จะสร้างผลผลิตให้กับเกษตรกร ซึ่งหากเกษตรกรเช่าที่ดิน หรือไม่ได้มีที่ดินเป็นกรรมสิทธิ์เป็นของตนเองก็อาจมีความไม่แน่นอนในระยะเวลาช่วงนี้ และจำเป็นต้องปลูกพืชเชิงเดี่ยวปริมาณที่มากเพื่อให้คุ้มค่ากับผลตอบแทนที่ต้องให้กับเจ้าของที่ดิน และการดำเนินการเกษตรแบบผสมผสานจำเป็นต้องมีการจัดสรรที่ดินเพื่อทำประโยชน์ต่าง ๆอย่างชัดเจน ดังนั้นการมีกรรมสิทธิ์ในที่ดินจึงมีความจำเป็นเพราะสามารถที่จะทำการวางแผนและจัดสรรที่ดินได้ตลอดช่วงเวลาของเกษตรกร ดังนั้น ความสัมพันธ์ของตัวแปรนี้เมื่อเทียบกับการตัดสินใจควรมีลักษณะในทิศทางเดี่ยวกัน คือ หากเกษตรกรมีที่ดินทำกินเป็นของตัวเองก็จะเป็นการเพิ่มโอกาสในการที่เกษตรกรจะทำการเกษตรแบบผสมผสาน

ในกลุ่มที่สองเป็นเรื่องเกี่ยวกับ**คุณลักษณะทางกายภาพของพื้นที่ทำการเกษตร** คือ การเข้าถึงแหล่งชลประทาน (WATER) ที่แสดงถึงความเพียงพอของน้ำที่ถือเป็นปัจจัยหลักในการทำการเกษตร การมีแหล่งน้ำที่เป็นของเกษตรกรเองในพื้นที่ (WELL) การเข้าถึงตลาดผลผลิต (MKT) การคมนาคม (WAY) ตัวแปรในกลุ่มนี้เป็นการพิจารณาถึงการเข้าถึงแหล่งสาธารณูปโภค โดยงานศึกษาในต่างประเทศ คือ ไต้หวัน และ ฟิลิปปินส์ พบว่าสาธารณูปโภคที่มีความจำเป็นต่อการทำการเกษตรผสมผสาน คือ การเข้าถึงตลาดผลผลิต และการคมนาคม (Mao 1975) ดังนั้นในการศึกษาคาดหวังที่จะพบความสัมพันธ์ในทางเดียวกัน คือ หากสาธารณูปโภคมีความพร้อมเกษตรกรก็มีโอกาสมากขึ้นที่จะทำการเกษตรแบบผสมผสาน และปัจจัยที่สำคัญอีกประการหนึ่งคือการที่เกษตรกรมีแหล่งน้ำเป็นของตนเอง เพราะ แหล่งน้ำเป็นปัจจัยที่ส่งผลต่อความสามารถในการทำการเกษตรได้ตลอดทั้งปี ซึ่งความสัมพันธ์ของตัวแปรที่คาดหวังก็มีลักษณะเช่นเดียวกับสาธารณูปโภคข้างต้น

ในกลุ่มที่สามเป็นข้อมูลที่เกี่ยวข้องกับ **สถานะทางการเงินของเกษตรกร** โดยปัจจัยแรกที่นำมาพิจารณา คือ การมีภาระหนี้สินของเกษตรกร ซึ่งหากเกษตรกรมีหนี้สินในระดับที่สูงขึ้นย่อมให้ความสามารถในการรับความเสี่ยงที่น้อยลง เพราะในการที่เกษตรกรจะลดความเสี่ยงในการดำเนินการผลิตย่อมทำให้ระดับความเสี่ยงทางการเงินสูงขึ้น (Gabriel, Baker 1980 และ Collins 1985) ดังนั้นเมื่อเกษตรกรจะลดความเสี่ยงในการผลิตในการทำการเกษตรแบบผสมผสานก็อาจทำให้มีความเสี่ยงทางการเงินที่สูงขึ้น และหากเกษตรกรมีภาระหนี้สินที่อยู่ในระดับที่สูงอยู่แล้วก็จะทำให้โอกาสที่เกษตรกรรายนั้นจำทำการเกษตรผสมผสานก็จะน้อยลง เป็นผลจากการที่ไม่สามารถภาระหนี้สินเพื่อรองรับกับภาระความเสี่ยงที่เพิ่มขึ้นได้ ในการศึกษาใช้ระดับของอัตราส่วนระหว่างหนี้สินกับสินทรัพย์ของเกษตรกร (DEBT) เป็นตัวเลขเพื่อแสดงภาระหนี้สินของเกษตรกรเมื่อเทียบกับความมั่งคั่งทั้งหมดที่เกษตรกรมีอยู่ ดังนั้นความสัมพันธ์ที่คาดหวังระหว่างตัวแปรนี้กับการ

ตัดสินใจของเกษตรกร คือ ความสัมพันธ์ในทิศทางที่ตรงกันข้าม นั่นคือ เมื่อเกษตรกรมีระดับหนี้สินที่สูงก็ย่อมทำให้โอกาสในการตัดสินใจทำการเกษตรผสมผสานลดลง

ตัวแปรต่อมา คือ รายได้นอกภาคการเกษตรเมื่อเทียบกับรายได้ในภาคการเกษตร (REV) ในตัวแปรนี้มาจากแนวความคิดของการที่เกษตรกรมีทางเลือกในการทำการผลิต ในสองลักษณะ คือ การปลูกพืชเชิงเดี่ยวและนำเวลาที่เหลือไปทำการสร้างรายได้นอกภาคการเกษตร กับการทำการเกษตรแบบผสมผสานและไม่สามารถไปทำการผลิตรายได้ในนอกภาคการเกษตรได้ เพราะข้อความจริงหนึ่ง คือ การทำการเกษตรแบบผสมผสานจำเป็นต้องใช้ทรัพยากรแรงงานอยู่ตลอดทั้งปี เพราะการผลิตจะต้องมีการทำอย่างต่อเนื่องทุกๆช่วงเวลา จึงอาจทำให้เกษตรกรไม่สามารถมีเวลาที่เหลือไปทำงานอย่างอื่น ดังนั้นหากเกษตรกรมีรายได้นอกภาคการเกษตรในระดับที่สูงย่อมแสดงได้อย่างหนึ่ง คือ เกษตรกรมีต้นทุนค่าเสียโอกาสที่สูงในการทำเกษตรแบบผสมผสานและอาจที่จะไม่เลือกทำการเกษตรในลักษณะเช่นนี้ ดังนั้น ความสัมพันธ์ที่คาดหวังของตัวแปรนี้คือ การมีทิศทางที่ตรงกันข้าม คือ หากอัตราส่วนนี้มีค่าที่สูง ก็จะทำให้โอกาสในการตัดสินใจทำการเกษตรแบบผสมผสานมีน้อยลง

อัตราส่วนระหว่างค่าใช้จ่ายและรายได้ของเกษตรกร (EXPENSE) อัตราส่วนของต้นทุนเมื่อเทียบกับรายได้ หรืออัตราส่วนกำไรขั้นต้น (COST) ทั้งสองรายการเป็นตัวแปรที่แสดงภาระการใช้จ่ายที่เป็นอยู่ของเกษตรกรเพื่อความเป็นอยู่และเพื่อการผลิต ซึ่งหากค่าใช้จ่ายของเกษตรกรอยู่ในระดับสูงย่อมทำให้โอกาสที่เกษตรกรจะทำการเกษตรแบบผสมผสานมีน้อยลง เพราะการทำการเกษตรแบบผสมผสานจำเป็นต้องมีค่าใช้จ่ายที่สูง และ ต้นทุนที่สูงขึ้น จากการเตรียมการผลิต การผลิต และการเก็บเกี่ยว แต่อีกแนวความคิดหนึ่ง คือ การทำการเกษตรแบบผสมผสานอาจทำให้ค่าใช้จ่ายบางประเภทสามารถลดลงได้ จากการใช้ทรัพยากรร่วมกัน หรือการใช้ทรัพยากรที่มีความต่อเนื่องกัน ดังนั้นในตัวแปรอัตราส่วนค่าใช้จ่ายกับรายได้อาจไม่สามารถระบุความสัมพันธ์ที่แน่ชัดขึ้นกับผลกระทบในแต่ละทาง แต่ในเบื้องต้น เหตุผลแรกน่าจะมีน้ำหนักมากกว่าจึงคาดว่าความสัมพันธ์จะมีทิศทางตรงกันข้าม

ตารางที่ 2
ตัวแปรที่ใช้ในการศึกษา

ตัวแปร	สัญลักษณ์	การกำหนดค่า
การตัดสินใจทำการเกษตรแบบผสมผสาน	Y	Y = 1 เมื่อเกษตรกรทำการเกษตรแบบผสมผสาน = 0 เกษตรกรทำการเกษตรเชิงเดี่ยว
ระดับการศึกษา	EDU	EDU = 1 ศึกษาน้อยกว่าหรือเท่ากับระดับประถม 4 = 0 ศึกษาสูงกว่าประถม 4
ประสบการณ์	EXPER	ตามประสบการณ์ของเกษตรกร
การมีพื้นที่เป็นของตนเอง	LAND	LAND = 1 เกษตรกรมีพื้นที่เป็นของตนเอง = 0 เกษตรกรไม่มีพื้นที่เป็นของตนเอง
แหล่งน้ำ	WATER	WATER = 1 มีการชลประทานเข้าถึง = 0 การชลประทานเข้าไม่ถึง
บ่อน้ำของตนเอง	WELL	WELL = 1 เกษตรกรมีแหล่งน้ำของตนเองในพื้นที่ = 0 เกษตรกรไม่มีแหล่งน้ำในพื้นที่
การคมนาคม	WAY	WAY = 1 การคมนาคมเข้าถึงพื้นที่ทำการเกษตร = 0 การคมนาคมเข้าไม่ถึงพื้นที่
การเข้าถึงตลาด	MKT	MKT = 1 เกษตรกรเข้าถึงตลาดได้ง่าย = 0 เกษตรกรเข้าไม่ถึงตลาด
อัตราส่วนหนี้สินต่อสินทรัพย์	DEBT	คำนวณโดยนำหนี้สินหารด้วยสินทรัพย์
อัตราส่วนรายได้	REV	รายได้นอกภาคการเกษตรหารด้วยรายได้ในภาคการเกษตร
อัตราส่วนค่าใช้จ่าย	EXPENSE	ค่าใช้จ่ายหารด้วยรายได้รวม
อัตราส่วนต้นทุน	COST	ต้นทุนในการทำการผลิตหารด้วยรายได้

ผลการศึกษา

ในการศึกษาใช้กลุ่มตัวอย่างจากเกษตรกรในจังหวัดนครนายกทั้งสิ้น 120 ราย ซึ่งมีการทำการเกษตรแบบผสมผสานและการเกษตรเชิงเดี่ยว ซึ่งมีจำนวนที่ต่างกันมากคือ เกษตรกรที่ทำการเกษตรแบบผสมผสานจำนวน 89 ราย และการเกษตรแบบเชิงเดี่ยวจำนวน 31 ราย ซึ่งเมื่อพิจารณาจะพบว่าจำนวนของกลุ่มที่ทำการเกษตรแบบผสมผสาน ($N_1 = 89$) เมื่อเทียบกับจำนวนเกษตรกรที่ปลูกพืชเชิงเดี่ยว ($N_2 = 31$) เป็นจำนวนมาก ($N_1 >> N_2$) ดังนั้นเพื่อเป็นการทดสอบความถูกต้องของตัวแบบที่นำมาใช้ จึงทำการสุ่มเลือกเกษตรกรที่ทำการเกษตรแบบผสมผสานจากจำนวนทั้งสิ้น 89 รายมาเป็นจำนวน 31 ราย เพื่อให้จำนวนกลุ่มตัวอย่างสองกลุ่มมีค่าเท่ากัน ($n_1 = n_2$) โดยมีการทดลองสุ่มจำนวน 3 ครั้งเพื่อเป็นการยืนยันผลที่ได้รับ

ผลการศึกษาในตารางที่ 3 มีการรายงานค่าสัมประสิทธิ์ และค่า Marginal Effect ในแต่ละตัวแบบและในแต่ละกลุ่มตัวอย่างที่สุ่มเลือกมา 3 กลุ่ม เพื่อตรวจสอบระดับนัยสำคัญทางสถิติใน 3 ระดับ คือ ที่ระดับนัยสำคัญ 1%, 5% และ 10% ตามลำดับ[4] การพิจารณาจะพิจารณาที่ค่า Marginal Effect ว่ามีนัยสำคัญและส่งผลต่อการตัดสินใจทำการเกษตรแบบผสมผสานในทิศทางใด ตรงกับความสัมพันธ์ที่คาดหวังหรือไม่ โดยที่ ถ้าค่า Marginal Effect มีค่าเป็นบวกอย่างมีนัยสำคัญสามารถบ่งชี้ว่าหากมีการเพิ่มปัจจัยนี้หนึ่งหน่วยจะทำให้โอกาส (หรือความน่าจะเป็น) ในการทำการเกษตรแบบผสมผสานเพิ่มขึ้นเท่ากับค่า Marginal Effect ที่รายงาน และอาจตรวจสอบอีกครั้งหนึ่งด้วยการพิจารณาความมีนัยสำคัญทางสถิติของสัมประสิทธิ์อีกครั้งหนึ่งก็ได้ ซึ่งจากผลการศึกษาที่ได้รับ**ทั้งในตัวแบบ Probit และ Logit** ที่เกิดขึ้น พบว่าการใช้**กลุ่มตัวอย่าง**ในทุกรูปแบบให้ผลที่ไม่ต่างกัน นั่นคือ มีตัวแปรอิสระเพียงบางตัวเท่านั้นที่ส่งผลต่อการตัดสินใจของเกษตรกร และตัวแปรนี้ก็แสดงผลที่เหมือนกันในทุกกลุ่มตัวอย่าง ได้แก่ การคมนาคม (WAY) การมีที่ดินเป็นของตนเอง (LAND) และประสบการณ์ (EXPER) ซึ่งผลการศึกษาแสดงในตารางที่ 3

---

[4] ตัวอย่างของการรายงานผลการศึกษาในตารางที่ 3 พิจารณาที่ตัวแบบ Probit สำหรับตัวอย่างทั้งหมด ในตัวแปร LAND ที่รายงานค่าสัมประสิทธิ์เท่ากับ 0.9306374117 และมีค่า t – statistic เท่ากับ 2.798*** แสดงว่า ปัจจัยคือการที่เกษตรกรที่ดินจะมีผลต่อการตัดสินใจในการทำการเกษตรแบบผสมผสานของเกษตรกรภายใต้ระดับนัยสำคัญ 1% และเมื่อพิจารณาถึง Marginal effect ที่รายงานค่า LAND เท่ากับ 0.2739703188 และค่า t – statistic ที่มีค่า 2.772*** แสดงว่าการที่เกษตรกรมีที่ดินเป็นของตนเองจะทำให้มีโอกาสในการที่จะทำการเกษตรผสมผสานเพิ่มขึ้น 27.4% ภายใต้ระดับนัยสำคัญ 1%

ตารางที่ 3

ผลการศึกษาเชิงประจักษ์

Model	Sample	Variable	constant	EDU	EXPER	LAND	WATER	WELL	WAY	MKT	DEBT	REV	EXPENSE	COST	McFadden R-Square
Probit Model	All Sample	Coefficient	0.007921707583	-0.1012972532	-0.01783952515	0.9306374117	-0.4276436054	-0.2731276086	1.273454614	-0.3432138309	0.07998272585	0.03520309351	-0.05387455785	0.1372678512	0.230943
			0.13	-0.280	-1.189	2.798***	-1.126	-0.755	2.957***	-0.851	1.043	0.401	-0.450	1.339	
		Marginal	0.002332071250	-0.0298208275	0.005251777257	0.273970188	-0.1258939878	-0.08040602824	0.3748922644	-0.1010387091	0.02354611219	0.01036343761	-0.01586012942	0.04041027847	
			0.013	-0.280	-1.185	2.772***	-1.133	-0.758	2.900***	-0.843	1.049	0.403	-0.450	1.354	
	Group 1	Coefficient	-0.9809637345	-0.07436163021	-0.07148020095	1.055291794	0.1660114916	-0.6599810174	1.721212622	-0.2308468321	0.1241775800	0.01591763716	-0.8207128327	0.1203595781	0.340981
			-0.934	-0.145	-1.992**	1.966**	0.299	-1.273	2.107**	-0.362	0.913	0.281	-0.340	0.682	
		Marginal	-0.3974493480	-0.2937046919	-0.2827189345	0.4168065578	0.06556923758	-0.2606714253	0.6798340187	-0.09117712658	0.04904617849	0.006286958348	-0.03241553594	0.04753818966	
			-0.940	-0.145	-2.019**	1.964**	0.299	-1.278	2.142**	-0.362	0.911	0.281	-0.339	0.683	
	Group 2	Coefficient	-0.3208972003	-0.2226401966	-0.04915104716	0.2994536886	-0.4708365076	-0.69920654391	2.443767948	-0.7244690521	0.1627967314	0.02803603334	-0.1267404796	0.1461333848	0.305507
			-0.399	-0.486	-1.774*	0.645	-0.907	-1.306	3.368***	-1.334	1.617	0.400	-0.603	0.798	
		Marginal	-0.1274533929	-0.08842784674	-0.01952172757	0.1189364961	-0.1870060266	-0.2748733495	0.9706115107	-0.2877433603	0.06465932312	0.01113530305	-0.05033856363	0.05684946927	
			-0.400	-0.486	-1.779*	0.649	-0.907	-1.37	3.409***	-1.337	1.618	0.400	-0.603	0.795	
	Group 3	Coefficient	-1.057728610	0.2755144799	-0.8178681620	0.8629019288	-0.4543056328	-0.8960507984	2.634368625	-0.5772015407	0.1997989367	0.05707328316	-0.2011559420	0.2191750886	0.411696
			-0.970	0.489	-2.009**	1.661*	-0.747	-1.540	2.782***	-0.871	1.275	0.454	-0.856	1.177	
		Marginal	-0.4166449723	0.1085266312	-0.03221626553	0.3399016976	-0.1789534252	-0.3529592151	1.037691930	-0.2273627825	0.07870187269	0.02248147233	-0.07923640437	0.8633424286	
			-0.977	0.488	-2.044**	1.662*	-0.747	-1.540	2.877***	-0.877	1.277	0.453	-0.856	1.181	
Logit Model	All Sample	Coefficient	0.1409407583	-0.2392005521	-0.03181699825	1.668574570	-0.7701285307	-0.4602952927	2.129590784	-0.58851919960	0.1330209798	0.05288996563	-0.1139292733	0.2428764779	0.235643
			0.137	-0.371	-1.193	2.841***	-1.126	-0.718	2.871***	-0.818	1.044	0.342	-0.565	1.240	
		Marginal	0.02291338433	-0.03888792888	0.005172635072	0.2712678070	-0.1252033211	-0.07483231309	0.3462173236	-0.09513734195	0.02162582970	0.008435989279	-0.01852200355	0.03948554096	
			0.137	-0.370	-1.178	2.890***	-1.138	-0.722	2.751***	-0.805	1.050	0.344	-0.566	1.264	
	Group 1	Coefficient	-1.601642009	-0.1858993332	-0.1193238261	1.820957455	0.03086898323	-1.144970809	2.915537239	-0.4358194987	0.2032696610	0.02247234797	-0.1321854678	0.1940932624	0.339233
			-0.858	-0.208	-1.912*	1.990**	0.334	-1.241	1.992**	-0.404	0.879	0.241	-0.322	0.655	
		Marginal	-0.3948012438	-0.04582377808	-0.02941306153	0.4488620124	0.07609136690	-0.2822081445	0.7186735375	-0.1074285510	0.05010552580	0.005539384506	-0.03258342801	0.04784356367	
			-0.867	-0.208	-1.939*	1.979**	0.334	-1.247	2.053**	-0.404	0.877	0.241	-0.322	0.658	
	Group 2	Coefficient	-0.5418819113	-0.4263930928	-0.07760853686	0.5112262572	-0.7791147262	-1.126208012	4.000230381	-1.168307319	0.2652133415	0.04223573725	-0.1898033366	0.2328373333	0.299017
			-0.373	-0.546	-1.646*	0.655	-0.901	-1.239	3.127***	-1.247	1.572	0.346	0.533	0.771	
		Marginal	-0.1345678296	-0.1058880023	-0.01927285659	0.1269549812	-0.1934808591	-0.2796760045	0.9933941495	-0.2901307036	0.06586155212	0.0148857948	-0.04713466630	0.05782148092	
			-0.374	-0.547	-1.652*	0.656	-0.901	-1.239	3.192***	-1.250	1.576	0.346	-0.533	0.771	
	Group 3	Coefficient	-1.893042054	0.3871050864	-0.1383959901	1.424720356	-0.7231404893	-1.430195686	4.497946017	-0.9458463582	0.3347703956	0.1044999386	-0.3040137093	0.3530216576	0.40758
			0.932	0.410	-1.912*	1.643	-0.704	-1.429	2.574***	-0.832	1.218	0.412	-0.782	1.121	
		Marginal	-0.4630813273	0.09469474638	-0.03385482043	0.3485191426	-0.1768966816	-0.3498585334	1.100300338	-0.2313756242	0.08189248559	0.02556307198	-0.07436869757	0.08635716116	
			-0.948	0.408	-1.964**	1.631	-0.703	-1.422	2.748***	-0.840	1.221	0.411	-0.776	1.128	

ตัวเลขในบรรทัดแรกเป็นค่าสัมประสิทธิ์ที่กำหนดได้ ตัวเลขในบรรทัดที่สองเป็นค่าสถิติ z สัญลักษณ์ * ระบุความมีนัยสำคัญที่ 10% ** ระบุความมีนัยสำคัญที่ 5% และ *** ระบุความมีนัยสำคัญที่ 1%

การคมนาคมเป็นปัจจัยหนึ่งที่ส่งผลให้เกษตรกรมีการตัดสินใจทำการเกษตรแบบผสมผสาน คือ การมีการคมนาคมที่สะดวกจะเป็นปัจจัยเสริมที่ทำให้เกษตรกรตัดสินใจในการทำการเกษตรแบบผสมผสานเพิ่มมากขึ้น ตรงตามการคาดการณ์และจากงานศึกษาของ Mao (1975) ที่นำเสนอในข้างต้น ซึ่งทั้งสองตัวแบบและทุกกลุ่มตัวอย่างต่างบ่งชี้ในลักษณะเดียวกัน นั่นคือ ค่าของสัมประสิทธ์มีค่าต่างศูนย์อย่างมีนัยสำคัญโดยส่วนใหญ่จะอยู่ที่ระดับ 1% และเมื่อพิจารณาถึงผลส่วนเพิ่มพบว่าในตัวแบบ Probit การคมนาคมทำให้การตัดสินใจของเกษตรกรเพิ่มขึ้นโดยเฉลี่ย 37% และ 34% สำหรับตัวแบบ Logit การเพิ่มโอกาสนี้เป็นไปอย่างมีนัยสำคัญที่ 1% ซึ่งเหตุผลประการหนึ่ง คือ การทำการเกษตรแบบผสมผสานจะมีผลผลิตที่เกิดขึ้นจากการทำการเกษตรทุกวัน ดังนั้นการที่คมนาคมสะดวกย่อมเป็นสิ่งหนึ่งที่เกษตรกรสามารถนำผลผลิตนั้นไปจำหน่ายได้โดยสะดวก และในกรณีที่ผู้ที่มารับซื้อผลผลิตในการทำการเกษตรก็สามารถที่จะมาได้โดยง่ายเช่นกัน ในทางกลับกันหากการคมนาคมไม่สะดวกการเก็บผลผลิตเพื่อการจำหน่ายก็จะทำได้ยากขึ้นและการขนย้ายทำได้โดยความยากลำบากทำให้การจัดสรรเวลาของเกษตรกรในการนำผลผลิตออกจำหน่ายทำได้โดยยากและอาจเป็นปัจจัยที่ทำให้เกษตรกรไม่ตัดสินใจทำการเกษตรแบบผสมผสาน

ดังนั้นแนวทางหนึ่งหากทางการต้องการให้เกษตรมีการทำการเกษตรผสมผสานเพิ่มขึ้นก็สามารถสนับสนุนได้โดยการทำให้การคมนาคมระหว่างพื้นที่ทำการเกษตรของเกษตรกรเป็นไปด้วยความสะดวก หรือในอีกมุมหนึ่งหากทางการต้องการหาเกษตรกรเพื่อเข้าร่วมโครงการเกษตรผสมผสานอาจพิจารณาจากเกษตรกรที่มีแหล่งทำการเกษตรมีความสะดวกด้านการคมนาคม

ตัวแปรที่สองที่มีผลต่อการตัดสินใจในการทำการเกษตรแบบผสมผสานของเกษตรกร ได้แก่ การมีที่ดินทำกินเป็นของตนเอง ซึ่งสามารถที่จะบ่งชี้ได้ว่า กลุ่มตัวอย่างส่วนใหญ่มีค่าสัมประสิทธ์ที่มากกว่าศูนย์อย่างมีนัยสำคัญ ย่อมแสดงว่าการที่เกษตรกรมีที่ดินทำกินเป็นของตนเองเป็นการเพิ่มโอกาสที่เกษตรกรจะเลือกทำการเกษตรแบบผสมผสาน และแม้ว่ามีค่าสัมประสิทธิ์บางส่วนจะมีค่าไม่ต่างจากศูนย์อย่างมีนัยสำคัญ (ในกลุ่มตัวอย่างชุดที่ 2) แต่ผลที่ได้รับก็แสดงค่าที่มากกว่าศูนย์ทุกกรณี ก็สามารถเป็นข้อมูลเพื่อยืนยันทิศทางของความสัมพันธ์ระหว่างตัวแปรทั้งสองนี้ ในกรณีของการพิจารณาค่าส่วนเพิ่มของตัวอย่าทั้งหมด พบว่า การมีที่ดินเป็นของตนเองทำให้เกษตรกรมีโอกาสที่จะตัดสินใจในการทำการเกษตรแบบผสมผสานเพิ่มขึ้นถึงประมาณ 27% ที่ระดับนัยสำคัญ 1% ในทั้งสองตัวแบบ ซึ่งตรงกับการคาดการณ์ข้างต้น

ตัวแปรที่เป็นตัวแปรในการตัดสินใจที่มีผลอีกตัวแปรหนึ่ง ได้แก่ ประสบการณ์ของเกษตรกร ซึ่งผลการศึกษามีลักษณะที่คล้ายกับกรณีของที่ดิน ที่ผลการศึกษาส่วนใหญ่สามารถที่จะอธิบายถึงความสัมพันธ์ได้ ในที่นี้มีข้อน่าสังเกตประการหนึ่ง คือ การที่ค่าสัมประสิทธิ์ในในทุกการทดลองมี

ค่าที่น้อยกว่าศูนย์ ซึ่งผลการศึกษานี้อาจบ่งชี้ว่าการที่เกษตรกรมีประสบการณ์ที่มากขึ้นก็ทำให้มีแนวโน้มที่จะตัดสินใจไม่ทำการเกษตรแบบผสมผสาน ซึ่งเมื่อผู้อ่านพิจารณาแล้วอาจเห็นว่าเกิดความไม่สมเหตุสมผล แต่ทั้งนี้เป็นเพราะการระบุนิยามของตัวแปรของประสบการณ์ของเกษตรกรนั้นเป็นประสบการณ์ที่เกษตรกรมีการทำการเกษตรในลักษณะของเชิงเดี่ยวรวมกับการทำการเกษตรแบบผสมผสาน ดังนั้นเมื่อเกษตรกรที่มีประสบการณ์ในการทำการเกษตรเชิงเดี่ยวที่ยาวนาน อาจไม่ยินดีที่จะรับเอาเทคโนโลยีใหม่ในที่นี้คือ การทำการเกษตรแบบผสมผสานเอาไว้ ทั้งนี้การยอมรับอย่างมีนัยสำคัญเกิดขึ้นในการใช้กลุ่มตัวอย่างชุดที่ 1, 2 และ 3 ภายใต้ระดับความเชื่อมั่น 5% และ 10% เหตุผลหนึ่งอาจเกิดจากจำนวนของกลุ่มตัวอย่างเพราะในตัวอย่างทั้งหมดมีเกษตรกรที่ทำการเกษตรเชิงเดี่ยวถึง 69 ราย ซึ่งอาจทำให้ผลที่ได้รับมีความโน้มเอียงไปยังด้านการทำการเกษตรเชิงเดี่ยว ในขณะที่การใช้กลุ่มตัวอย่างที่ 1, 2, และ 3 เป็นการสุ่มให้กลุ่มของเกษตรกรที่ทำการเกษตรแบบผสมผสานและเชิงเดี่ยวมีจำนวนที่เท่ากัน แต่จากผลการศึกษาค่าส่วนเพิ่มที่ได้รับระหว่างชุดตัวอย่างมีความแตกต่างกันตั้งแต่ประมาณ 20 – 34% แต่ทิศทางของความสัมพันธ์เป็นไปตามการคาดการณ์

สำหรับตัวแปรอื่นที่ใช้ในการศึกษาครั้งนี้พบว่า นอกเหนือจากตัวแปรทั้งสามที่นำเสนอมาข้างต้น ไม่มีตัวแปรใดที่แสดงผลกระทบอย่างมีนัยสำคัญ แต่มีประเด็นที่น่าตั้งเป็นข้อสังเกต คือ โดยส่วนใหญ่แล้วตัวแปรมีค่าที่แสดงทิศทางไปในลักษณะเดียวกันในทุกกลุ่มตัวอย่าง โดยที่ตัวแปรที่ได้ผลลัพธ์ตามที่คาดการณ์ไว้ ได้แก่ อัตราส่วนต้นทุนต่อรายได้และอัตราส่วนระหว่างค่าใช้จ่ายต่อกำไร แต่สำหรับตัวแปรอื่นๆซึ่งได้แก่ การมีบ่อน้ำของตนเอง การเข้าถึงตลาด และอัตราส่วนรายได้นอกภาคการเกษตรต่อรายได้ในภาคการเกษตรที่ให้ผลในทิศทางเดียวกับการตัดสินใจในการทำการเกษตรแบบผสมผสาน (อาจอธิบายได้ในอีกทางหนึ่งได้ว่า การที่เกษตรกรมีรายได้นอกภาคการเกษตรที่สูงขึ้นอาจทำให้เกษตรกรมีความสามารถในการรองรับความเสี่ยงที่สูงขึ้นได้ เพราะในการเปลี่ยนมาทำการเกษตรแบบผสมผสานอาจมีความเสี่ยงในแง่ความรู้ ประสบการณ์ของเกษตรกรที่จะรับเอาการเกษตรแบบใหม่ ดังนั้นเมื่อเกษตรกรมีรายได้นอกภาคการเกษตรที่สูงขึ้นก็อาจที่จะตัดสินใจทำการเกษตรผสมผสานได้) แม้ว่าทิศทางของผลกระทบที่ได้รับอาจไม่ตรงกับการคาดการณ์โดยเหตุผลที่นำเสนอข้างต้น แต่จากตัวแบบก็สามารถปฏิเสธผลที่เกิดขึ้นตามระดับนัยสำคัญ 10% และโดยสรุปตัวแปรที่เหลือเหล่านี้ไม่ได้ระบุและแสดงความสัมพันธ์ระหว่างตัวแปรกับการเลือกทำการเกษตรแบบผสมผสานของเกษตรที่เป็นกลุ่มตัวอย่าง

การนำผลการศึกษาไปใช้ ควรมีความระมัดระวังในการตีความข้อมูลเพราะเป็นเพียงข้อมูลที่มาจากกลุ่มตัวอย่างในพื้นที่เดี่ยวกัน และเป็นข้อมูลที่เกษตรกรเป็นกลุ่มลูกค้าของธนาคารเพื่อการเกษตรและสหกรณ์การเกษตรในลักษณะเดียวกัน แต่หากพิจารณาตามผลของตัวแปรที่ได้รับ ชี้

ว่า หากทางการต้องการสนับสนุนให้เกษตรกรเข้าร่วมโครงการการเกษตรแบบผสมผสาน พื้นที่ที่ควรพิจารณาเป็นอันดับแรก คือ การคมนาคมที่ต้องมีความสะดวก และเกษตรกรควรมีพื้นที่ทำกินเป็นของตนเอง และอีกประการควรเป็นเกษตรกรที่ไม่ได้มีประสบการณ์ที่ทำการเกษตรมาอย่างยาวนาน ในทางกลับกันหากพิจารณาแล้วว่าจะให้เกษตรกรทำการเกษตรแบบผสมผสานก็ควรสนับสนุนการสร้างการคมนาคมที่สะดวกให้แก่เกษตรกร เช่น การสร้างถนน เป็นต้น นอกจากนี้ควรมีการส่งเสริมให้เกษตรกรมีที่ทำกินเป็นของตนเองในรูปแบบต่างๆ เช่น การให้สิทธิในการถือครอง อาจดำเนินการเป็นสัญญาระยะยาวที่ให้เกษตรกรมีความคุ้มค่าต่อการดำเนินการ

บรรณานุกรม

A. M. Strout. **"Some Definition Problems with Multiple – Crop Diversification"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 308 – 316.

Arturo A. Gomez. **"Introduction and Implication of Multiple Cropping in Selected Communities in The Philipine"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 288 – 294.

Baker B. and Gabriel C. **"Concepts of Business and Financial Risk"** : American Journal of Agriculture Economics, Vol 62 ,No 8, Aug 1980 : p. 560 – 564.

C. S. Lee, C. Y. Lee and C. H. Tseng. **"Impact of Multiple – crop Diversification on Farm Income in Taiwan"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 77 – 87.

Chamnien Boonma and Delane F. Welsch**. "Multiple – Crop Diversification in Central Thailand"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 258 – 271.

Chien – pan Cheng. **"Natural and Technological Factors Contributing to Multiple – Crop Diversification in Taiwan"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 47 – 63.

Collins A. Robert. "**Expected Utility, Debt – Equity Structure, and Risk Balancing"**: American Journal of Agriculture Economics, Vol 67, No 3, 1985 : p. 627 – 629.

Diosdado A. Carandang. **"Prospects of Multiple Cropping in The Philipines"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 279 – 287.

Gordon R. Banta and Richard R. Harwood. **"The Multiple – Cropping Program at Irri"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 300 – 306.

Harry T. Oshima. **"Multiple – Cropping in Asian Development : Summary and Further Reserch"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 7 – 25.

Hsing – yiu Chen. "**Farming Diversification and Products Marketing"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 88 – 125.

Keizo Tsuchiya. **"Agricultural Prices and Diversification in Japan"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 295 – 300.

Robert S. Pindyck and Daniel L. Rubinfield. **"Econometric Models and Economic Forecasts"** , Fourth Edition, Singapore : McGraw – Hill, 1997.

T. H. Lee. **"Planning Multiple – Crop Diversification for Agricultural Development – Some Suggestions for Developing Countries"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 200 – 215.

T. S. Wu and H. C. Tsai. **"Patterns of Agricultural Outmigration and Multiple – Crop Farming in Taiwan"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 138 – 148.

Wanyong Kuo. **"Effects of Land Reform, Agricultural Pricing Policy and Economic Growth on Multiple – Crop Diversification in Taiwan"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 149 - 174

William H. Greene. **"Econometric Analysis"** Fourth Edition, Prentice Hall International Inc., 2000.

Y. T. Wang and Terry Y. H. Yu. **"Historical Evolution and Future Prospect of Multiple – Crop Diversification in Taiwan'** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 26 – 46.

Yu-kang Mao. **"Implication of Taiwan's Experience in Miltiple – Crop Diversification for Other Asian Countries"** : The Philippine Economic Journal, Number Twenty Seven, Volume XIV, Nos. 1&2, 1975 : p. 216 – 234.

MAXIMUM FEASIBLE FARM CREDITS:

CASES FOR THAILAND

Anya Khanthavit, *Ph.D.**

Professor of Finance and Banking and TRF Senior Researcher

Faculty of Commerce and Accountancy, Thammasat University

Bangkok, Thailand

Chaiyuth Punyasavatsut, *Ph.D.*

Assistant Professor of Economics

Faculty of Economics, Thammasat University

Bangkok, Thailand

Woranoot Kongtanakomtunyakit

Analyst, Thailand Securities Depository Co. Ltd.

Bangkok, Thailand

Teerawut Sripinit

Lecturer of Economics

Faculty of Economics, Thammasat University

Bangkok, Thailand

* Corresponding author. Thammasat University, Bangkok 10200, Thailand, Tel: (662) 613-2223, Fax: (662) 225-2109, E-mail: akhantha@tu.ac.th.

The authors thank Thailand Research Fund for the financial supports.

ABSTRACT

MAXIMUM FEASIBLE FARM CREDITS: CASES FOR THAILAND

We show how banks can use the information on statistical distributions of crop returns to set limits for farm loans so that borrowing farmers are able to repay their loans by the crop income with an accepted default probability. We then apply the technique proposed by Ramirez (1997, 2000) to estimate the return distribution. Its resulting credit limits are tested against the ones under the normality assumption. The Ramirez limits can pass the in-sample and out-of-sample tests. And, they outperform the normality limits. We apply the resulting limits to evaluate the limits set by the Bank of Agriculture and Agricultural Co-operatives--Thailand's largest provider of farm loans. Those limits can be justified by the revealed behavior of the crop returns.

บทคัดย่อ

การระบุเพดานเงินกู้ของเกษตรกรในประเทศไทย

การศึกษาชี้ว่าสถาบันการเงินซึ่งให้เงินกู้แก่เกษตรกรไทยสามารถใช้ข้อมูลพฤติกรรมของอัตราผลตอบแทนของพืชผลทางการเกษตรที่เกษตรกรผลิตไป เพื่อระบุขนาดความสามารถของเกษตรกรที่จะใช้รายได้จากการผลิตพืชผลนั้นๆ มาชำระคืนเงินกู้ จากนั้นการศึกษาจึงใช้วิธีการของ Ramirez เพื่อระบุรูปแบบการแจกแจงของอัตราผลตอบแทนของพืชผล แล้วใช้ผลลัพธ์นี้ตรวจสอบถึงความสำเร็จของการใช้ข้อมูลในการกำหนดเพดานเงินกู้ การศึกษาพบว่าวิธีการนี้สามารถระบุเพดานเงินกู้ได้อย่างถูกต้องเหมาะสม และยังพบต่อไปอีกว่าเพดานเงินกู้ที่การศึกษาระบุได้มีขนาดใกล้เคียงกับเพดานเงินกู้ที่ธนาคารเพื่อการเกษตรและสหกรณ์การเกษตรระบุ

Maximum Feasible Farm Credits:

Cases for Thailand

I. INTRODUCTION

Farm loans contribute to the success of farm production. The loans help farmers with satisfying the liquidity needs and with financing the investment the farmers cannot afford by their equity. While more loans can lessen business risk, they raise financial risk to borrowing farmers. Future income from farm production can vary so much with volatile market prices and uncertain outputs. In certain years, income can be so low that farmers are unable to repay loans, thereby resulting in bankruptcy. As Fetherstone et al. (1988) pointed out, the probability of bankruptcy rises with the size of the loans. Davies (1996) noted further that, because farms are family businesses, bankruptcy makes those farmers to lose their home, their farms and their way of life. Hence, how much credit should be offered to finance farm production is not only an important economic question but also an important social question.

Agricultural economists have studied the problem of farm debt burdens from theoretical and empirical perspectives. For example, Featherstone et al. (1988) studied the optimum leverage level chosen by farmers in an expected utility maximization framework. Assuming normality, farmers choose the optimum leverage level to balance the default probability with the expected income. While the study helps us to understand the farmers' choice for leverage, it does not relate the choice with the ability to repay loans. So, it is difficult for banks to apply this study to design the limits for farm loans.

Hanson and Thompson (1980) identified the maximum farm debt burdens, using the data simulated from the returns on farms in Southern Minnesota from 1966 to 1975. This approach is very practical. The resulting maximum farm debt burdens can be adopted as maximum credit limits if the return sample is sufficiently large. But if the sample is small--which is usually the case in the studies using farm returns, Kupiec (1995) reports that simulation results can be biased upward. The resulting credit limit will be too high. Banks that adopt this limit will incur loan failure too frequently.

Recent studies, e.g. Ramirez (1997, 2000) and Richardson et al. (2000), on distributions of farm returns suggest that the information can be used by banks to set credit limits. These studies estimated the distributions for certain crop returns, but they did not actually apply the results to make any recommendations on credit limits. In this study we adopt the approach that applies the information on return distributions to identify farm credit limits. We explain in detail how banks can use the information. We then estimate the distributions of certain crop returns in Thailand and use that information to recommend the credit limits for these particular crops. These recommendations are tested for the validity, using in-sample and out-of-sample data. Finally, we use our findings to evaluate the policies on farm credit set by Thailand's Bank for Agriculture and Agricultural Co-operatives (BAAC).

We use the approach proposed by Ramirez (1997, 2000) to estimate the distributions of the percentage returns on Thailand's major produces. We find that maximum credits vary with crops, production areas, and seasons. The Ramirez credit limits can pass the in-sample validity tests for all of the sample crops and pass the out-of-sample tests for most of the crops. In terms of the rejection rates, they outperform the limits set under the normality assumption--which is usually made in most studies. Finally, we find that the credit limits set by the BAAC are can be justified by the revealed behavior of farm returns, if the bank chooses a 5% default probability and sets its expectations of farm income with respect to the average farm returns.

II. METHODOLOGY

II.1 DETERMINING THE MAXIMUM CREDIT LIMIT

Practicing the classic 4 C's principle, banks evaluate farmers' capacity, character, collateral and covenant before they decide whether and how much loans are offered. Although at times borrowing farmers use non-farm income for loan repayment, the source of cash flows is dominantly farm income. Hence, the maximum credits should not be greater than the ability to repay based on that income.

It should be noted that the investment on farm production is made today with known costs. It can be financed by equity and debt. If farmers choose loans to finance a part of the investment, income must at least cover the contractual loan repayment.

Let Y be the farm income and D be the loan size. To avoid the loan failure, it must be that

$$Y \geq D. \qquad (1)$$

Moreover, let C be the production cost, the condition (1) implies

$$y \geq \frac{D-C}{C} = -\frac{E}{C}, \qquad (2)$$

where $y = \frac{Y-C}{C}$ is the rate of return on farm production in percentage of the cost C. E is the equity financing. C = E + D by the fact that the production cost is financed by debt and equity. Equation (2) states that farmers are solvent as long as the loss is absorbed by the equity. Because y is a random variable--whose minimum value is 100% amounting to a total loss, default is possible for any case in which D > 0. Given the distribution of y and the level of equity financing $\frac{E}{C}$, default probability can be identified by the percentile at the point $-\frac{E}{C}$ of the distribution.

Banks must accept that defaults are possible when they offer loans. But the default probability must not be too high. Suppose banks set it as a policy to accept the maximum default probability of α. Banks can use the information on the distribution of y and require the equity financing of at least $-y_{\alpha}$ at the α^{th} percentile so that the default probability of α is achieved. Hence, the maximum credit limit is $1+ y_{\alpha}$.

II.2 ESTIMATION OF THE RETURN DISTRIBUTION

The distribution of the rate of farm return y is key to identify the maximum farm credit. But the distribution cannot be observed. It must be estimated. Due to its simplicity, normality is generally assumed to describe farm returns. However, researchers--e.g. Just and Weninger (1999) and Ramirez (1997, 2000), have found that returns on certain crops are not normally distributed but skewed. So, for those crops the credit limits set under the normality assumption can be too low or too high.

A more appropriate distribution is the one that can sufficiently describe possible skewness and fat-tailedness found for the return. In addition, the estimation technique must give accurate estimates in small samples, because it is difficult to find a long time-series or a broad cross-sectional return data set on any crop. Recently, Ramirez (1997, 2000) proposed an inverse hyperbolic sine transformation method to transform the unknown distribution of the farm return to a normal distribution, estimate its parameters, and use the estimates to recover the unobserved distribution by simulation. It is found that the resulting distribution can describe the farm return very well even when the sample size is small.

Let y_i be the i^{th} observation of the farm return. It is assumed that the distribution of y_i be fixed for all the observations in the estimation sample. The inverse hyperbolic sine transformation V_i of y_i can be defined by

$$\mathbf{sinh}^{-1}\{y_i - \bar{y}\} \quad = \quad V_i \qquad (3)$$

Where

$$V_i \quad = \quad \frac{\mathbf{ln}\left\{ [\theta\{y_i - \bar{y}\}] + \left\{[\theta\{y_i - \bar{y}\}]^2 + 1\right\}^{0.5} \right\}}{\theta}.$$

$\bar{y}$ is the mean of y_i and θ is the transformation parameter. V_i is obtained from y_i being transformed by $\sinh^{-1}\{.\}$--the inverse hyperbolic sine function. Ramirez (1997, 2000) showed that V_i is distributed normally with mean μ and variance σ^2. For the return samples $y_{i=1}$, $y_{i=2,\ldots,}$ $y_{i=n}$, the parameter estimates maximize the following likelihood function L.

$$L \quad = \quad -\frac{n}{2} + \sum_{i=1}^{n}[\mathbf{ln}(G_i)] - 0.5\sum_{i=1}^{n}[H_i^2] \qquad (4)$$

Where

$G_i = \frac{F(\theta,\mu)}{\mathbf{sign}(\mu)\sigma(1+R_i^2)^{0.5}}$,

$H_i = \theta^{-1}\,\mathbf{ln}\{R_i + (1+R_i^2)^{0.5}\} - \mu$,

$R_i = \frac{F(\theta,\mu)\theta}{\mathbf{sign}(\mu)\sigma}\left\{(y_i - \bar{y}) + \frac{\mathbf{sign}(\mu)\sigma}{\theta}\right\}$, and

$F(\theta,\mu) = \frac{(e^{0.5\theta^2})(e^{\theta\mu} - e^{-\theta\mu})}{2}$. **sign**($\mu$) denotes the sign of μ.

Once we have the parameter estimates, we can simulate the normal variable V_s infinitely many times. The simulated samples V_s correspond with the return samples y_s via

$$y_s = \frac{\mathbf{sign}(\mu)\sigma}{F(\mu,\theta)\theta}\mathbf{sinh}(\theta V_s) + \bar{y} - \frac{\mathbf{sign}(\mu)\sigma}{\theta}. \qquad (5)$$

Hence, we can simulate the returns samples y_s infinitely many times too. These samples possess the same statistical properties as the original return samples y_s do. In this study, we will simulate 10,000 return samples. These returns will be ranked in a descending order. For the accepted default probability α, the maximum credit limit ($1+y_\alpha$) is constructed from the return at the $10000\alpha^{th}$ position.

II.3 THE COMPETING DISTRIBUTION

The normal distribution is usually assumed for agricultural returns due to its familiarity and simplicity. For this reason, in this study we will use the normal distribution as the competing distribution for the benchmark so that the performance of the Ramirez model can be compared. The credit limit set under the normal distribution is $1+y_\alpha^N$, where

$$y_\alpha^N = \mu + z_\alpha\sigma^2. \qquad (6)$$

z_α is the inverse cumulative probability density function of a standard normal variable, evaluated at α. μ and σ are the mean and standard deviation of the sample return.

II.4 VALIDITY TESTS

If the credit limit of $1+y_\alpha$ is appropriate, banks must find that farm income cannot cover loan repayment in only 100α times out of 100 loans. We apply this empirical regularity to test for the validity of the models. We consider two test procedures--the three-zone approach and the likelihood approach.

II.4.1 The Three-Zone Approach

The three-zone approach, proposed by the Bank for International Settlements or BIS (1996), is a supervisory approach adopted by most banks and central banks in all countries. The three zones--green, yellow and red, are identified by the probability (β) of making a type-I error from the model rejection. The red zone corresponds with $\beta <$ 0.0001, the yellow zone corresponds with $0.0001 \geq \beta \geq 0.05$, and the green zone corresponds with $\beta > 0.05$. The model is rejected if it falls into the red zone. The model is accepted if it falls into the green zone. The BIS (1996, p. 9) recommends the model be adjusted if it falls into the yellow zone.

Let n be the number of exceptions in which the income cannot cover the credit limit set by the model. Given the α default probability and the N independent loans, the probability β of type-I error is

$$\beta = \sum_{i=n}^{N} b_i \qquad (7.1)$$

where b_i is the binomial probability of exactly i exceptions out of N loans.

$$b_i = \binom{N}{i}(1-\alpha)^{N-i}\alpha^i \qquad (7.2)$$

and $\binom{N}{i} = \frac{N!}{i!(N-i)!}$.

The BIS approach is conservative. By its construction, models that recommend smaller credit limits are less likely to fall into the red zone. Although banks are safer from fewer defaults, they may lose valuable businesses with respect to the accepted default probability (α).

II.4.2 The Likelihood Approach

The likelihood approach proposed by Kupiec (1995) is considered because it is commonly applied in the literature on distribution tests. It does not have the weakness found for the BIS approach. The Kupiec approach is based on the binomial probability of the model's exceptions. If the model is accurate, the exception ratio $\left(\frac{n}{N}\right)$ should be close to α.

Kupiec (1995) relies on this observation to show that the following likelihood ratio (LR) statistic for an accurate model must be distributed as a chi-squared variable with one degree of freedom. However, the LR statistic cannot be computed when n = 0.

$$\text{LR} \quad = \quad -2\,\mathbf{ln}\left\{(1-\alpha)^{N-n}\alpha^{n}\right\} + 2\,\mathbf{ln}\left\{\left(1-\frac{n}{N}\right)^{N-n}\left(\frac{n}{N}\right)^{n}\right\}. \qquad (8)$$

II.4.3 Test Samples

We will conduct both in-sample and out-of-sample tests for validity of the models for the sample crops. In the in-sample test, we estimate the models' parameters from the full sample, use the estimates to set the credit limit, and then apply that same sample set to check for the number of exceptions. The test is not very realistic because in reality the credit limit set from the available data is used for the next production season. However, the test is necessary and can be considered preliminary. Our relatively small sample sets do not allow us to use a part of the sample for the estimation and leave enough observations for a reliable out-of-sample test.

We recognize the need for out-of-sample tests for model validity. But the tests need a large data set. In order to proceed with the test, we bootstrap 1,250 observations from the original sample set of each crop.[1] This technique is recommended by Sobehart et al. (2000). We use the first 250 observations to estimate the models' parameters and set the credit limits. Then we test these limits against the sample in the next draw. The procedure is repeated 1,000 times, in which the most recent 250 observations are used for the estimation. This number of observations is recommended by the BIS (1996, p. 5).

III. DATA

This study focuses on the credit limits set for the production of five major crops in Thailand--rice, maize, sorghum, soybean, and mungbean. The sample rates of returns are time-series and cross-sectional data of the crops in all the provinces in four production regions. They are computed from the season's income net of the production costs. The income is estimated by the product of the average output per rai and the average output price in provinces.[2] The production costs are the average production costs per rai of the produce in the region. The costs include land rent, labor costs, funding costs, fertilizer, insecticide, gas, depreciation, etc. The data range from the 1981/1982 production season to the 1998/1999 season for provinces in the regions. These data are collected from the Office of Agricultural Economics, Ministry of Agriculture and Agricultural Co-operatives.

Rice can be cultivated in irrigated and non-irrigated areas. We have 16 return series for this crop. The first four series--Rice1, Rice2, Rice3 and Rice4, are the rice return in non-irrigated areas in the northern, northeastern, central, and southern regions of Thailand, where the numbers 1, 2, 3, and 4 indicates the regions in which it is cultivated respectively. In the irrigated region, farmers can choose to grow rice either

---

[1] The credit limits are estimated under the assumed distributions from the full sample and are reported earlier in Table 1. The simulated returns are used here only for validity tests.

[2] One rai is approximately 0.4 acre.

once or twice a year. The series Rice_IR1 to Rice_IR 4 are the returns in the four regions, where the farmers choose to grow it only once. When the farmers choose to grow it twice annually, they can do it from March to June and from November to April of the next year. The next eight series--Second Rice1_1 to Second Rice1_4 and Second Rice2_1 to Second Rice2_4, are the series for the first crop and the second crop for the four regions.

Maize, sorghum, soybean and mungbean can be cultivated from March to July and from August to February of the next year for the four regions, except for soybean and sorghum in the south where the climate allows only the first crops. This constitutes 28 return series from Maize1_1 to Sorghum2_3, where the former number identifies the cultivation season and the latter number identifies the region.

TABLE 1

DESCRIPTIVE STATISTICS OF CROP RETURNS

Statistics	Crop											
	Rice1	Rice2	Rice3	Rice4	Rice_IR1	Rice_IR2	Rice_IR3	Rice_IR4	Second Rice1_1	Second Rice1_2	Second Rice1_3	Second Rice1_4
Mean	28.14	10.96	4.22	-7.25	60.58	38.80	45.55	10.70	34.63	27.63	32.93	9.67
Std. Dev.	38.25	25.93	31.11	21.98	41.81	37.20	48.60	30.80	40.58	36.26	42.21	27.00
Skewness	0.53	0.83	0.92	0.48	0.10	0.32	0.92	0.34	0.55	0.67	0.42	0.65
Kurtosis	2.58	5.85	5.71	3.37	3.08	2.87	4.09	2.66	2.75	2.99	2.79	3.40
Max	135.52	130.93	162.37	71.46	201.14	147.44	228.30	90.46	159.91	162.97	161.76	107.18
Min	-48.15	-52.06	-68.49	-53.95	-82.73	-49.45	-57.16	-50.85	-35.05	-40.14	-82.43	-38.83
5^{th} Percentile	-24.66	-28.74	-41.87	-41.34	-6.84	-18.97	-15.18	-33.52	-20.40	-19.49	-26.09	-27.23
95^{th} Percentile	97.34	51.30	54.48	31.62	129.57	104.74	137.16	67.47	116.12	93.74	106.77	58.14
Jarque-Bera	15.56*	135.87*	140.75*	10.67*	0.54	5.44	80.79*	5.21	14.79*	23.15*	12.89*	12.88*
Observations	289	300	315	238	288	297	425	212	280	311	406	167

Statistics	Crop											
	Second Rice2_1	Second Rice2_2	Second Rice2_3	Second Rice2_4	Maize1_1	Maize1_2	Maize1_3	Maize1_4	Maize2_1	Maize2_2	Maize2_3	Maize2_4
Mean	24.54	4.41	25.32	1.60	17.79	22.62	18.79	-13.27	17.28	16.24	14.77	2.27
Std. Dev.	38.42	31.45	39.41	26.97	31.62	35.08	41.41	38.21	40.32	32.12	38.95	46.99
Skewness	0.34	0.50	0.17	0.64	-0.04	0.29	0.51	0.63	0.21	0.06	0.54	0.59
Kurtosis	2.78	2.59	2.58	3.80	2.83	2.77	2.99	2.48	2.98	2.82	3.48	2.76
Max	140.75	87.61	132.74	107.67	103.94	113.42	144.90	68.12	146.57	113.42	156.70	106.45
Min	-56.86	-56.36	-84.96	-54.48	-68.11	-51.04	-63.79	-76.56	-71.76	-51.04	-75.20	-80.40
5^{th} Percentile	-29.02	-38.84	-31.51	-33.37	-33.47	-39.23	-45.01	-56.39	-51.65	-38.79	-44.98	-43.94
95^{th} Percentile	90.84	59.50	89.45	47.19	68.34	62.52	101.99	58.40	83.81	62.23	86.72	82.90
Jarque-Bera	4.67	12.10*	3.80	12.07*	0.44	2.99	10.96*	2.17	1.83	0.27	11.09*	1.15
Observations	221	247	318	128	314	134	249	28	244	134	192	19

Note: * and ** indicate the statistic is significant at a 1% and 5% level

Statistics	Crop									
	Mungbea n1_1	Mungbea n1_2	Mungbean 1_3	Mungbea n1_4	Mungbea n2_1	Mungbea n2_2	Mungbea n2_3	Mungbean 2_4	Soybean 1_1	Soybean 1_2
Mean	30.09	22.34	32.24	17.40	36.02	25.00	22.22	48.38	20.15	22.89
Std. Dev.	31.65	33.82	39.40	25.99	37.98	33.96	36.21	40.28	27.55	31.23
Skewness	0.37	0.22	0.16	-0.26	-0.18	-0.02	1.05	0.82	0.50	0.94
Kurtosis	2.93	2.28	2.94	3.01	3.30	3.90	6.33	3.09	4.07	4.29
Max	120.49	99.91	131.35	76.55	151.54	119.26	208.31	147.89	150.72	133.14
Min	-39.56	-53.98	-74.97	-47.03	-94.77	-86.64	-59.21	-10.49	-47.00	-41.95
5^{th} Percentile	-19.36	-26.28	-23.66	-29.10	-26.08	-27.02	-25.69	-5.39	-20.46	-15.31
95^{th} Percentile	86.38	82.34	101.41	54.40	93.63	79.12	78.69	125.69	64.74	81.43
Jarque-Bera	6.58**	4.36	0.81	0.72	1.87	4.06	121.36*	3.45	27.15*	26.76*
Observations	288	147	188	65	201	119	188	31	304	124

Statistics	Crop									
	Soybean 1_3	Soybean 2_1	Soybean2 _2	Soybean 2_3	Sorghum 1_1	Sorghum 1_2	Sorghum 1_3	Sorghum2 _1	Sorghum 2_2	Sorghum 2_3
Mean	33.14	35.84	15.89	17.85	14.44	-0.05	16.81	13.50	4.95	19.74
Std. Dev.	34.46	36.00	27.62	36.51	29.31	35.90	48.20	33.46	28.17	29.76
Skewness	0.34	0.12	0.06	0.49	0.60	0.08	3.20	1.44	-0.17	0.63
Kurtosis	2.60	3.17	2.57	3.02	3.56	2.04	19.85	6.83	2.99	4.92
Max	131.74	150.05	79.77	127.37	102.95	60.21	313.75	141.79	60.63	142.90
Min	-41.06	-87.69	-49.97	-51.69	-44.41	-51.76	-53.76	-44.37	-56.84	-55.53
5th Percentile	-17.62	-18.07	-30.59	-33.61	-25.28	-45.99	-32.50	-32.85	-48.29	-27.58
95th Percentile	90.84	92.35	61.89	81.91	61.12	46.47	84.28	65.67	52.80	61.68
Jarque-Bera	4.42	1.11	1.35	2.78	4.88	0.35	1042.16*	95.76*	0.26	27.01*
Observations	172	305	164	69	66	9	77	100	52	123

Note: * and ** indicate the statistic is significant at a 1% and 5% level

Table 1 reports descriptive statistics of the returns on the 44 sample crops. The average returns on most crops, except for the Rice4, Maize1_4, and Sorghum1_1, are positive. The returns on the same crops show variations across production regions.

The standard deviations are average about 35%, which is quite high when they are compared with the grand mean of about 20%, suggesting that the crop returns are very volatile. All the return samples are positively skewed, except for the Maize1_1 series. This result is similar to what has been reported by previous studies for the crops in other countries.

At a 95% confidence level, however, the Jarque-Bera (JB) test can reject normality only for 22 crops. And at a 99% confidence level, it can reject normality for only 19 case. This finding helps us to justify the use of the normal distribution as the benchmark for comparison because the distribution does not necessarily describe the crop return distribution poorly.

IV. EMPIRICAL RESUTLS

IV.1 MAXIMUM CREDIT LIMITS

We estimate the maximum credit limits from the Ramirez distributions and normal distributions for the sample crops and report the results in Table 2. The limits are set for the acceptable default probabilities (α) of 1% and 5%.[3]

[3] The parameters of the Ramirez distributions are estiamted using maximum likelihood and the credit limits are set with respect to the α100th percentiles of the 10,000 simulated returns. These estimates are not reported but are available from the corresponding author upon request. The parameters for the normal distributions are the means and standard deviations of the sample crops in Table 1.

TABLE 2

CREDIT LIMITS SET UNDER COMPETING DISTRIBUTIONS

FOR THE ACCEPTABLE DEFAULT PROBABILITIES OF 1 AND 5 PERCENT

Crops	Credit Limits Set under Competing Distributions*			
	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Rice1	60.21	39.02	74.48	65.22
Rice2	49.44	50.54	71.96	68.31
Rice3	40.37	31.74	59.80	53.05
Rice4	49.63	41.53	60.01	56.59
Rice_IR1	66.31	63.16	93.25	91.80
Rice_IR2	62.45	52.13	81.90	77.61
Rice_IR3	59.82	32.31	81.19	65.60
Rice_IR4	49.34	38.94	64.41	60.03
Second Rice1_1	64.98	40.08	78.88	67.88
Second Rice1_2	67.35	43.15	78.88	67.99
Second Rice1_3	49.65	34.58	69.82	63.50
Second Rice1_4	61.20	46.77	71.76	65.26
Second Rice2_1	48.07	35.03	66.77	61.34
Second Rice2_2	48.33	31.14	60.03	52.68
Second Rice2_3	39.99	33.50	63.15	60.50
Second Rice2_4	51.66	38.76	62.93	57.24
Maize1_1	43.72	44.12	65.43	65.78
Maize1_2	50.45	41.09	68.77	65.05
Maize1_3	40.01	22.31	58.49	50.67
Maize1_4	24.28	-2.30	36.39	23.88
Maize2_1	30.39	23.33	53.97	50.95
Maize2_2	43.50	41.40	64.43	63.40
Maize2_3	38.65	24.03	57.14	50.71
Maize2_4	17.76	-7.22	40.87	24.97

Crops	Credit Limits Set under Competing Distributions*			
	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Mungbean1_1	66.30	56.35	82.24	68.06
Mungbean1_2	53.17	43.54	71.03	56.05
Mungbean1_3	46.25	40.44	69.58	55.02
Mungbean1_4	57.47	56.84	74.95	66.46
Mungbean2_1	48.21	47.53	73.74	61.58
Mungbean2_2	38.48	45.87	71.19	58.44
Mungbean2_3	55.45	37.85	71.83	51.25
Mungbean2_4	84.41	54.53	96.33	69.43
Soybean1_1	63.73	55.96	78.42	66.15
Soybean1_2	64.69	50.12	82.03	61.68
Soybean1_3	64.90	52.85	81.34	65.60
Soybean2_1	54.76	51.96	78.16	65.28
Soybean2_2	53.79	51.54	71.50	61.75
Soybean2_3	49.28	32.78	65.21	46.29
Sorghum1_1	58.52	46.15	71.93	56.99
Sorghum1_2	26.08	16.30	46.32	29.59
Sorghum1_3	52.02	4.50	67.69	22.34
Sorghum2_1	41.32	35.54	68.39	47.92
Sorghum2_2	39.78	39.31	59.01	49.74
Sorghum2_3	52.97	50.40	74.56	61.41

Note: *Credit limits cannot be negative. The negative credit limits reported for Maize1_4 and Maize2_4 under normality are mathematical artifacts.

From the table, it is found that the credit limits set under the Ramirez distributions are higher than the ones set under the normal distributions for most of the cases. These results are expected from the fact in Table 1 that the crop returns are positively skewed. The credit policies under the normal distribution tend to be more conservative. Given the true but unobserved distributions, the realized default cases under the normal distribution are necessarily fewer. It should be noted, however, that a more conservative credit limit is not necessarily preferred because it may result in banks losing valuable businesses of acceptable default risk. A preferred credit limit should most correspond with the chosen default probability α.

IV.2 VALIDITY TESTS

IV.2.1 In-Sample Tests

Table 3 reports the numbers of exceptions for the Ramirez and normal distributions, when the default probability is 1% and 5%. Let us turn first to the BIS' three-zone test. We find from the reported numbers of exceptions that the limits set under the two competing distributions are in the green zone for all the crops and for the two acceptable default probabilities.[4] All the limits can pass the test. Hence, based on the BIS' three-zone tests we cannot differentiate the performance of the two models.

TABLE 3

NUMBERS OF EXCEPTIONS UNDER THE COMPETING DISTRIBUTIONS

The numbers of exceptions are tested for the validity of credit limits by the Kupiec 1995 test. Significance at 1% and 5% are indicated by * and **, respectively.

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Rice1	2	0	13	6**
Rice2	1	1	19	11
Rice3	5	1	20	8**
Rice4	2	0	14	7
Rice_IR1	1	1	15	13
Rice_IR2	2	1	17	11
Rice_IR3	6	0	16	9*
Rice_IR4	1	0	9	7

[4] The zone identification for the sample crops can be obtained from the corresponding author upon request.

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Second Rice1_1	1	0	13	2*
Second Rice1_2	2	0	13	2*
Second Rice1_3	3	1	12**	9*
Second Rice1_4	1	0	7	4
Second Rice2_1	1	0	9	6
Second Rice2_2	2	0	11	4*
Second Rice2_3	3	1	9	9
Second Rice2_4	1	0	6	2**
Maize1_1	4	4	13	13
Maize1_2	2	0	11	5
Maize1_3	4	0	17	7
Maize1_4	1	0	1	1
Maize2_1	2	0	14	13
Maize2_2	0	0	9	8
Maize2_3	2	0	11	5
Maize2_4	0	0	1	1
Mungbean1_1	2	0	16	0
Mungbean1_2	1	0	6	4
Mungbean1_3	3	2	8	7
Mungbean1_4	1	1	5	5
Mungbean2_1	2	2	10	10
Mungbean2_2	1	2	5	5
Mungbean2_3	1	0	9	4**
Mungbean2_4	0	0	2	0
Soybean1_1	2	1	15	12
Soybean1_2	3	0	4	4
Soybean1_3	2	0	8	6
Soybean2_1	2	2	14	13
Soybean2_2	1	1	10	10
Soybean2_3	1	0	4	1

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Sorghum1_1	1	0	3	2
Sorghum1_2	0	0	0	0
Sorghum1_3	1	0	4	0
Sorghum2_1	0	0	6	2
Sorghum2_2	0	0	5	5
Sorghum2_3	1	1	9	5

Also in Table 3, we denote the significance of the Kupiec tests at 1% and 5% by * and **, respectively.[5] From the table, the test cannot reject the credit limits set under either distribution for any crop when the default probability is 1 percent. However, when the probability is 5 percent, the limit under the Ramirez distribution can be rejected only once for Second Rice1_3 at a 5% significance level. For the normal distribution, the credit limits are rejected at a 1% level in five cases for Rice_IR3, Second Rice1_1, Second Rice 1_2, Second Rice1_3, and Second Rice 2_2. They are rejected at a 5% level in four cases for Rice1, Rice3, Second Rice2_4 and Mungbean2_3.

The credit limits under the Ramirez distribution are more consistent with the data than those under the normal distribution. The test results and the exception numbers jointly indicate that the credit limits set under the normal distribution are too low to be consistent with the default probability, especially when it is set at 5%.

IV.2.2 Out-Of-Sample Tests

The simulated returns enable us to generate 1,000 samples for the out-of-sample BIS and Kupiec tests. For the BIS test, the yellow zone covers the range from 15 to 23 exceptions (62 to 76 exceptions) for the 1%- (5%-) default probability. For the Kupiec test, the non-rejection region at 1% (5%) significance is [4,17] ([34,68]) and [5,16] ([38,64]) exceptions for the 1% and 5% default probability, respectively. Table 4 reports the number of exceptions with the test results. * and ** indicate 1% and 5% significance, respectively.

[5] The LR statistics can be obtained upon request.

TABLE 4

OUT-OF-SAMPLE TESTS FOR THE VALIDITY

OF CREDIT LIMITS UNDER COMPETING DISTRIBUTIONS

The tests use 250 estimation samples and roll forward for 1,000 iterations, hence constituting 1,000 test samples. For the BIS' three-zone test, the yellow zone covers 15 to 23 exceptions for a 1% default probability and 62 to 76 for a 5% default probability. The Kupiec test rejects the limits at 1% (5%) significance when the exception number is outside the acceptance ranges [4,17] ([5,16]) and [34,68] ([38,64]) for a 1% and 5% default probability, respectively. * and ** indicate significance at 1% and 5%.

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Rice1	12 Green	0* Green	47 Green	20* Green
Rice2	12 Green	1* Green	66** Yellow	41 Green
Rice3	11 Green	4** Green	63 Yellow	28* Green
Rice4	14 Green	0* Green	65** Yellow	27* Green
Rice_IR1	3** Green	1* Green	58 Green	48 Green
Rice_IR2	5 Green	2* Green	63 Yellow	45 Green
Rice_IR3	13 Green	0* Green	39 Green	19* Green
Rice_IR4	9 Green	0* Green	40 Green	28* Green

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Second Rice1_1	6 Green	0* Green	44 Green	6* Green
Second Rice1_2	6 Green	0* Green	48 Green	18* Green
Second Rice1_3	9 Green	0* Green	40 Green	20* Green
Second Rice1_4	10 Green	0* Green	43 Green	28* Green
Second Rice2_1	5 Green	0* Green	36** Green	22* Green
Second Rice2_2	8 Green	0* Green	49 Green	21* Green
Second Rice2_3	1* Green	0* Green	57 Green	26* Green
Second Rice2_4	16 Yellow	0* Green	44 Green	25* Green
Maize1_1	8 Green	7 Green	30* Green	24* Green
Maize1_2	0* Green	0* Green	82* Red	76* Yellow
Maize1_3	10 Green	1* Green	32* Green	23* Green
Maize1_4	19* Yellow	0* Green	40 Green	33* Green
Maize2_1	3* Green	0* Green	65** Yellow	62 Yellow
Maize2_2	0* Green	0* Green	74* Yellow	78* Red

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Maize2_3	11 Green	1* Green	49 Green	30* Green
Maize2_4	33* Red	0* Green	49 Green	49 Green
Mungbean1_1	9 Green	1* Green	59 Green	44 Green
Mungbean1_2	5 Green	2* Green	43 Green	21* Green
Mungbean1_3	11 Green	11 Green	40 Green	36** Green
Mungbean1_4	10 Green	16 Yellow	66** Yellow	73* Yellow
Mungbean2_1	5 Green	9 Green	47 Green	55 Green
Mungbean2_2	13 Green	13 Green	57 Green	43 Green
Mungbean2_3	10 Green	0* Green	43 Green	18* Green
Mungbean2_4	3* Green	0* Green	59 Green	0* Green
Soybean1_1	12 Green	1* Green	61 Green	39 Green
Soybean1_2	31* Red	0* Green	32* Green	32* Green
Soybean1_3	7 Green	0* Green	58 Green	52 Green

Crops	One-Percent Default Probability		Five-Percent Default Probability	
	Ramirez	Normal	Ramirez	Normal
Soybean2_1	7 Green	9 Green	53 Green	51 Green
Soybean2_2	6 Green	6 Green	60 Green	57 Green
Soybean2_3	10 Green	0* Green	50 Green	20* Green
Sorghum1_1	19* Yellow	0* Green	47 Green	34** Green
Sorghum1_2	0* Green	0* Green	43 Green	40 Green
Sorghum1_3	8 Green	0* Green	61 Green	0* Green
Sorghum1_1	0 Green	0* Green	83* Red	23* Green
Sorghum1_2	0 Green	0* Green	103* Red	103* Red
Sorghum1_3	8 Green	4** Green	67** Yellow	47 Green

From the table, for the 1% default probability the Ramirez limits are in the red for 2 crops, while none of the normality limits is in the red zone. However, when this result is analyzed with the Kupiec tests, we notice that the normality limits are inaccurate. They tend to be too small and are inconsistent with the assumed 1% default probability. The normality limits are rejected at 1% significance for 35 cases and at 5% significance for 2 cases. These rejection cases are many more than those of the Ramirez limits with only 10 rejections at 1% significance and a single rejection at 5% significance. As for the 5% default probability, both Ramirez and normality limits fall into the red zone for two cases. But the Kupiec tests reject the Ramirez limits at 1% significance for only 7 cases as opposed to the normality limits for 28 cases. Based on these empirical tests, we conclude that the Ramirez limits are more accurate and consistent with the assumed default probability than the normality limits.[6]

IV.3 EVALUATING THE BAAC'S CREDIT LIMITS

We demonstrate the application of these resulting Ramirez limits by assessing the performance of the BAAC's credit limits against them. The BAAC is Thailand's largest provider of farm credits. Hence, the appropriate size of its credit limits will affect farmers on a large scale in terms of their production and default.

The BAAC's approach differs from ours. The bank fixes the limits at 60% of the expected income from crop sales, while we set the limits in percentage of today's observed production costs. In order to assess the BAAC's limits against ours, we need the expected income on crop sales to convert the BAAC's limits to the percentages of the production costs.

For a one-baht production cost, the expected income is 1+E(y), where E(y) denotes the expected rate of return. Hence, the BAAC's comparable credit limit must be 0.60{1+E(y)}. Because we cannot observe the expectations E(y) of the BAAC, we have to substitute E(y) by our estimates. We consider 7 choices for the substitutes--the mean return, the maximum, the minimum, the mean plus and minus 1.64 standard deviations, and the returns at the 5^{th} and 95^{th} percentiles. The mean return is considered because it is the unconditional expectation based upon the crop's realized return. The expectations computed from the maximum and minimum give the largest and smallest levels of possible credit limits. The expectations equal to the mean return plus and minus 1.64 standard deviations constitute boundaries covering 90% of the possible returns, when normality is assumed. Finally, the returns at the 5^{th} and 95^{th} percentiles are considered because they are the 90% boundaries of the realized returns. These credit limits are compared with the Ramirez limits in Table 5.

---

[6] We also try 250 and 2500 test samples. The results are qualitatively similar. These results are available upon request.

TABLE 5

THE ASSESSMENT OF THE BAAC'S CREDIT LIMITS FOR SAMPLE CROPS

The table computes the credit limits implied by the BAAC's procedure. These limits are compared with the Ramirez limits under the 1% and 5% default probability. The BAAC's credit limits are set to 0.60 times 1 plus the expected return on sample crops. Seven choices for the expected returns are the average return, the maximum and minimum returns, the mean return plus and minus 1.64 standard deviations, and the returns at the 5^{th} and 95^{th} percentiles.

Crops	Ramirez		BAAC						
	1% Default	5% Default	Mean	Maximum	Minimum	Mean+1.64SD	Mean-1.64SD	5^{th} Percentile	95^{th} Percentile
Rice1	60.21	74.48	76.88	141.31	31.11	114.52	39.25	45.20	118.40
Rice2	49.44	71.96	66.58	138.56	28.76	92.09	41.06	42.76	90.78
Rice3	40.37	59.80	62.53	157.42	18.91	93.14	31.92	34.88	92.69
Rice4	49.63	60.01	55.65	102.88	27.63	77.28	34.02	35.20	78.97
Rice_IR1	66.31	93.25	96.35	180.68	10.36	137.49	55.21	55.90	137.74
Rice_IR2	62.45	81.90	83.28	148.46	30.33	119.88	46.68	48.62	122.84
Rice_IR3	59.82	81.19	87.33	196.98	25.70	135.15	39.51	50.89	142.30
Rice_IR4	49.34	64.41	66.42	114.28	29.49	96.73	36.11	39.89	100.48

Crops	Ramirez		BAAC						
	1% Default	5% Default	Mean	Maximum	Minimum	Mean+1.64SD	Mean-1.64SD	5^{th} Percentile	95^{th} Percentile
Second Rice1_1	64.98	78.88	80.78	155.95	38.97	120.71	40.85	47.76	129.67
Second Rice1_2	67.35	78.88	76.58	157.78	35.92	112.26	40.90	48.31	116.24
Second Rice1_3	49.65	69.82	79.76	157.06	10.54	121.29	38.22	44.35	124.06
Second Rice1_4	61.20	71.76	65.80	124.31	36.70	92.37	39.23	43.66	94.88
Second Rice2_1	48.07	66.77	74.72	144.45	25.88	112.53	36.92	42.59	114.50
Second Rice2_2	48.33	60.03	62.65	112.57	26.18	93.59	31.70	36.70	95.70
Second Rice2_3	39.99	63.15	75.19	139.64	9.02	113.97	36.41	41.09	113.67
Second Rice2_4	51.66	62.93	60.96	124.60	27.31	87.50	34.42	39.98	88.31

Crops	Ramirez		BAAC						
	1% Default	5% Default	Mean	Maximum	Minimum	Mean+1.64SD	Mean-1.64SD	5^{th} Percentile	95^{th} Percentile
Maize1_1	43.72	65.43	70.67	122.36	19.13	101.79	39.56	39.92	101.00
Maize1_2	50.45	68.77	73.57	128.05	29.38	108.09	39.05	36.46	97.51
Maize1_3	40.01	58.49	71.27	146.94	21.73	112.02	30.53	32.99	121.19
Maize1_4	24.28	36.39	52.04	100.87	14.06	89.64	14.44	26.17	95.04
Maize2_1	30.39	53.97	70.37	147.94	16.94	110.04	30.69	29.01	110.29
Maize2_2	43.50	64.43	69.74	128.05	29.38	101.35	38.14	36.73	97.34
Maize2_3	38.65	57.14	68.86	154.02	14.88	107.19	30.54	33.01	112.03
Maize2_4	17.76	40.87	61.36	123.87	11.76	107.60	15.12	33.64	109.74
Mungbean1_1	66.30	82.24	78.05	132.29	36.26	109.20	46.91	48.38	111.83
Mungbean1_2	53.17	71.03	73.40	119.95	27.61	106.68	40.13	44.23	109.40
Mungbean1_3	46.25	69.58	79.34	138.81	15.02	118.11	40.57	45.80	120.85
Mungbean1_4	57.47	74.95	70.44	105.93	31.78	96.01	44.87	42.54	92.64

Crops	Ramirez		BAAC						
	1% Default	5% Default	Mean	Maximum	Minimum	Mean+1.64SD	Mean-1.64SD	5^{th} Percentile	95^{th} Percentile
Mungbean2_1	48.21	73.74	81.61	150.92	3.14	118.98	44.24	44.35	116.18
Mungbean2_2	38.48	71.19	75.00	131.56	8.02	108.42	41.58	43.79	107.47
Mungbean2_3	55.45	71.83	73.33	184.99	24.47	108.96	37.70	44.59	107.21
Mungbean2_4	84.41	96.33	89.03	148.73	53.71	128.66	49.39	56.77	135.41
Soybean1_1	63.73	78.42	72.09	150.43	31.80	99.20	44.98	47.72	98.84
Soybean1_2	64.69	82.03	73.73	139.88	34.83	104.46	43.00	50.81	108.86
Soybean1_3	64.90	81.34	79.88	139.04	35.36	113.79	45.98	49.43	114.50
Soybean2_1	54.76	78.16	81.50	150.03	7.39	116.93	46.08	49.16	115.41
Soybean2_2	53.79	71.50	69.53	107.86	30.02	96.71	42.36	41.65	97.13
Soybean2_3	49.28	65.21	70.71	136.42	28.99	106.64	34.78	39.83	109.15
Sorghum1_1	58.52	71.93	68.66	121.77	33.35	97.51	39.82	44.83	96.67
Sorghum1_2	26.08	46.32	59.97	96.13	28.94	95.30	24.64	32.41	87.88
Sorghum1_3	52.02	67.69	70.09	248.25	27.74	117.51	22.66	40.50	110.57
Sorghum2_1	41.32	68.39	68.10	145.07	33.38	101.02	35.18	40.29	99.40
Sorghum2_2	39.78	59.01	62.97	96.38	25.90	90.69	35.25	31.03	91.68
Sorghum2_3	52.97	74.56	71.84	145.74	26.68	101.13	42.56	43.45	97.01

From the table, the Ramirez credit limits set at a 1% and 5% default probability are within the BAAC's ranges, when its limits are set by the minimum and maximum returns, the mean return plus and minus 1.64 standard deviations and the returns at the 5^{th} and 95^{th} percentiles. It is very interesting to find that when the mean returns are used to form the expected income, even though the BAAC's limits are higher than the Ramirez 5%-default limits in most of the cases, the two limits are very close. Therefore, if it is the case that the BAAC's forecasts of farm income is 1 plus the mean return and its accepted default probability is 5%, the credit limits can be justified by the revealed behavior of the sample crop returns.

However, two important points are worth discussing. Firstly, the BAAC's forecasts of farm income are revised each season. So, the forecasts are conditional, changing with the new information set, and are unlikely to match the average returns. As is suggested by Table 1, farm income is very volatile. So, it is difficult to estimate the future income precisely. Even if the average of its conditional forecasts is equal to the mean income, the default probability is not necessarily 5%. Secondly, the BAAC's limits do not relate possible loan sizes with production costs, for which the loans finance. Our approach is more practical. The limits are percentages of the observed production costs and based upon the revealed behavior of the realized farm return. They do not incur forecasting errors. Hence, it is more likely that the resulting defaults under our limits are closer to the target than those under the BAAC's limits are.

V. CONCLUSION

Farm credit is important to the success of farm production. However, too much credit can raise default probability, resulting in farmers losing their home, their farms, and their way of life. In this study, we propose banks use the information on statistical distributions of crop returns to set the credit limits so that borrowing farmers are able to repay their loans by the crop income with an accepted default probability. To set the credit limits, we recommend the technique proposed by Ramirez (1997, 2000) to estimate the return distribution.

REFERENCES

Bank for International Settlements, 1996, *Basle Committee on Banking Supervision: Supervisory framework for the use of " Backtesting" in conjunction with the internal models approach to market risk capital requirement*, Bank for International Settlements, Basle.

Davies, Alan S., 1996, Insolvency in Agriculture: Bad Managers or the Agricultural Policy?, *Applied Economics* 28, 185-193.

Featherstone, A. M., Moss, C. B., Baker, T. G. and Preckel, P. V., 1988, The Theoretical Effects of Farm Policies on Optimal Leverage and the Probability of Equity Losses, *American Journal of Agricultural Economics* 70, 572-579.

Hanson, G. D. and Thompson, J.L., 1980, A Simulation Study of Maximum Feasible Farm Debt Burdens by Farm Type, *American Journal of Agricultural Economics* 62, 727-733.

Just, E. R. and Weniger, Q., 1999, Are Crop Yields Normally Distributed?," *American Journal of Agriculture Economics* 81, 287-304.

Kupiec, Paul H., 1995, Techniques for Verifying the Accuracy of Risk Measurement Models, *Journal of Derivatives* 3, 73-84.

Ramirez, O. A., 1997, Estimation and Use of a Multivariate Parametric Model for Simulating Heteroskedastic, Correlated, Nonnormal Random Variables: The Case of Corn Belt Corn, Soybean, and Wheat Yields, *American Journal of Agriculture Economics* 79, 191-205

Ramirez, O. A., 2000, Parametric Modeling and Simulation of Joint Price-Production Distributions under Non-Normality, Autocorrelation and Heteroscedasticity: A tool for Assessing Risk in Agriculture, *Journal of Agricultural and Applied Economics* 30, 283-297.

Richardson, J, W., Klose. S, L. and Gray. A, W., 2000, An Applied Procedure for Estimating and Simulating Multivariate Empirical (MVE) Probability Distributions In Farm-Level Risk Assessment and Policy Analysis, *Journal of Agricultural and Applied Economics* 32, 299-315.

Sobehart, Jorge R., Sean C. Keenan, and Roger M. Stein, 2000, Benchmarking Quantitative Default Risk Models: A Validation Methodology, Moody's Investor Services, New York.

MEASURING RISK WITH STOCHASTIC JUMPS

Anya Khanthavit, Ph.D.

Professor of Finance and Banking and TRF Senior Researcher

Faculty of Commerce and Accountancy

Thammasat University, Bangkok, Thailand

Tel: (662) 613 2223, 613 2239

Fax: (662) 225 2109

E-mail: akhantha@tu.ac.th

and

Pariyada Srisopitsawat, D.B.A.*

Senior Analyst

Stock Exchange of Thailand

Bangkok, Thailand

Tel: (662) 229 2148

Fax: (662) 654 5825

E-mail: spariyada@hotmail.com

* Corresponding author. Financial supports from Thailand Research Fund are gratefully acknoledged.

ABSTRACT

MEASURING RISK WITH STOCHASTIC JUMPS

We propose a trimodal distribution of returns which combines normal distribution and stochastic jumps, where both the positive and negative jumps are allowed for the presence of asymmetry. We apply the proposed distribution in a Value at Risk (VaR) analysis. The model is compared with the four competing models including the normal distribution, the student's *t* distribution, the extreme value theory, and the bimodal distribution. Using daily returns on S&P500 index, we find that the trimodal distribution gives a better VaR forecast in all performance measures.

JEL classification: C16; C22; C51; G10

Keywords: Risk management; Stochastic jumps; Trimodal distribution; Value at Risk

บทคัดย่อ

การวัดขนาดความเสี่ยงซึ่งพิจารณาพฤติกรรม "การกระโดด" ของราคาหลักทรัพย์

การศึกษาเสนอการแจกแจงซึ่งมีสามโหนกเพื่อพรรณนาพฤติกรรมความเสี่ยงของหลักทรัพย์ ซึ่งอาจมีราคาปรับตัวสูงขึ้นหรือลดลงอย่างรุนแรงบางครั้งในลักษณะกระโดด จากนั้นจึงใช้การแจกแจงนี้ไปพยากรณ์ขนาดของมูลค่าความเสี่ยงของดัชนี S&P 500 เพื่อเปรียบเทียบกับการพยากรณ์ของการแจกแจงรูปแบบอื่น การศึกษาพบว่า การแจกแจงแบบสามโหนกนี้สามารถให้ผลการพยากรณ์ซึ่งแม่นยำกว่าการแจกแจงรูปแบบอื่นอย่างมีนัยสำคัญ

MEASURING RISK WITH STOCHASTIC JUMPS

1. Introduction

Rapid globalization has made firms recognize the growing importance of risk management. This has led to the development of various methods and tools to measure the risks firms face. Value at Risk (VaR) originated by J.P. Morgan RiskMetrics is the popular technique used to measure a portfolio's market risk. It is defined as the maximum expected loss over a given horizon period at a given level of confidence. Nevertheless, the VaR approach has been subjected to several criticisms. The most significant one is the normal distribution assumption which makes the estimated VaR inaccurate because of the presence of fat tails in financial data (Baillie and de Gennaro, 1990; Pagan, 1996; Zangari, 1996a; Campbell et al., 1997). Other studies propose parametric approaches as alternatives by employing more appropriate distributions that can incorporate observed fat tails, such as the student's *t* distribution (Huisman et al., 1998; Pownall and Koedijk, 1999; Glasserman et al., 2000; Lucas, 2000) and the mixture of normal distributions (Zangari, 1996b, 1996c; Venkataraman, 1997; Hull and White, 1998; de Raaij and Raunig, 1999). Those studies reveal that by adjusting for fat tails in the return distributions, their VaR estimates are more accurate than those calculated under the normal distribution assumption. Nevertheless, the main drawback of the parametric methods is that we have to assume the distribution for returns which might be incorrect.

There are nonparametric approaches which do not impose any distribution assumption. The simplest one is the historical simulation. Allen (1994), Crnkovic and Drachman (1996), Mahoney (1996), Aussenegg and Pichler (1997), and Barone-Adesi et al. (1998, 1999, 2000) find the improvement in the VaR estimates obtained from the historical simulation over the normal approach. However, Kupiec (1995) finds that it is inefficient when dealing with tail observations. The estimated VaR is subject to both high variation and upward bias. Another approach to estimate VaR, being developed under the nonparametric paradigm, is the kernel density estimation (Butler and Schachter, 1997; Gouriéroux et al., 2000) which is a way of generalizing a histogram constructed with the sample data. The advantage of this approach is the smooth sampling distribution. Nevertheless, Daníelsson and de Vries (2000) comment that the advantages of the kernel method are dependent on a properly constructed kernel distribution which will provide good estimates for the interior but the tails are not described adequately.

Since one drawback of previous VaR measures is the focus of the estimation on central observations or on the returns under normal market conditions rather than the observations in the tails which come from the extreme events, many studies, such as Daníelsson and de Vries (1997a, 1997b, 2000), Embrechts et al. (1997), Bensalah(2000) , Daníelsson and Morimoto (2000), Këllezi and Gilli (2000) ,Longin (2000), McNeil and Frey (2000), Neftci (2000), Byströ m(2001) ,and Jondeau and Rockinger)2001(, have employed the extreme value theory, which is the study of the tails of distributions in particular, in estimating VaR. Their results confirm that the extreme value approach provides a more accurate VaR estimates than the other approaches, especially when the tails become more extreme.

However, since the presence of discontinuities is found in financial data (Ball and Torous, 1985; Jorion, 1989; Vlaar and Palm, 1993), then the stochastic jump process should be included in the model of financial returns. So, in order to improve the VaR estimates, we propose the trimodal distribution of returns which combines normal distribution and stochastic jumps. The study on the jumps occurred in the extreme events gives importance to the tail area which is the main focus of the VaR. Further, we focus on both the lower and upper tails. Then, the model is general and can accommodate the analysis of the portfolios which may contain both long and short positions. Traders who have the long positions are concerned when the price of the asset falls. On the other hand, the traders who have the short positions borrowed and sold the asset in the market, then they will lose money when the price increases because they have to buy the asset at a higher price to give it back to the lender. Therefore, the upper or right tail is of importance for the short positions while the lower or left tail for the long positions. Since our model is based on parametric approach, the inclusion of the two-sided jumps nests the model with one-sided jump and can avoid misspecification and bias. Further, the inclusion of both positive and negative jumps allow for the possibility of the asymmetric distribution where the symmetric distribution such as normal and student's *t* distributions are unlikely to give appropriate results. Our trimodal distribution can explain the skewness and kurtosis of the series, as will be shown in Appendix A.

To test the performance of our model, we compare the trimodal distribution with the four competing models which are the normal distribution, the student's *t* distribution, the extreme value approach, and the bimodal distribution. The empirical results from the distribution test which utilizes the information on the entire distribution reveal the better fit of the trimodal distribution while the other models are rejected at a level more than 99%. From the likelihood ratio test based on proportions of failures, the trimodal distribution reveals the superior performance than the normal distribution, the student's *t* distribution, and the extreme value theory and the comparable results to the bimodal distribution. Besides, the trimodal distribution gives the minimum distance from the true model based on the information test. Further, according to the nonnested comparison testing, the trimodal distribution is preferred to the four competing models at all quantiles in the lower tail with only two exceptional cases in the upper tail.

The paper is organized as follows. In section 2, we consider the proposed trimodal distribution and the methodology employed in the estimation. To show that our VaR estimate is improved over the VaRs obtained from other methods, the performance tests and comparisons are also included. Section 3 is concerned with the data employed in the study. The empirical results from our trimodal distribution and competing models are presented in section 4. Finally, section 5 gathers some concluding remarks.

2. Methodology

2.1. Estimation of a trimodal distribution

According to the parametric approach, the first step in estimating VaR is to model the distribution of returns. Because of the discontinuities presented in financial data, our model allows for the stochastic jumps where both the positive and negative jumps are included in the model. The model is considered as the trimodal distribution since there are three possibilities that can occur which are no jump, positive jump, and negative jump. The probability is assigned to each case. Then, the model is specified as follows:

$$r_t = \begin{cases} \mu + \varepsilon_t^0 & \text{when no jump} \quad \text{with probability} \quad 1 - p - q \\ (\mu + \mu^+) + \varepsilon_t^+ & \text{when positive jump} \quad \text{with probability} \quad p \\ (\mu + \mu^-) + \varepsilon_t^- & \text{when negative jump} \quad \text{with probability} \quad q \end{cases}$$

where r_t is the daily return at time *t*; μ is the mean return when there is no jump. The positive jump size is assumed to be normally distributed with expectation μ^+ (positive value) and variance η^2 while the negative jump size has the expectation μ^- (negative value) and variance ω^2. When there is no jump, the mean is equal to μ. When the positive jumps occur, we have the mean shifted by μ^+ and the variance is increased by η^2 while when the negative jumps occur, we have the mean shifted by μ^- and the variance is increased by ω^2. They are assumed to be independent of each other. The probabilities of positive and negative jumps are *p* and *q*, respectively. The stochastic jumps are modeled by the Bernoulli process where only one abnormal circumstance is allowed. For practical considerations, since the daily data is employed in this study, no more than one abnormal information arrival is to be expected on average in a day. Then, for these jump intensities, we concentrate on the Bernoulli distribution.

The model by Vlaar and Palm (1993) is considered as a special case of our model when only one-sided jump is assumed, that is, either the probability of positive or negative jump is assumed to be zero. Further, our model also nests the normal distribution which assumes that both the probabilities of the positive and negative jumps are zero. These models may encounter the misspecification problem if the two-sided jumps are presented in the observed data. Besides, our model with stochastic jumps is not the same as the mixture of normal distributions proposed by Zangari (1996b, 1996c) and Venkataraman (1997). In those models, the return can be drawn from one of, for example, two normal disributions by having a binary variable determining which distribution is chosen with specified probability. These two distributions are different where one will have a higher variance to incorporate the unusual events that may happen to increase volatility. The benefit of this approach is that it allows for the possibility that occasionally the return is generated from a distribution with higher variance while maintaining the structure of normal densities and having the binary variable to determine a jump from one distribution to another, not the stochastic jumps. So, the mixture of normal distributions does not reflect the distribution with stochastic jumps but a return distribution that is more volatile and has the fatter tail. Nevertheless, though Zangari (1996c) suggests that the normal mixture approach can improve the VaR estimates over the standard normal approach, it still underestimates VaR by a sizeable amount.

In the trimodal distribution, there are three possibilities for the stochastic jumps which are no jump, positive jump, and negative jump. If the stochastic jump is present, the mean return and volatility will be adjusted by the jump size and volatility drawn from the distribution of the jump. The distribution function of returns is specified by:

$$L(r) = \begin{cases} f(r;\mu,\sigma^2) & \text{with probability} \quad 1-p-q \\ f(r;\mu,\sigma^2) + g(r;\mu^+,\eta^2) & \text{with probability} \quad p \\ f(r;\mu,\sigma^2) + h(r;\mu^-,\omega^2) & \text{with probability} \quad q \end{cases}$$

which leads to

$$L(r) = f(r;\mu,\sigma^2) + p \cdot g(r;\mu^+,\eta^2) + q \cdot h(r;\mu^-,\omega^2)$$

We employ the maximum likelihood technique in estimating our parameters. The log-likelihood function is specified as follows:

$$\ln(L) = -\frac{n}{2}\ln(2\pi) + \sum_{t=1}^{n} \ln \left\{ \begin{aligned} & \left[\frac{(1-p-q)}{(\sigma^2)^{\frac{1}{2}}}\right] \exp\left[-\frac{(\varepsilon_t - (-p\mu^+ - q\mu^-))^2}{2\sigma^2}\right] \\ & + \left[\frac{p}{(\sigma^2+\eta^2)^{\frac{1}{2}}}\right] \exp\left[-\frac{(\varepsilon_t - ((1-p)\mu^+ - q\mu^-))^2}{2(\sigma^2+\eta^2)}\right] \\ & + \left[\frac{q}{(\sigma^2+\omega^2)^{\frac{1}{2}}}\right] \exp\left[-\frac{(\varepsilon_t - ((1-q)\mu^- - p\mu^+))^2}{2(\sigma^2+\omega^2)}\right] \end{aligned} \right\}$$

To test whether the trimodal exists, we will perform tests on the positive and negative sides. Both the joint tests and the tests on individual estimates will be employed. *The tests on the joint hypotheses* are performed on the estimated probabilities and means through the Wald test. The null hypothesis for the two estimated means is specified as:

$$H_0 : \mu^+ = \mu^- = 0$$

For the joint hypothesis, if the above null hypothesis could not be rejected, it means that the trimodal does not exist. On the other hand, if we could reject this null hypothesis, then it means that there exists the trimodal in the return distribution. Further, we perform the joint test on the two estimated probabilities.

$$H_0 : p = q = 0$$

The interpretation is the same as the previous test, that is, to confirm the existence of the trimodal distribution, this joint hypothesis has to be rejected. Next, *the tests on individual estimates* through the *t*-tests also enable us to investigate the existence of the trimodal distribution. The four estimates which are (1) the mean of positive jumps; $H_0 : \mu^+ = 0$, (2) the mean of negative jumps; $H_0 : \mu^- = 0$, (3) the probability of positive jumps; $H_0 : p = 0$, and (4) the probability of negative jumps; $H_0 : q = 0$, are tested whether they are significant. To confirm that the trimodal exists, all of the above null hypotheses on individual estimates should be rejected. On the other hand, if we could not reject any of them, then it means that there exists only the unimodal or the normal distribution. However, if the null hypotheses for positive side could not be rejected but those for negative side is rejected, then the bimodal return distribution including only the negative jumps is correctly specified. In contrast, if it is appeared that the two parameters on positive jumps are statistically significant while the remaining parameters are not, it means that there exists the bimodal distribution with only the positive jumps.

Since our proposed trimodal distribution of returns is a complex model and deals with many variables, then we employ the Monte Carlo simulation in estimating VaR. The values are sorted from the largest profit down to the largest loss and VaR is defined as the largest loss within the distribution of potential future values measured at a certain confidence level.

2.2. Performance tests

To test the performance of our model, we will compare our proposed model with the normal distribution, the student's *t* distribution, the extreme value approach, and the bimodal distribution as in Vlaar and Palm (1993). The first competing model considered is the basic approach to VaR originated by J.P. Morgan RiskMetrics. It is often assumed that *f*(*r*) represents ***a normal distribution*** with mean μ and variance σ^2. Then, the VaR for the upper and lower tails are estimated as follows:

$$VaR_U = \mu + Z_\alpha \sigma$$
$$VaR_L = \mu - Z_\alpha \sigma$$

where Z_α is obtained from the standard normal table. Besides, we consider another competing model that incorporates the fat tails usually found in financial data. ***The student's t distribution***, with fatter tails, provides an alternative to the normal distribution (Huisman et al., 1998; Pownall and Koedijk, 1999; Glasserman et al., 2000; Lucas, 2000). The fat tails imply the higher chance of extremely high losses than under the normal distribution. Then, the VaR obtained from the student's *t* distribution is likely to be higher than the one estimated from the normal. The VaR estimation under the student's *t* model is the same as the normal except the replacement of t_α which can be received from the *t* table.

Next, we consider the latest innovation in VaR estimation employed in Daníelsson and de Vries (1997a, 1997b, 2000), Embrechts et al. (1997), Bensalah(2000) ,Daníelsson and Morimoto (2000), Këllezi and Gilli (2000) ,Longin (2000), McNeil and Frey (2000), Neftci (2000), Byströ m(2001) ,and Jondeau and Rockinger)2001 .(***The extreme value theory*** tells us what the asymptotic distribution of extreme values should look like. Based on the peak over threshold (POT) method, the observations which are greater than a certain threshold *u* are considered as the exceedances. According to the extreme value theorem, the conditional excess distribution function is well approximated by the generalized Pareto distribution (Balkerma and de Haan, 1974; Pickands, 1975).

$$G_{\xi,\sigma}(y) = \begin{cases} 1-\left(1-\dfrac{\xi}{\sigma}y\right)^{1/\xi} & \text{if} \quad \xi \neq 0 \\ 1-e^{-y/\sigma} & \text{if} \quad \xi = 0 \end{cases}$$

where the parameter ξ is the tail index which will give an indication of the heaviness of the tails. The bigger the parameter ξ, the heavier the tail. The maximum likelihood method is employed in estimating parameters of the GPD.

Lastly, following the study by Vlaar and Palm (1993), the stochastic jump process is included in ***the bimodal distribution*** where only one-sided jump, either positive or negative, is incorporated in the model. The jump size has a mean μ^* and variance υ^2 with the jump probability *d*.

$$r_t = \begin{cases} \mu + \varepsilon_t^0 & \text{when there is no jump} \quad \text{with probability} \quad 1-d \\ (\mu + \mu^*) + \varepsilon_t^* & \text{when there is a jump} \quad \text{with probability} \quad d \end{cases}$$

Then, to test and compare the performance of these models with our trimodal distribution, we employ three different tests which are the distribution test for the fit of the distribution, the likelihood ratio test for the accuracy of the VaR estimated from each competing model, and the information test for the specification and comparison of those VaR models.

2.2.1. Distribution test

In order to test for the appropriateness of the distribution, we perform the distribution test proposed by Crnkovic and Drachman (1996) which utilizes the information on the entire distribution. This test procedure is based on the Rosenblatt (1952) transformation that transforms all the realizations of profit/loss into the series of independent and identically distributed random variables as follows:

$$x_t = \int_{-\infty}^{r_t} \hat{f}(u)du = \hat{F}(r_t)$$

where r_t is the portfolio profit/loss realization and $\hat{f}(u)$ is the forecasted distribution. Rosenblatt (1952) shows that x_t is iid and distributed uniformly on (0,1). Therefore, we can use this probability integral transformation and test for violations of either independence or uniformity. To test for uniformity, Crnkovic and Drachman (1996) suggest using the Kuiper statistic. This statistic is based on the distance between the empirical and the theoretical cumulative distribution function. Then, the smaller the distance, the better the fit to the theoretical distribution. The Kuiper statistic is given by:

$$K = \max_{0 \le x \le 1}\left(D(x) - x\right) + \max_{0 \le x \le 1}\left(x - D(x)\right)$$

The distribution of K for n observations is as follows:

$$\mathrm{P}\left(k < K\right) = G\left(\left[\sqrt{n} + 0.155 + \frac{0.24}{\sqrt{n}}\right]K\right)$$

Where

$$G(\lambda) = 2\sum_{j=1}^{\infty}\left(4j^2\lambda^2 - 1\right)e^{-2j^2\lambda^2}$$

2.2.2. Likelihood ratio test

Following Kupiec (1995), the likelihood ratio test based on proportion of failures is implemented. The proportion of failures is obtained through the backtesting approach where the VaR estimates from each method are compared with the realized returns. Then, the model will perform well if the proportion of failures is closed to the expected number. We perform the out-of-sample performance test where the estimation window is 1000.[1] In the rolling-window method, we re-estimate the model each day and roll the 1000-day window to the end of the sample. That is, from the total number of observations *n*, the first window range is from *t* = 1, 2…, 1000. After the estimation, we roll the 1000-day window to *t* = 2, 3…, 1001. This rolling-window method is appropriate when there is a change in the regime because the old regime samples will be excluded from the window range as we roll the window forward. On the other hand, we also employ another method that is to append the window which is suitable for the stable samples because the number of observations will grow bigger as time passes. For the appending-window method, with the 1000-day window, the first window range is the same as the previous method but the second range will be from *t* = 1, 2…, 1001. That is, we do not exclude the first observation from the window because we do not roll the window but append it by one observation each time. For both methods, each time we forecast the next day VaR and count the number of exceptions, which is said to occur whenever the realized returns are not covered by the estimated VaRs. Then, we test whether the proportion of failures is equal to the expected number. The likelihood ratio test statistic is given by:

$$LR = -2Log\left[\left(1-p^*\right)^{n-x}\left(p^*\right)^{x}\right] + 2Log\left[\left(1-\frac{x}{n}\right)^{n-x}\left(\frac{x}{n}\right)^{x}\right] \to \chi_1^2$$

[1] Following many previous studies for comparison purpose, the window range of 1000 is selected which implies that we use less than the last four years of data for each prediction. In addition, if the window range is too short, then the stochastic jumps may not present because the abnormal circumstances which lead to the jumps do not occur frequently.

where p^* is the probability of a failure under the null hypothesis, x is the number of exceptions, and n is the total number of observations.

2.2.3. Information test

Since the likelihood ratio test based on backtesting depends only on the number of exceptions, then to verify the accuracy of the VaR measures, we also follow the information test proposed by Christoffersen et al. (2001) for specification testing and comparing different VaR measures. Since the VaR measure may be misspecified, then we should allow for the possibility of misspecification. Thus, the VaR specification testing in this case becomes the test for misspecification by applying Kitamura and Stutzer (1997) $\mathcal{K}$-test[2] which is based on the intuition that the estimator will minimize the Kullback-Leibler Information Criterion (KLIC). Then, the concept of this approach is to measure the distance of the proposed model to the true but unobserved model based on the information set. The $\mathcal{K}$-test takes the following form:

$$\hat{\kappa}_T = -2T \log M_T(\hat{\beta}_T, \hat{\gamma}_T) = -2T \log\left(\frac{1}{T} \sum_{t=1}^{T} \exp\left[\hat{\gamma}' f(x_t, \hat{\beta}) \right] \right) \rightarrow \chi^2_{r-m}$$

where $\hat{\beta}$ is a parameter vector, $\hat{\gamma}$ is a dual variable,[3] r is the number of moments, and m is the number of estimated parameters. Furthermore, we follow the method proposed by Kitamura (1997) which is developed further for the comparison of the nonnested models based on the difference between the KLIC distances. Under the null hypothesis $M(\beta^*, \gamma^*) = N(\theta^*, \lambda^*)$ which means that the two measures are equally suitable, we have the following:

$$\sqrt{T} \left(M_T \left(\hat{\beta}_T, \hat{\gamma}_T \right) - N_T \left(\hat{\theta}_T, \hat{\lambda}_T \right) \right) \rightarrow N(0, \sigma^2_\infty)$$

Where

$$\sigma^2_\infty = \lim_{T \to \infty} Var\left(\frac{1}{\sqrt{T}} \sum_{t=1}^{T} \exp\left[\gamma^{*\prime} f(x_t, \beta^*) \right] - \exp\left[\lambda^{*\prime} g(x_t, \theta^*) \right] \right)$$

---

[2] This $\mathcal{K}$-test is the information theoretic version of the GMM *J*-test and it is suggested as the alternative to that *J*-test because of its applicability to the nonnested comparisons of possibly misspecified models.

[3] See Kitamura and Stutzer (1997, Sec. 2.2) and Christoffersen et al. (2001, Sec. A.3.1.) for a discussion and a proof.

Then, the significantly large positive value of the test statistic will lead to a rejection of the null hypothesis in favor of the VaR model which is denoted by $E\left[f(x,\beta^{*})\right]=0$.

3. Data

Following many previous studies for comparison purpose, this study employs the daily data of S&P500 index at closing time obtained from Datastream. The sample range is from January 2, 1969 to August 10, 2001 resulting in 8508 observations. Table 1 reports the descriptive statistics.

Table 1

Descriptive Statistics

This table reports the descriptive statistics of the daily returns on the S&P500 index. The total number of observations is 8508 ranging from January 2, 1969 to August 10, 2001. The Jarque-Bera test of normality is performed. The *p*-value of the test is given below in the parenthesis.

S&P500	
Number of Observations	8508
Mean	0.000332
Median	0.000079
Maximum	0.090994
Minimum	-0.204139
Standard Deviation	0.009603
Skewness	-1.123277
Kurtosis	31.733510
Jarque-Bera Test	294468.696933
	(0.0000)

During the sample period, the mean of the returns is 0.0332 percent while the maximum and mimimum returns tend to deviate much from the mean. Further, the skewness parameter indicates the asymmetry in the return distribution and the excess kurtosis is revealed. The nonnormality of the distribution of returns is confirmed by the Jarque-Bera test of normality which rejects the null hypothesis that the distribution of returns on the S&P500 index during the observed period is normal at any statistical level of significance. Then, the approach based on normal distribution will give the inaccurate VaR estimate. Besides, according to the presence of skewness, then the symmetric distribution such as the normal and student's *t* distributions are unlikely to give appropriate results.

We investigate further the plot of the S&P500 returns and its histogram for the evidences of the jumps occurred during the observation period. Figure 1 shows the plot of the daily returns on the S&P500 index and figure 2 presents the histogram of returns.

Figure 1

Daily Returns on the S&P500 Index

This figure plots the daily returns on the S&P500 index from January 2, 1969 to August 10, 2001.

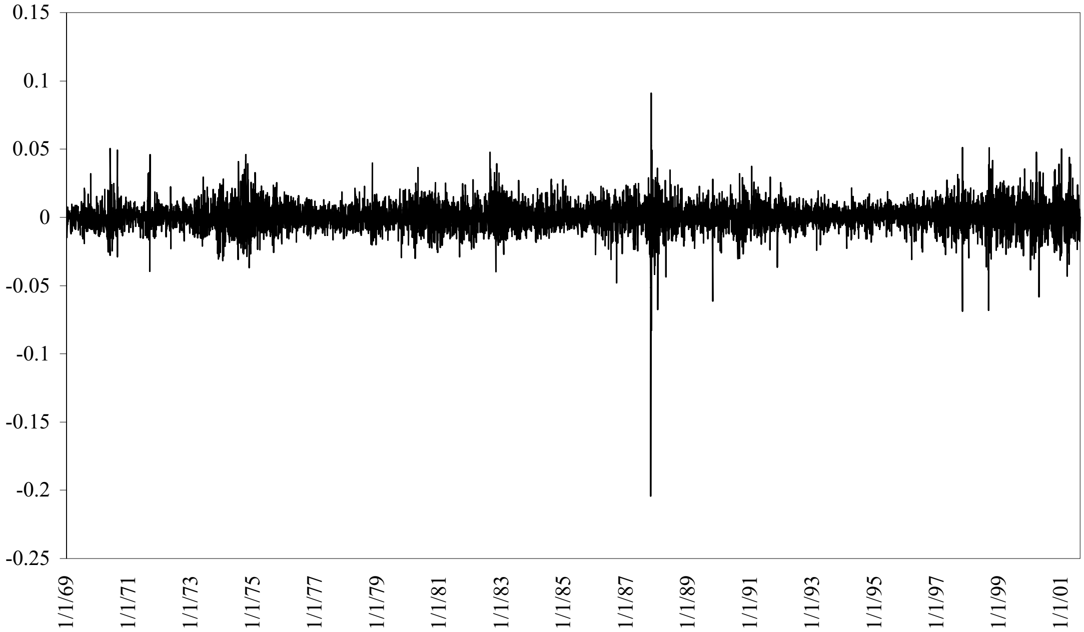

Figure 2

Histogram of S&P500 Returns

This figure presents the histogram of the returns on S&P500 index from January 2, 1969 to August 10, 2001. The enlarged sections of the histogram corresponding to the lower and upper tails are also shown.

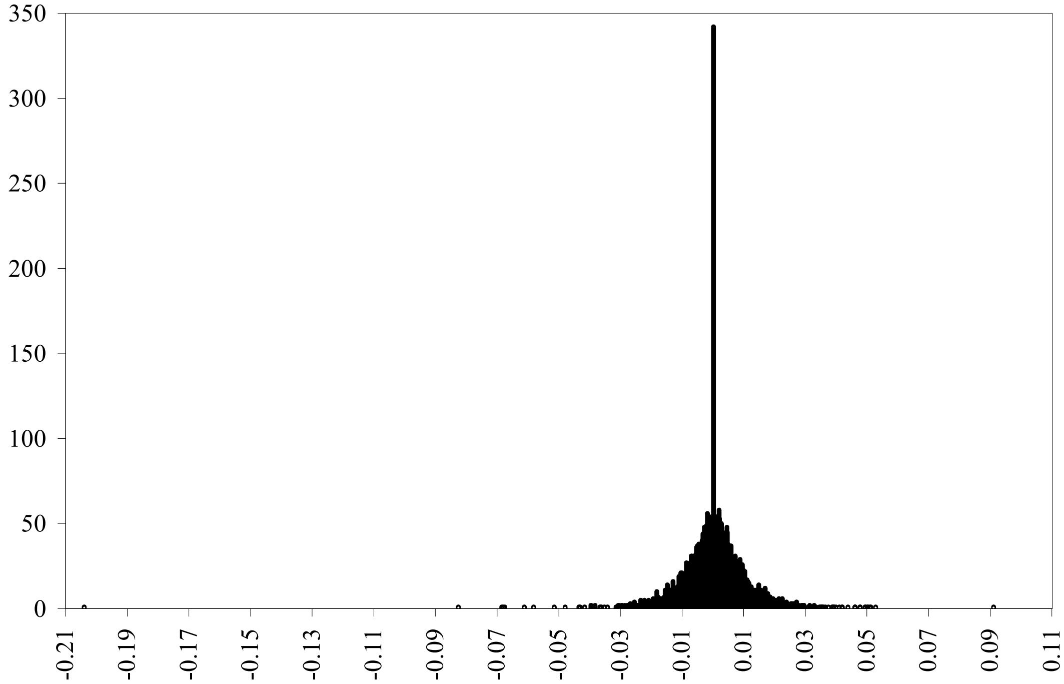

Fig. 2a. Histogram of the returns on S&P500 index

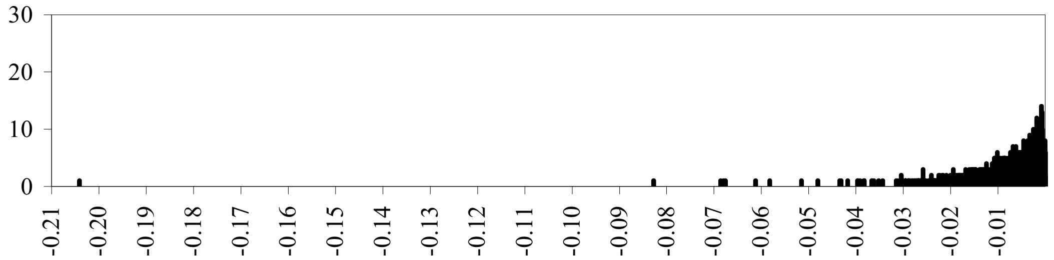

Fig. 2b. Enlarged section of the histogram of the returns on S&P500 index corresponding to the lower tail

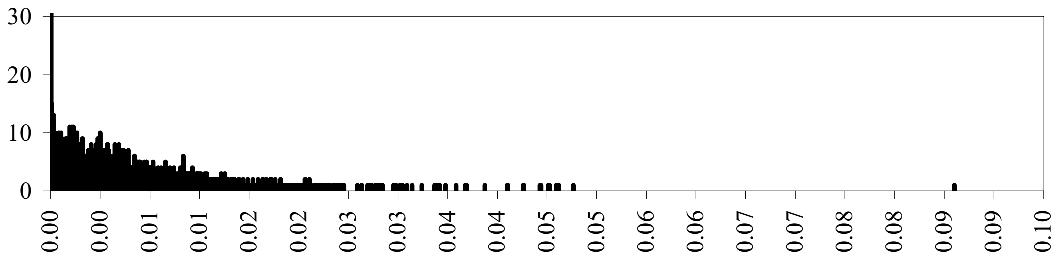

Fig. 2c. Enlarged section of the histogram of the returns on S&P500 index corresponding to the upper tail

By observing the plot in figure 1, it shows that there are extremely large positive and negative returns during the well-known October 1987 and also in some other periods. So, these indicate possible presence of the jumps during the observed period. We further examine figure 2 which presents the histogram of returns on S&P500 index. Since jumps are observed on both tails of return distribution, then the bimodal distribution assumption may be misspecified if there are positive and negative jumps. In addition, the extreme value theory that reveals the fat tails in the distribution does not fit the return distribution that appears to have jumps in the tails because the distributions assumed in the extreme value approach are smooth and unimodal while the jumps in the tail area may give a wavy shape and discontinuity may occur if jumps are large. Thus, based on the histogram of the return distribution of S&P500 index, among the competing models, our proposed trimodal distribution is the most appropriate model for the distribution of returns where both the positive and negative jumps are observed.

4. Empirical results

4.1. Estimation of a trimodal distribution

Table 2 contains the maximum likelihood estimation of the parameters in our proposed trimodal distribution of returns.

Table 2

Estimation of a Trimodal Distribution

This table gives the maximum likelihood estimates of the parameters of the trimodal distribution of returns on S&P500 index. Eight parameters are estimated: the mean return μ, the variance of returns σ^2, the probability of positive jumps *p*, the mean of positive jumps μ^+, the variance of positive jumps η^2, the probability of negative jumps *q*, the mean of negative jumps μ^-, and the variance of negative jumps ω^2. In the estimation, we enforce the positivity of μ^+ and the negativity of μ^-. The *p*-values of each estimate are given below in the parentheses. The joint hypotheses $H_0 : \mu^+ = \mu^- = 0$ and $H_0 : p = q = 0$ are also tested. The Wald tests on the means and probabilities of positive and negative jumps are carried out. The *p*-values of the tests are given below in the parentheses.

Parameter	Estimate (*p*-value)
Mean	0.000268 (0.0043)
Variance	0.000020 (0.0000)
Probability of positive jump	0.012601 (0.0000)
Mean of positive jump	0.002109 (0.0000)
Variance of positive jump	0.001584 (0.0000)
Probability of negative jump	0.562191 (0.0000)
Mean of negative jump	-0.000519 (0.0000)
Variance of negative jump	0.000094 (0.0000)

Null Hypothesis	Wald test (*p*-value)
$H_0 : \mu^+ = \mu^- = 0$	23925.308 (0.0000)
$H_0 : p = q = 0$	18971.192 (0.0000)

The estimated jump parameters which are the mean of the positive jumps (μ^+), the mean of the negative jumps (μ^-), the probability of positive jumps (*p*), and the probability of negative jumps (*q*) are statistically significant. Then, these mean that there exist both the positive and negative jumps in the return distribution which reveal the suitability of our trimodal distribution in modelling the sample series. The estimated parameter *q* happens to be very large because in the trimodal distribution, the tail areas are not always be modeled as another node but may appear as the continuous curve. The significance of the stochastic jumps is further supported by the Wald tests which reject both the joint hypothesis that the two probabilities are equal to zero and the joint hypothesis that the two means are equal to zero. The model can also capture the skewness since the means (in absolute value) of the positive and negative jumps are not equal. So, this fits the distribution of realized returns where the skewness is revealed. Further, the fat tails are captured by the significance of stochastic jumps both in the lower and upper tails.

4.2. Performance tests

4.2.1. Distribution test

The distribution test procedure suggested by Crnkovic and Drachman (1996) which is based on the entire distribution is performed. Figure 3 presents the histograms of transformed returns of all five models.

Figure 3

Histogram of Transformed Returns

This figure displays the histograms of the transformed returns under the distributions predicted by the five models: normal distribution, student's *t* distribution, extreme value theory, bimodal distribution, and trimodal distribution. The transformed returns are plotted against the expected uniform distribution.

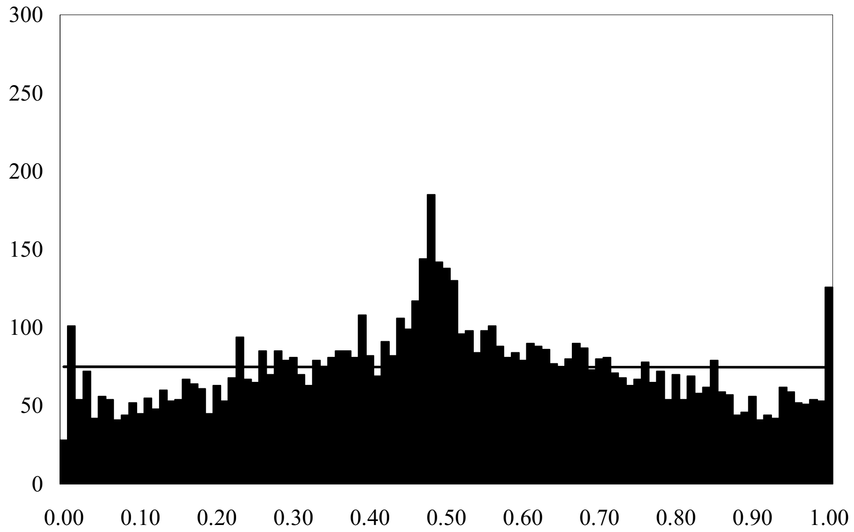

Fig. 3a. Normal distribution

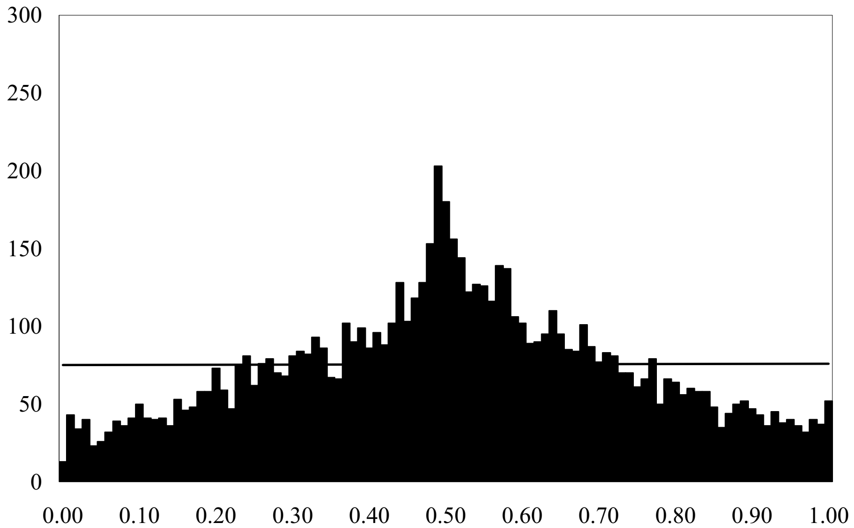

Fig. 3b. Student's *t* distribution

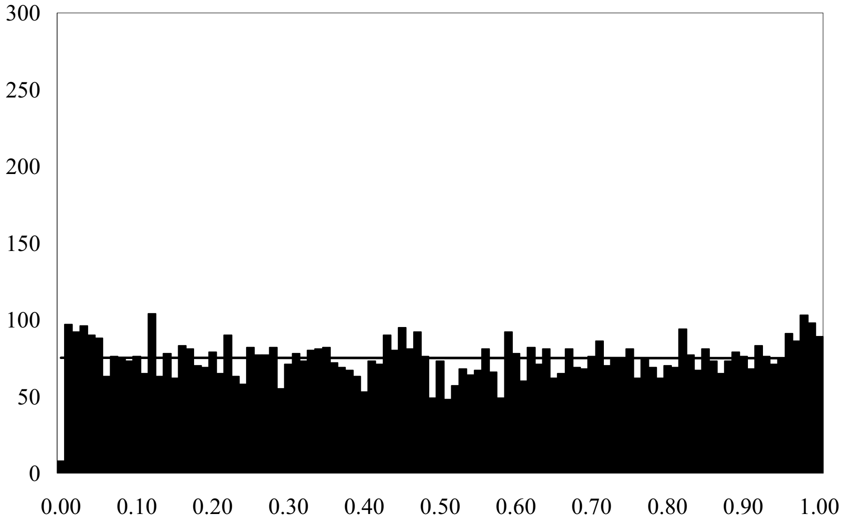

Fig. 3c. Extreme value theory

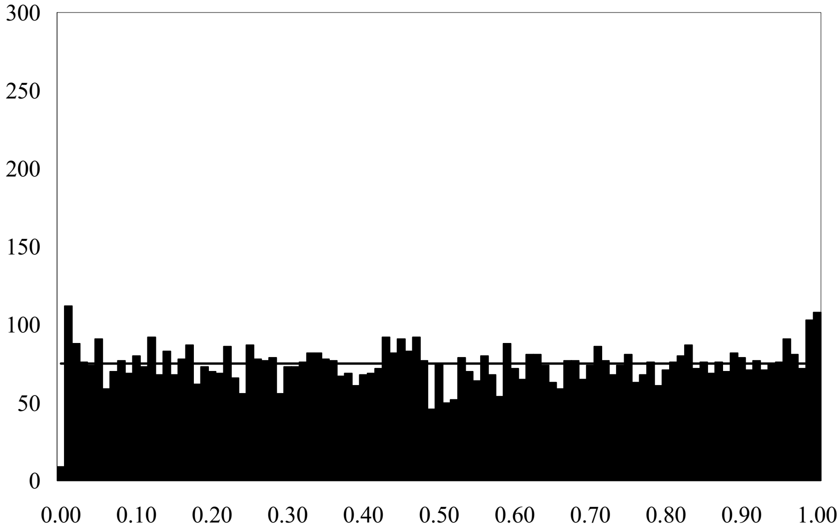

Fig. 3d. Bimodal distribution

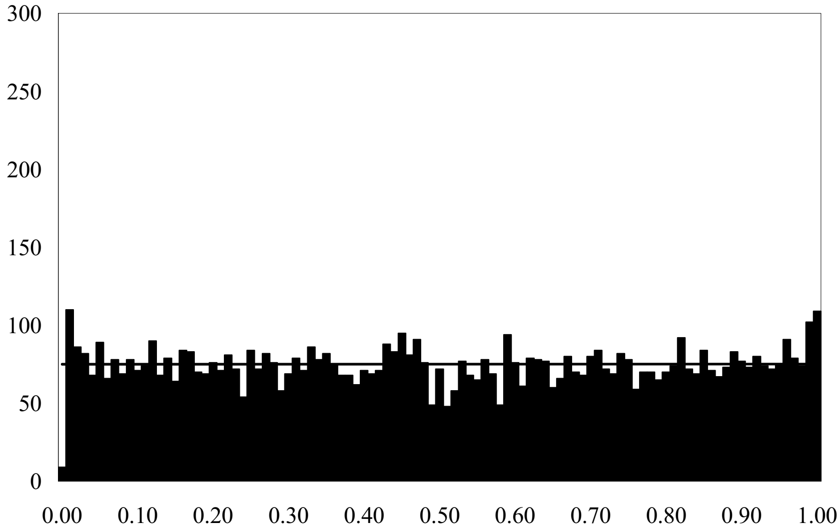

Fig. 3e. Trimodal distribution

Since the transformed data should be uniformly distributed, if the assumed model is correct, the histogram should be closed to flat. Diebold et al. (1998) demonstrate that histogram of transformed returns can reveal useful information about model failures. Figure 3 shows that the normal distribution deviates significantly from the uniform distribution since there are higher numbers of observations in the center and also in the tails. With respect to the tails, since the student's *t* model is the fat-tailed distribution then the large losses and gains should be captured by the student's *t* model. However, the student's *t* model shows the higher probability mass in the center of the distribution and only a few observations left in the tails which make it differ from the uniform distribution. This will be confirmed by the uniformity test. On the other hand, the trimodal distribution, the bimodal distribution, and the extreme value approach perform better with respect to the tails where the lower tail has better fit than the upper tail. Since the histograms of transformed data are closed to flat, then they are closer to the uniform distribution. To check for uniformity, the test based on the Kuiper statistic is performed. Table 3 displays the distribution test results.

Table 3

Distribution Test

This table shows the results from the distribution tests on five models: normal distribution, student's *t* distribution, extreme value theory, bimodal distribution, and trimodal distribution. Under the null hypothesis that the distribution is uniform, the Kuiper statistic of each model is displayed in the table. The *p*-value is given below in the parenthesis.

Model	Kuiper Statistic (*p* -value)
Normal Distribution	0.1030
	(0.0000)
Student's *t* Distribution	0.1809
	(0.0000)
Extreme Value Theory	0.0267
	(0.0002)
Bimodal Distribution	0.0224
	(0.0062)
Trimodal Distribution	0.0217
	(0.0100)

The results show that the null hypothesis of uniformity is rejected at a level of more than 99% for all models except the trimodal distribution. Therefore, according to the distribution test, our proposed trimodal distribution is considered as the most appropriate distribution among the five competing models, followed by the bimodal distribution and the extreme value theory. Besides, the test statistics indicate that the student's *t* model performs worst in reproducing the distribution of returns.

4.2.2. Likelihood ratio test

The performance test of our VaR estimated from the underlying trimodal returns distribution and the comparisons are performed through the Kupiec (1995) likelihood ratio test. The likelihood ratio test statistics based on proportions of failures from the five models are presented in table 4.

Table 4

Likelihood Ratio Test

This table displays the results from the likelihood ratio tests based on the ratios of exceptions from the backtesting approach on five models: normal distribution, student's *t* distribution, extreme value theory, bimodal distribution, and trimodal distribution. Panel A and B present the results from the rolling-window and the appending-window methods, respectively. The likelihood ratio test statistics are defined with the quantile. Four quantile estimates are considered: 0.99, 0.975, 0.95, and 0.90. The likelihood ratio test statistics are shown in the table. The *p*-values are given below in the parentheses.

Model	Lower tail				Upper tail			
	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
	Panel A: Rolling-window method							
Normal Distribution	27.2807	7.8502	0.3718	6.1372	26.6561	11.6871	1.9423	3.1289
	(0.0000)	(0.0051)	(0.5420)	(0.0132)	(0.0000)	(0.0006)	(0.1634)	(0.0769)
Student's *t* Distribution	4.1655	10.9186	19.7993	41.1609	7.1076	10.1975	15.8440	29.4978
	(0.0413)	(0.0010)	(0.0000)	(0.0000)	(0.0077)	(0.0014)	(0.0001)	(0.0000)
Extreme Value Theory	18.5423	12.5981	0.0002	57.2367	4.0811	11.3903	8.5352	0.2051
	(0.0000)	(0.0004)	(0.9889)	(0.0000)	(0.0434)	(0.0007)	(0.0035)	(0.6506)
Bimodal Distribution	8.7744	6.4209	5.8993	2.3514	6.5711	8.6139	7.2481	4.1089
	(0.0031)	(0.0113)	(0.0151)	(0.1252)	(0.0104)	(0.0033)	(0.0071)	(0.0427)
Trimodal Distribution	9.1684	7.3591	5.2743	1.7164	6.2313	8.1011	7.6058	3.9118
	(0.0025)	(0.0067)	(0.0216)	(0.1902)	(0.0126)	(0.0044)	(0.0058)	(0.0479)
	Panel B: Appending-window Method							
Normal Distribution	16.4497	5.5421	0.3310	9.3699	24.8175	10.2376	0.8430	5.0187
	(0.0000)	(0.0186)	(0.5651)	(0.0022)	(0.0000)	(0.0014)	(0.3585)	(0.0251)
Student's *t* Distribution	6.6298	15.8598	23.8705	39.3611	6.1719	9.8476	17.7596	33.2533
	(0.0100)	(0.0001)	(0.0000)	(0.0000)	(0.0130)	(0.0017)	(0.0000)	(0.0000)
Extreme Value Theory	14.5826	13.2545	2.1642	5.7514	19.7659	48.5348	61.8624	90.7796
	(0.0001)	(0.0003)	(0.1413)	(0.0165)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bimodal Distribution	2.3501	11.0969	5.7399	0.5418	1.3870	3.4392	5.7399	8.1694
	(0.1253)	(0.0009)	(0.0166)	(0.4617)	(0.2389)	(0.0637)	(0.0166)	(0.0043)
Trimodal Distribution	1.9367	10.8070	5.2743	0.5055	1.3870	2.9476	4.9743	8.5912
	(0.1640)	(0.0010)	(0.0216)	(0.4771)	(0.2389)	(0.0860)	(0.0257)	(0.0034)

With the rolling-window method, in all cases except one, our proposed trimodal distribution is rejected. On the other hand, with the appending-window method, our model is rejected in only four cases. So, the trimodal distribution reveals the better performance with the appending-window method than with the rolling-window method. The results are comparable to the bimodal distribution but the better fit over the rest. The student's *t* model has the worst performance since it is rejected in all cases both with the rolling- and appending-window methods. This can be explained by the proportion of failures which is the main concept of this approach. Since the student's *t* distribution tends to give the larger VaR numbers than others, then it is violated less frequent than other models resulting in the lower number of exceptions and lower proportion of failures. So, the likelihood ratio test which provides the test whether the proportion of failures is equal to the expected number gives the high test value for the student's *t* model in which the proportion of failures is far from the expected number. Though the low number of exceptions can satisfy the regulators, the company may not desire the overestimation of the VaR that results in excess capital.

4.2.3. Information test

In the likelihood ratio test based on the backtesting, the information provided by the predicted distribution is reduced to a binary variable and the magnitude of the distance are not considered. Only the number of exceptions is taken into account. So, following the information test proposed by Christoffersen et al. (2001), the specification testing results are summarized in table 5 and the results from performing the pairwise comparison testing of the five competing models are shown in table 6.

Table 5

Information Test

This table presents the results from the information test on five models: normal distribution, student's *t* distribution, extreme value theory, bimodal distribution, and trimodal distribution. Under the null hypothesis that the model is correctly specified, the K-test value is presented in the table. The *p*-value is given below in the parenthesis.

Model	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
	Panel A: Lower tail			
Normal Distribution	5.7368	7.6663	16.4686	28.3719
	(0.1251)	(0.0534)	(0.0009)	(0.0000)
Student's *t* Distribution	5.7370	7.6573	16.4661	28.6751
	(0.1251)	(0.0537)	(0.0009)	(0.0000)
Extreme Value Theory	4.2628	8.0803	18.1441	28.9468
	(0.2345)	(0.0444)	(0.0004)	(0.0000)
Bimodal Distribution	5.8572	8.5109	15.4866	29.4375
	(0.1188)	(0.0366)	(0.0014)	(0.0000)
Trimodal Distribution	3.6052	4.1494	7.6289	13.1255
	(0.3074)	(0.2458)	(0.0543)	(0.0044)
	Panel B: Upper tail			
Normal Distribution	23.1654	51.6550	35.0210	26.8735
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Student's *t* Distribution	23.1652	40.7780	35.0443	26.8816
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Extreme Value Theory	17.2791	43.8944	41.5406	27.7745
	(0.0006)	(0.0000)	(0.0000)	(0.0000)
Bimodal Distribution	18.1701	50.9007	37.7309	26.7776
	(0.0004)	(0.0000)	(0.0000)	(0.0000)
Trimodal Distribution	18.4060	35.7496	28.4350	37.6786
	(0.0004)	(0.0000)	(0.0000)	(0.0000)

Table 6

Nonnested Comparison Test

This table demonstrates the results from the pairwise comparison testing based on the KLIC distances of the five models: normal distribution, student's *t* distribution, extreme value theory, bimodal distribution, and trimodal distribution. Under the null hypothesis that the two models are equally suitable, the test values are shown in the table. The *p*-values are given below in the parentheses. If the null hypothesis is rejected, a positive value indicates that Model 1 is preferred while a negative value denotes that Model 2 is preferred.

Model 1	Model 2	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
		Panel A: Lower tail			
Trimodal	**Normal**	0.6201	0.7956	1.2803	1.7637
		(0.5352)	(0.4263)	(0.2004)	(0.0778)
Trimodal	**Student's t**	0.6202	0.7990	1.2806	1.7955
		(0.5351)	(0.4243)	(0.2003)	(0.0726)
Trimodal	**EVT**	0.1394	0.9104	1.3944	1.8362
		(0.8891)	(0.3626)	(0.1632)	(0.0663)
Trimodal	**Bimodal**	0.6761	0.9579	1.1983	1.8899
		(0.4990)	(0.3381)	(0.2308)	(0.0588)
Bimodal	**Normal**	-0.3204	-0.7822	0.1705	-0.7970
		(0.7486)	(0.4341)	(0.8646)	(0.4254)
Bimodal	**Student's t**	-0.3159	-0.7676	0.1704	-0.6524
		(0.7521)	(0.4427)	(0.8647)	(0.5141)
Bimodal	**EVT**	-0.4214	-0.2662	0.7886	-0.2986
		(0.6735)	(0.7901)	(0.4304)	(0.7652)
EVT	**Normal**	0.4191	-0.2687	-0.2303	-0.3699
		(0.6752)	(0.7881)	(0.8179)	(0.7114)
EVT	**Student's t**	0.4187	-0.2760	-0.2310	-0.1913
		(0.6754)	(0.7825)	(0.8173)	(0.8483)
Student's t	**Normal**	-0.0077	0.0716	0.0328	-0.8528
		(0.9939)	(0.9429)	(0.9739)	(0.3938)
		Panel B: Upper tail			
Trimodal	**Normal**	0.8346	1.3387	0.6372	-1.2445
		(0.4039)	(0.1807)	(0.5240)	(0.2133)
Trimodal	**Student's t**	0.8346	0.3750	0.6393	-1.2440
		(0.4040)	(0.7077)	(0.5226)	(0.2135)
Trimodal	**EVT**	-0.1459	0.8156	1.0525	-1.1483
		(0.8840)	(0.4147)	(0.2926)	(0.2508)
Trimodal	**Bimodal**	-0.0403	1.3569	0.8699	-1.2578
		(0.9678)	(0.1748)	(0.3843)	(0.2085)
Bimodal	**Normal**	1.7609	0.2096	-1.4460	0.1884
		(0.0783)	(0.8340)	(0.1482)	(0.8505)
Bimodal	**Student's t**	1.7688	-0.5936	-1.4285	0.2600
		(0.0769)	(0.5528)	(0.1531)	(0.7949)
Bimodal	**EVT**	-0.1607	-1.2690	0.4528	1.1900
		(0.8723)	(0.2045)	(0.6507)	(0.2340)
EVT	**Normal**	0.9888	1.2048	-0.7833	-0.8789
		(0.3227)	(0.2283)	(0.4334)	(0.3795)
EVT	**Student's t**	0.9875	-0.2010	-0.7798	-0.8975
		(0.3234)	(0.8407)	(0.4355)	(0.3694)
Student's t	**Normal**	0.0051	0.5974	-0.4876	-0.0371
		(0.9959)	(0.5502)	(0.6259)	(0.9704)

Considering the results from the specification testing for the lower tail, the trimodal distribution performs better than the other four models since the model is not rejected in all cases except at the 0.90 quantile in which all models are rejected. Nevertheless, for the upper tail, all models are rejected at all quantile which implies that all models are misspecified. Even though the models are misspecified, the test values which are the KLIC distances still be important because, among those misspecified models, we can see which misspecified model is the closest to the true but unobserved distribution. So, we perform the pairwise comparison test whether one of the two models is better than one another. The model with smaller KLIC distance will be considered as the better model. From table 6, the trimodal distribution is preferred to the four competing models in all cases with only two exceptional cases in the upper tail. However, since most of the models are misspecified, then the significance tests of the nonnested comparisons reveal only a few rejections and at the 10% significance level. At the 0.90 quantile of the lower tail, the trimodal distribution is significantly better than the normal distribution, the student's *t* distribution, the model based on the extreme value, and also the bimodal distribution.

5. Concluding remarks

This study is concerned with the application of the proposed distribution of returns in risk management. We propose the trimodal distribution for the returns on S&P500 index and apply it with the estimation of the Value at Risk (VaR). The maximum likelihood estimation and the Monte Carlo simulation are employed. The VaR obtained from our model is compared with the four competing models including the normal distribution, the student's *t* distribution, the extreme value theory, and the bimodal distribution. The performance of these models are tested and compared by three different tests which are the distribution test, the likelihood ratio test, and the information test.

The distribution test which utilizes the information on the entire distribution reveals the better fit of the trimodal distribution where the other models are rejected at a level more than 99%. Furthermore, according to the likelihood ratio test based on proportions of failures, the trimodal distribution reveals the superior performance than the normal distribution, the student's *t* distribution, and the extreme value theory and the comparable results to the bimodal distribution. In addition, among the competing models, the trimodal distribution gives the minimum distance from the true but unobserved distribution based on the information test. This is confirmed by the nonnested comparison testing which performs the pairwise ranking of all the models. The trimodal distribution is preferred to the four competing models at all quantiles in the lower tail with only two exceptional cases in the upper tail.

The limitaion of our study is that all models are assumed to be unconditional. Then, they do not respond to changing volatility and tend to generate large number of exceptions in stress periods. Then, our trimodal distribution can be extended to the conditional estimates and this issue is addressed in our current development.

Acknowledgements

We would like to thank the Thailand Research Fund (TRF) for a research grant. We would also like to thank Peter Christoffersen, Roger Koenker, and Manfred Gilli for sharing their Gauss and Matlab source code, and Casper G. de Vries and Stefan Mittnik for their constructive suggestions. We are also grateful to Sureeporn Yamashita, Jin E. Zhang, Latha Shanker, Tong Yu, Arnat Leemakdej, and seminar and workshop participants at the 2002 Thammasat-TRF Workshop, Thammasat University, Bangkok; the 2002 APFA/PACAP/FMA Finance Conference, Tokyo; the 2002 FMA Annual Meeting, San Antonio, Texas; and the 2002 10th Annual Professor Sangvien Indaravijaya Conference on Thailand's Financial Markets, Thammasat University, Bangkok for helpful comments.

Appendix A. Moments of the stochastic jump process

The distribution of the error term of our trinomial model with normally distributed jump sizes and innovations can be expressed as follows:

$$\begin{aligned}\varepsilon_t \quad \sim \quad & \left(1-p-q\right)N\left(-p\mu^{+}-q\mu^{-},\sigma^{2}\right)+pN\left((1-p)\mu^{+}-q\mu^{-},\sigma^{2}+\eta^{2}\right)\\ & +qN\left((1-q)\mu^{-}-p\mu^{+},\sigma^{2}+\omega^{2}\right)\end{aligned}$$

From this distribution, the first four unconditional moments are computed:

A.1. First moment

$$\begin{aligned}E(\varepsilon_t) \quad = \quad & \left(1-p-q\right)\left(-p\mu^{+}-q\mu^{-}\right)\\ & +p\left((1-p)\mu^{+}-q\mu^{-}\right)+q\left((1-q)\mu^{-}-p\mu^{+}\right)\end{aligned}$$

$$\mu_1 = \begin{aligned}&\left(-p\mu^+ - q\mu^- + p^2\mu^+ + pq\mu^- + pq\mu^+ + q^2\mu^-\right)\\ &+p\left(\mu^+ - p\mu^+ - q\mu^-\right) + q\left(\mu^- - q\mu^- - p\mu^+\right)\end{aligned}$$

$$M_1 = 0$$

A.2. Second moment

$$E(\varepsilon_t)^2 = \begin{aligned}&(1-p-q)\left\{\left(-p\mu^+ - q\mu^-\right)^2 + \sigma^2\right\}\\ &+p\left\{\left((1-p)\mu^+ - q\mu^-\right)^2 + \sigma^2 + \eta^2\right\}\\ &+q\left\{\left((1-q)\mu^- - p\mu^+\right)^2 + \sigma^2 + \omega^2\right\}\end{aligned}$$

$$\mu_2 = \begin{aligned}&\left\{(1-p-q)\left(-p\mu^+ - q\mu^-\right)^2 + (1-p-q)E\sigma^2\right\}\\ &+\left\{p\left(\mu^+ - p\mu^+ - q\mu^-\right)^2 + p\sigma^2 + p\eta^2\right\}\\ &+\left\{q\left(\mu^- - q\mu^- - p\mu^+\right)^2 + q\sigma^2 + q\omega^2\right\}\end{aligned}$$

$$M_2 = \begin{aligned}&(1-p)(1+q)\left(p\left(\mu^+\right)^2 - q\left(\mu^-\right)^2\right)\\ &+(p+q-3)pq\mu^+\mu^- + \sigma^2 + p\eta^2 + q\omega^2\end{aligned}$$

A.3. Third moment

$$E(\varepsilon_t)^3 = \begin{aligned}&(1-p-q)\left\{\left(-p\mu^+ - q\mu^-\right)^3 + 3\left(-p\mu^+ - q\mu^-\right)\sigma^2\right\}\\ &+p\left\{\left((1-p)\mu^+ - q\mu^-\right)^3 + 3\left((1-p)\mu^+ - q\mu^-\right)\left(\sigma^2 + \eta^2\right)\right\}\\ &+q\left\{\left((1-q)\mu^- - p\mu^+\right)^3 + 3\left((1-q)\mu^- - p\mu^+\right)\left(\sigma^2 + \omega^2\right)\right\}\end{aligned}$$

$$\mu_3 = \begin{aligned}&(1-p-q)\left(-p\mu^+ - q\mu^-\right)^3 + 3(1-p-q)\left(-p\mu^+ - q\mu^-\right)\sigma^2\\ &+p\left((1-p)\mu^+ - q\mu^-\right)^3 + 3p\left((1-p)\mu^+ - q\mu^-\right)\left(\sigma^2 + \eta^2\right)\\ &+q\left((1-q)\mu^- - p\mu^+\right)^3 + 3q\left((1-q)\mu^- - p\mu^+\right)\left(\sigma^2 + \omega^2\right)\end{aligned}$$

$$
\begin{aligned}
&= p\left(\mu^{+}\right)^{3}\left(p^{3}+2p^{2}-3p+1\right)+q\left(\mu^{-}\right)^{3}\left(q^{3}+2q^{2}-3q+1\right) \\
&\quad -3pq\mu^{+}\mu^{-}\left((1-2p)\mu^{+}+(1-2q)\mu^{-}\right)-p^{2}q^{2}\left(\left(\mu^{+}\right)^{3}+\left(\mu^{-}\right)^{3}\right) \\
&\quad +3p\eta^{2}\left(\mu^{+}-p\mu^{+}-q\mu^{-}\right)+3q\omega^{2}\left(\mu^{-}-q\mu^{-}-p\mu^{+}\right)
\end{aligned}
$$

$$
M_{3} = \frac{\begin{bmatrix} p\left(\mu^{+}\right)^{3}\left(p^{3}+2p^{2}-3p+1\right)+q\left(\mu^{-}\right)^{3}\left(q^{3}+2q^{2}-3q+1\right) \\ -3pq\mu^{+}\mu^{-}\left((1-2p)\mu^{+}+(1-2q)\mu^{-}\right)-p^{2}q^{2}\left(\left(\mu^{+}\right)^{3}+\left(\mu^{-}\right)^{3}\right) \\ +3p\eta^{2}\left(\mu^{+}-p\mu^{+}-q\mu^{-}\right)+3q\omega^{2}\left(\mu^{-}-q\mu^{-}-p\mu^{+}\right) \end{bmatrix}}{\begin{bmatrix} (1-p)(1+q)\left(p\left(\mu^{+}\right)^{2}-q\left(\mu^{-}\right)^{2}\right) \\ +\left(p+q-3\right)pq\mu^{+}\mu^{-}+\sigma^{2}+p\eta^{2}+q\omega^{2} \end{bmatrix}^{\frac{3}{2}}}
$$

A.4. Fourth moment

$$
\begin{aligned}
E(\varepsilon_{t})^{4} = \; & (1-p-q)\begin{Bmatrix} \left(-p\mu^{+}-q\mu^{-}\right)^{4}+3\sigma^{4} \\ +6\left(-p\mu^{+}-q\mu^{-}\right)^{2}\sigma^{2} \end{Bmatrix} \\
& +p\begin{Bmatrix} \left((1-p)\mu^{+}-q\mu^{-}\right)^{4}+3\left(\sigma^{2}+\eta^{2}\right)^{2} \\ +6\left((1-p)\mu^{+}-q\mu^{-}\right)^{2}\left(\sigma^{2}+\eta^{2}\right) \end{Bmatrix} \\
& +q\begin{Bmatrix} \left((1-q)\mu^{-}-p\mu^{+}\right)^{4}+3\left(\sigma^{2}+\omega^{2}\right)^{2} \\ +6\left((1-q)\mu^{-}-p\mu^{+}\right)^{2}\left(\sigma^{2}+\omega^{2}\right) \end{Bmatrix}
\end{aligned}
$$

$$
\begin{aligned}
\mu_{4} = \; & (1-p-q)\begin{Bmatrix} \left(-p\mu^{+}-q\mu^{-}\right)^{4}+3\sigma^{4} \\ +6\left(p^{2}\left(\mu^{+}\right)^{2}+2pq\mu^{+}\mu^{-}+q^{2}\left(\mu^{-}\right)^{2}\right)\sigma^{2} \end{Bmatrix} \\
& +p\begin{Bmatrix} \left((1-p)\mu^{+}-q\mu^{-}\right)^{4}+3\left(\sigma^{4}+2\sigma^{2}\eta^{2}+\eta^{4}\right) \\ +6\left((1-p)^{2}\left(\mu^{+}\right)^{2}-2(1-p)q\mu^{+}\mu^{-}+q^{2}\left(\mu^{-}\right)^{2}\right)\left(\sigma^{2}+\eta^{2}\right) \end{Bmatrix} \\
& +q\begin{Bmatrix} \left((1-q)\mu^{-}-p\mu^{+}\right)^{4}+3\left(\sigma^{4}+2\sigma^{2}\omega^{2}+\omega^{4}\right) \\ +6\left((1-q)^{2}\left(\mu^{-}\right)^{2}-2p(1-q)\mu^{+}\mu^{-}+p^{2}\left(\mu^{+}\right)^{2}\right)\left(\sigma^{2}+\omega^{2}\right) \end{Bmatrix}
\end{aligned}
$$

$$
= \left\{ \begin{array}{l} -p\left(\mu^{+}\right)^{4}\left(3p^{3}-6p^{2}+4p-1\right)-q\left(\mu^{-}\right)^{4}\left(3q^{3}-6q^{2}+4q-1\right) \\ +3\left(\sigma^{4}+p\eta^{4}+q\omega^{4}\right) \\ -2pq\left(\begin{array}{l} 2\left(\mu^{+}\right)^{3}\mu^{-}\left(3p^{2}-3p+1\right)+2\mu^{+}\left(\mu^{-}\right)^{3}\left(3q^{2}-3q+1\right) \\ +3\left(\mu^{+}\right)^{2}\left(\mu^{-}\right)^{2}\left(3pq-p-q\right) \end{array} \right) \\ -6\left(\begin{array}{l} p(p-1)\left(\mu^{+}\right)^{2}\left(\sigma^{2}-(p-1)\eta^{2}\right) \\ +q(q-1)\left(\mu^{-}\right)^{2}\left(\sigma^{2}-(q-1)\omega^{2}\right) \\ +2pq\mu^{+}\mu^{-}\left(\sigma^{2}-\left((p-1)\eta^{2}-(q-1)\omega^{2}\right)\right) \\ -pq^{2}\left(\mu^{-}\right)^{2}\eta^{2}-p^{2}q\left(\mu^{+}\right)^{2}\omega^{2}-\left(p\eta^{2}+q\omega^{2}\right)\sigma^{2} \end{array} \right) \end{array} \right\}
$$

$$
M_{4} = \frac{\left[\begin{array}{l} -p\left(\mu^{+}\right)^{4}\left(3p^{3}-6p^{2}+4p-1\right) \quad -q\left(\mu^{-}\right)^{4}\left(3q^{3}-6q^{2}+4q-1\right) \\ +3\left(\sigma^{4}+p\eta^{4}+q\omega^{4}\right) \\ -2pq\left(\begin{array}{l} 2\left(\mu^{+}\right)^{3}\mu^{-}\left(3p^{2}-3p+1\right)+2\mu^{+}\left(\mu^{-}\right)^{3}\left(3q^{2}-3q+1\right) \\ +3\left(\mu^{+}\right)^{2}\left(\mu^{-}\right)^{2}\left(3pq-p-q\right) \end{array} \right) \\ -6\left(\begin{array}{l} p(p-1)\left(\mu^{+}\right)^{2}\left(\sigma^{2}-(p-1)\eta^{2}\right) \\ +q(q-1)\left(\mu^{-}\right)^{2}\left(\sigma^{2}-(q-1)\omega^{2}\right) \\ +2pq\mu^{+}\mu^{-}\left(\sigma^{2}-\left((p-1)\eta^{2}-(q-1)\omega^{2}\right)\right) \\ -pq^{2}\left(\mu^{-}\right)^{2}\eta^{2}-p^{2}q\left(\mu^{+}\right)^{2}\omega^{2}-\left(p\eta^{2}+q\omega^{2}\right)\sigma^{2} \end{array} \right) \end{array} \right]}{\left[\begin{array}{l} (1-p)(1+q)\left(p\left(\mu^{+}\right)^{2}-q\left(\mu^{-}\right)^{2}\right) \\ +\left(p+q-3\right)pq\mu^{+}\mu^{-}+\sigma^{2}+p\eta^{2}+q\omega^{2} \end{array} \right]^{2}}
$$

References

Allen, Michael, 1994, Building a role model, Risk 7 (September), 73-80.

Aussenegg, Wolfgang, and Stefan Pichler, 1997, Empirical evaluation of simple models to calculate value-at-risk of fixed income instruments, Working Paper, Vienna University of Technology (September).

Baillie, Richard T., and de Gennaro, R. P., 1990, Stock returns and volatility, Journal of Financial and Quantitative Analysis 25, 203-214.

Ball, Clifford A., and Walter N. Torous, 1985, On jumps in common stock prices and their impact on call option pricing, Journal of Finance 40 (1:March), 155-173.

Barone-Adesi, Giovanni, Frederick Bourgoin, and Kostas Giannopoulos, 1998, Don't look back, Risk 11 (August), 100-104.

Barone-Adesi, Giovanni, Kostas Giannopoulos, and Les Vosper, 1999, VaR without correlations for non-linear portfolios, Journal of Futures Markets 19 (August), 583-602.

Barone-Adesi, Giovanni, Kostas Giannopoulos, and Les Vosper, 2000, Filtering historical simulation: Backtest analysis, Working Paper (March).

Basle Committee on Banking Supervision, 1996, Supervisory framework for the use of "backtesting" in conjunction with the internal models approach to market risk capital requirements, Basle (January).

Bensalah, Younes, 2000, Steps in applying extreme value theory to finance: A review, Working Paper 2000-20, Bank of Canada (November).

Berkowitz, Jeremy, 2000, Testing density forecasts, with applications to risk management, Working Paper, University of California, Irvine (December).

Best, Philip, 1998, Implementing Value at Risk (John Wiley and Sons, Chichester).

Butler, J. S., and Barry Schachter, 1998, Estimating value at risk with a precision measure by combining kernel estimation with historical simulation, Review of Derivatives Research 1, 371-390.

Byström, Hans NE, 2001, Managing extreme risks in transquil and volatile markets using conditional extreme value theory, Working Paper, Lund University (October).

Campbell, John Y., Andrew W. Lo, and A. Craig MacKinlay, 1997, The econometrics of financial markets (Princeton University Press, New Jersey).

Christoffersen, Peter, Jinyong Hahn, and Atsushi Inoue, 2001, Testing and comparing Value-at-Risk measures, Journal of Empirical Finance 8, 325-342.

Crnkovic, Cedomir, and Jordan Drachman, 1996, A universal tool to discriminate among risk measurement techniques, Risk 9, 138-143.

Daníelsson, Jón, and Casper G. de Vries, 1997a, Extreme returns, tail estimation, and value-at-risk, Working Paper, University of Iceland and Tinbergen Institute, Erasmus University.

Daníelsson, Jón, and Casper G. de Vries, 1997b, Tail index and quantile estimation with very high frequency data, Journal of Empirical Finance 4, 241-257.

Daníelsson, Jón, and Casper G. de Vries, 2000, Value-at-risk and extreme returns, Working Paper (January).

Daníelsson, Jón, and Yuji Morimoto, 2000, Forecasting extreme financial risk: A critical analysis of practical methods for the Japanese market, IMES Discussion Paper Series 2000-E-8 (April), Bank of Japan.

de Raaij, Gabriela, and Burkhard Raunig, 1999, Value at risk approaches in the case of fat-tailed distributions of risk factors, Manuscript, Austrian National Bank.

Diebold, Francis X., Todd A. Gunther, and Anthony S. Tay, 1998, Evaluating density forecasts, International Economic Review 39, 863-883.

Dowd, Kevin, 1998, Beyond Value at Risk: The New Science of Risk Management, John Wiley and Sons, Chichester.

Embrechts, Paul, C. Klüppelberg, and T. Mikosch, 1997, Modelling extremal events for insurance and finance, Spring Verlag, Berlin.

Fama, Eugene F., 1963, Mandelbrot and the stable Paretian hypothesis, Journal of Business 36, 420-429.

Fama, Eugene F., 1965, The behavior of stock market prices, Journal of Business 38, 34-105.

Glasserman, Paul, Philip Heidelberger, and Perwez Shahabuddin, 2000, Portfolio value-at-risk with heavy-tailed risk factors, Paine Webber Working Paper Series in Money, Economics, and Finance 00-06, Columbia University (June).

Goorbergh, Rob W. J. van den, and Peter J. G. Vlaar, 1999, Value-at-risk analysis of stock returns historical simulation, variance techniques or tail index estimation?, Working Paper, De Nederlandsche Bank (March).

Gouriéroux, Christian, J. P. Laurent, and O. Scaillet, 2000, Sensitivity analysis of values at risk, Journal of Empirical Finance 7, 225-245.

Huisman, Ronald, Kees G. Koedijk, and Rachel A. Pownall, 1998, VaR-x: fat tails in financial risk management, Journal of Risk 1 (Fall), 47-61.

Hull, John, and Alan White, 1998b, Value at risk when daily changes in market variables are not normally distributed, Journal of Derivatives 5 (3:Spring), 9-19.

Jondeau, Eric, and Michael Rockinger, 2001, Testing for differences in the tails of stock-market returns, Working Paper (October).

Jorion, Philippe, 1989, On jump processes in the foreign exchange and stock markets, Review of Financial Studies 1 (4), 427-445.

J.P. Morgan and Reuters, 1996, RiskMetrics™-Technical Document (4th ed.), New York.

Këllezi, Evis, and Manfred Gilli, 2000, Extreme value theory for tail-related risk measures, Working Paper, University of Geneva (April).

Kitamura, Yuichi, 1997, Comparing misspecified dynamic econometric models using nonparametric likelihood, Manuscript, Department of Economics, University of Wisconsin, Madison.

Kupiec, Paul H., 1995, Techniques for verifying the accuracy of risk measurement models, Journal of Derivatives 3, Winter, 73-84.

Lehar, Alfred, Martin Scheicher, and Christian Schittenkopf, 2002, GARCH vs. stochastic volatility: Option pricing and risk management, Journal of Banking and Finance 26, 323-345.

Longin, François M., 2000, From value at risk to stress testing: The extreme value approach, Journal of Banking and Finance 24 (7), 1097-1130.

Lucas, Andre, 2000, A note on optimal estimation from a risk-management perspective under possibly misspecified tail behavior, Journal of Business & Economic Statistics 18 (1), 31-39.

Mahoney, J. M., 1996, Forecast biases in value-at-risk estimations: Evidence from foreign exchange and global equity portfolios, Working Paper, Federal Reserve Bank of New York.

Mandelbrot, Benoit, 1963, The variation of certain speculative prices, Journal of Business 36, 394-419.

McNeil, Alexander J., and Rüdiger Frey, 2000, Estimation of tail-related risk measures for heteroscedastic financial time series: An extreme value approach, Journal of Empirical Finance 7, 271-300.

Mittnik, Stefan, Marc S. Paolella, and Svetlozar T. Rachev, 2000, Diagnosing and treating the fat tails in financial returns data, Journal of Empirical Finance 7, 389-416.

Pagan, Adrian, 1996, The econometrics of financial markets, Journal of Empirical Finance 3, 15-102.

Pownall, Rachel A. J., and Kees G. Koedijk, 1999, Capturing downside risk in financial markets: The case of the Asian crisis, Journal of International Money and Finance 18 (December), 853-870.

Rosenblatt, M., 1952, Remarks on a multivariate transformation, Annals of Mathematical Statistics 23, 470-472.

Smith, Richard L., 1989, Extreme value analysis of environmental time series: An application to trend detection in ground-level ozone, Statistical Science 4 (4), 367-393.

Venkataraman, Subu, 1997, Value at risk for a mixture of normal distributions: The use of quasi-Bayesian estimation techniques, Economic Perspectives 21 (2:March/April), 2-13.

Vlaar, Peter J. G., and Franz C. Palm, 1993, The message in weekly exchange rates in the European monetary system: Mean reversion, conditional heteroscedasticity, and jumps, Journal of Business & Economic Statistics 11 (3:July), 351-360.

Zangari, Peter, 1996a, An improved methodology for measuring VaR, RiskMetrics Monitor 2Q96, 7-25.

Zangari, Peter, 1996b, A value-at-risk analysis of currency exposures, RiskMetrics Monitor 2Q96, 26-33.

Zangari, Peter, 1996c, When is non-normality a problem? The case of 15 times series from emerging markets, RiskMetrics Monitor 4Q96, 20-32.

MEASURING RISK WITH STOCHASTIC JUMPS AND CONDITIONAL HETEROSKEDASTICITY

Anya Khanthavit, Ph.D.

Professor of Finance and Banking and TRF Senior Researcher

Faculty of Commerce and Accountancy

Thammasat University, Bangkok, Thailand

Tel: (662) 613-2223, 613-2239

Fax: (662) 225-2109

E-mail: akhantha@tu.ac.th

and

Pariyada Srisopitsawat, D.B.A.*

Senior Analyst

Stock Exchange of Thailand

Bangkok, Thailand

Tel: (662) 229 2148

Fax: (662) 654 5825

E-mail: spariyada@hotmail.com

---

* Corresponding author. Financial supports from Thailand Research Fund are gratefully acknoledged.

Abstract

Measuring Risk with Stochastic Jumps and Conditional Heteroskedasticity

We extend previously proposed trimodal model which combines normal distribution and stochastic jump process where both the positive and negative jumps are allowed for the presence of asymmetry to incorporate the conditional heteroskedasticity. Both the GARCH and the asymmetric EGARCH processes are considered. We propose the conditional trimodal distribution for the returns on S&P500 index and apply it with the estimation of the Value at Risk (VaR). The model is compared with the three competing models including the conditional normal distribution, the conditional student's *t* distribution, and the conditional bimodal distribution. The issue of the unconditional and conditional models is still inconclusive since the more complicated conditional models do not grant better performance in some cases.

JEL classification: C16; C22; C51; G10

Keywords: Conditional heteroskedasticity; Risk management; Stochastic jumps; Trimodal distribution; Value at Risk

บทคัดย่อ

การวัดขนาดความเสี่ยงซึ่งพิจารณาพฤติกรรมการกระโดด และความผันผวนอย่างมีเงื่อนไขของราคาหลักทรัพย์

การศึกษาขยายผลการพัฒนาตัวแบบจำลองเพื่อพรรณนาพฤติกรรมของราคาหลักทรัพย์ โดยใช้การแจกแจงแบบสามโหนกที่เกิดจากการปรับตัวลดลงและเพิ่มขึ้นของราคาอย่างรุนแรง ให้พิจารณาเพิ่มเติมถึงความผันผวนอย่างมีเงื่อนไขของราคา แล้วนำการแจกแจงที่ได้เป็นผลลัพธ์ไปเปรียบเทียบความสามารถกับการแจกแจงอื่น โดยการเปรียบเทียบใช้ข้อมูลดัชนี S&P 500 การศึกษาพบว่า แม้การแจกแจงที่พัฒนาขึ้นนี้จะมีลักษณะยืดหยุ่นที่สุดสำหรับการพรรณนาพฤติกรรมความเสี่ยงของราคาหลักทรัพย์ แต่ความสามารถในการพยากรณ์มูลค่าความเสี่ยงกลับไม่ต่างอย่างมีนัยสำคัญจากการแจกแจงรูปแบบอื่นทั่วไป

Measuring Risk with Stochastic Jumps and Conditional Heteroskedasticity

1. Introduction

In previous chapter, all models are assumed to be unconditional. Then, they do not respond to changing volatility and tend to generate large number of exceptions in stress periods. According to empirical evidence, volatility is not constant but rather varies over time (Bollerslev et al., 1992, 1994; Bera and Higgins, 1993). Volatility clustering is one of the well-known characteristics common to many financial time series. The large changes tend to follow large changes and small changes tend to follow small changes. Consequently, using the constant volatility method in VaR calculation could be very misleading and may not give an accurate VaR estimate. To capture this behavior, Engle (1982) proposes the autoregressive conditional heteroskedasticity (ARCH) process to model time-varying conditional variance where the past disturbances are used. Further, Bollerslev (1986) has developed the generalized autoregressive conditional heteroskedasticity (GARCH) which is the generalized model of the ARCH process which can reduce the high ARCH orders.

However, the GARCH method does not allow for the asymmetric response of stock volatility to past returns. This leverage effect is first noted by Black (1976). It refers to the fact that stock volatility is higher as a result of a large negative return than it does as a result of a large positive return of same magnitude. The exponential generalized autoregressive conditional heteroskedasticity (EGARCH) is proposed by Nelson (1990) to deal with this leverage effect. Several studies have forecasted the conditional variance with this asymmetric GARCH model (e.g., Pagan and Schwert, 1990; Khanthavit, 1995; Brailsford and Faff, 1996; Fiszeder and Romański, 1998; Franses et al., 1998; Loudon et al., 2000; Peters, 2001). If the EGARCH method is more appropriate, then the GARCH model may underpredict the volatility when there is a large decrease in stock prices occurred the previous day. On the other hand, the GARCH model could overestimate the VaR following large positive returns (Engle and Ng, 1993).

The models in the ARCH/GARCH family are extensively used in the risk management (e.g., Barone-Adesi et al., 1998; Byström, 2001; Christoffersen et al., 2001; Lehar et al., 2002). However, due to the presence of the fat tails found in financial data (Mandelbrot, 1963; Fama, 1965; Baillie and de Gennaro, 1990; Pagan, 1996; Zangari, 1996; Campbell et al., 1997), the conditional model under the assumption of normal distribution of returns is inadequate. Since volatility clustering accounts for some but not all of the fat-tail behavior, parts of the fat tails observed in financial data can result from the presence of the non-Gaussian return distributions. Then, several studies have suggested various types of distribution in the conditional model for VaR estimation (e.g., Pownall and Koedijk, 1999; Cotter, 2000; Lucas, 2000; McNeil and Frey, 2000; Mittnik et al., 2000; Giot and Sébastien, 2001).

Nevertheless, those studies still ignore the presence of discontinuities found in financial data (Ball and Torous, 1985; Jorion, 1989). Then, the stochastic jump process should be included in the model of financial returns. However, Vlaar and Palm (1993) claimed that if the unconditional model is assumed, when a jump occurs, the high volatility following a jump might mistakenly be taken as the additional jumps. Then, Vlaar and Palm (1993) and Khanthavit (1995) have provided the empirical evidence on the GARCH-jump models where both the GARCH and the stochastic jump processes are included in the return distribution. Although the inclusion of both the stochastic jump process and the conditional variance in the model specification is more appropriate, the study should not be limited to only one-sided jump. The inclusion of the two-sided jumps nests the model with one-sided jump and can avoid misspecification and bias. Further, the inclusion of both positive and negative jumps also allow for the possibility of the asymmetric distribution.

So, in this study, the trimodal model which combines normal distribution and stochastic jump process where both the positive and negative jumps are allowed for the presence of asymmetry is extended to include the conditional heteroskedasticity. Both the GARCH and the EGARCH processes are considered. Then, we apply the proposed conditional trimodal distribution in the VaR analysis.

To test the performance of our models, we compare the conditional trimodal distribution with the three competing models which are the conditional normal distribution, the conditional student's *t* distribution, and the conditional bimodal distribution. The empirical results from the distribution test which utilizes the information on the entire distribution show that the null hypothesis of a uniform distribution is rejected for all GARCH and EGARCH models being considered. From the likelihood ratio test based on proportions of failures, the trimodal distribution reveals the superior performance with the appending-window method than the rolling-window method. For the trimodal-EGARCH model, the null hypothesis that the proportion of failures is equal to the expected number cannot be rejected at all quantile both in the lower and upper tails. Besides, for the lower tails, the trimodal distribution gives the minimum distance from the true model based on the information test. Further, according to the nonnested comparison testing, the trimodal distribution is preferred to the three competing models at most quantiles in the lower tail but more exceptional cases occur in the upper tail.

The paper is organized as follows. In section 2, we consider the proposed conditional trimodal distribution and the methodology employed in the estimation. To show that our VaR estimate is improved over the VaRs obtained from other methods, the performance tests and comparisons are also included. The empirical results from our conditional trimodal distribution and competing models are presented in section 3. Finally, section 4 gathers some concluding remarks.

2. Methodology

We extend the unconditional trimodal distribution in previous chapter to the conditional model by incorporating the time-varying volatility. Then, the conditional trimodal distribution combines normal distribution and stochastic jumps, where both the positive and negative jumps are included in the model, and also allows for time-varying conditional variance. Similar to the unconditional trimodal model, there are three possibilities that can occur which are no jump, positive jump, and negative jump. The conditional trimodal model is specified as follows:

$$r_t = \begin{cases} \mu + \varepsilon_t^0 & \text{when no jump} & \text{with probability} & 1 - p - q \\ (\mu + \mu^+) + \varepsilon_t^+ & \text{when positive jump} & \text{with probability} & p \\ (\mu + \mu^-) + \varepsilon_t^- & \text{when negative jump} & \text{with probability} & q \end{cases}$$

Since the daily data is employed in this study, the stochastic jumps are modeled by the Bernoulli process where only one abnormal circumstance is allowed. We employ the maximum likelihood technique in estimating our parameters. The log-likelihood function is specified as follows:

$$\ln(L) = -\frac{n}{2}\ln(2\pi) + \sum_{t=1}^{n}\ln\left\{\begin{aligned}&\left[\frac{(1-p-q)}{(h_t)^{\frac{1}{2}}}\right]\exp\left[-\frac{(\varepsilon_t-(-p\mu^+-q\mu^-))^2}{2h_t}\right]\\&+\left[\frac{p}{(h_t+\eta^2)^{\frac{1}{2}}}\right]\exp\left[-\frac{(\varepsilon_t-((1-p)\mu^+-q\mu^-))^2}{2(h_t+\eta^2)}\right]\\&+\left[\frac{q}{(h_t+\omega^2)^{\frac{1}{2}}}\right]\exp\left[-\frac{(\varepsilon_t-((1-q)\mu^- -p\mu^+))^2}{2(h_t+\omega^2)}\right]\end{aligned}\right\}$$

where r_t is the daily return at time t; μ is the mean return when there is no jump. The positive jump size is assumed to be normally distributed with expectation μ^+ (positive value) and variance η^2 while the negative jump size has the expectation μ^- (negative value) and variance ω^2. The parameter h_t represents the conditional variance which is assumed to follow the GARCH and EGARCH processes. The GARCH process is specified as follows:

$$h_t = \alpha_0 + \beta_1 h_{t-1} + \alpha_1\varepsilon_{t-1}^2$$

For the EGARCH process, it has the following form:

$$\ln\left(h_t\right) = \alpha_0 + \beta_1\ln\left(h_{t-1}\right) + \alpha_1\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \gamma_1\left(\frac{\left|\varepsilon_{t-1}\right|}{\sqrt{h_{t-1}}} - \sqrt{\frac{2}{\pi}}\right)$$

Both the joint tests and the tests on individual estimates are performed to test for the existence of the trimodal model. Then, to test and compare VaRs from different models, we employ the same tests as in previous chapter which are the distribution test, the likelihood ratio test, and the information test.

3. Empirical results

Using the same set of data employed in previous chapter, this study employs the daily data of S&P500 index at closing time obtained from Datastream. The sample range is from January 2, 1969 to August 10, 2001 resulting in 8508 observations.[1]

3.1. Estimation of a conditional trimodal distribution

Tables 1 and 2 present the maximum likelihood estimation of the parameters in the two conditional trimodal distribution of returns, the GARCH and the EGARCH models, respectively.

[1] The descriptive statistics, the plot, and the histogram of the data during the observed period are shown in table 1, figure 1, and figure 2 of previous chapter, respectively.

Table 1

Estimation of a Trimodal-GARCH Distribution

This table gives the maximum likelihood estimates of the parameters of the trimodal-GARCH distribution of returns on S&P500 index. Ten parameters are estimated: the mean return μ, the probability of positive jumps *p*, the mean of positive jumps μ^+, the variance of positive jumps η^2, the probability of negative jumps *q*, the mean of negative jumps μ^-, the variance of negative jumps ω^2, and the GARCH parameters; α_0, α_1, and β_1. The *p*-values of each estimate are given below in the parentheses. The joint hypotheses $H_0 : \mu^+ = \mu^- = 0$ and $H_0 : p = q = 0$ are also tested. The Wald tests on the means and probabilities of positive and negative jumps are carried out. The *p*-values of the tests are given below in the parentheses.

Parameter	Estimate (*p*-value)
Mean	0.000043 (0.0000)
Probability of positive jump	0.021314 (0.0000)
Mean of positive jump	0.000441 (0.0000)
Variance of positive jump	0.000625 (0.0000)
Probability of negative jump	0.000089 (0.0071)
Mean of negative jump	-0.001030 (0.0000)
Variance of negative jump	0.000036 (0.0000)
α_0 $(\times 10^4)$	0.007872 (0.0000)
α_1	0.047254 (0.0000)
β_1	0.935329 (0.0000)

Null Hypothesis	Wald test (*p*-value)
$H_0 : \mu^+ = \mu^- = 0$	-3200.201 (0.0000)
$H_0 : p = q = 0$	-166.640 (0.0000)

Table 2

Estimation of a Trimodal-EGARCH Distribution

This table gives the maximum likelihood estimates of the parameters of the trimodal-EGARCH distribution of returns on S&P500 index. Eleven parameters are estimated: the mean return μ, the variance of returns σ^2, the probability of positive jumps *p*, the mean of positive jumps μ^+, the variance of positive jumps η^2, the probability of negative jumps *q*, the mean of negative jumps μ^-, the variance of negative jumps ω^2, and the EGARCH parameters; α_0, α_1, β_1, and γ_1. The *p*-values of each estimate are given below in the parentheses. The joint hypotheses $H_0 : \mu^+ = \mu^- = 0$ and $H_0 : p = q = 0$ are also tested. The Wald tests on the means and probabilities of positive and negative jumps are carried out. The *p*-values of the tests are given below in the parentheses.

Parameter	**Estimate (*p*-value)**
Mean	0.000027
	(0.0000)
Probability of positive jump	0.136818
	(0.0000)
Mean of positive jump	0.000256
	(0.0000)
Variance of positive jump	0.000053
	(0.0000)
Probability of negative jump	0.006593
	(0.0000)
Mean of negative jump	-0.000259
	(0.0000)
Variance of negative jump	0.000805
	(0.0000)
α_0	0.494091
$(\times 10^4)$	(0.0000)
α_1	-0.047589
	(0.0000)
β_1	0.999998
	(0.0000)
γ_1	0.131931
	(0.0000)

Null Hypothesis	**Wald test (*p*-value)**
$H_0 : \mu^+ = \mu^- = 0$	-9194.227 (0.0000)
$H_0 : p = q = 0$	206.559 (0.0000)

For both models, the estimated jump parameters which are the mean of the positive jumps (μ^{+}), the mean of the negative jumps (μ^{-}), the probability of positive jumps (*p*), and the probability of negative jumps (*q*) are statistically significant. Then, these confirm the existence of both the positive and negative jumps in the return distribution which reveal the suitability of our trimodal distribution in modelling the sample series. The significance of the stochastic jumps is further supported by the Wald tests which reject both the joint hypothesis that the two probabilities are equal to zero and the joint hypothesis that the two means are equal to zero. The model can also capture the skewness since the means (in absolute value) of the positive and negative jumps are not equal. So, this fits the distribution of realized returns where the skewness is revealed. Further, the fat tails are captured by the significance of stochastic jumps both in the lower and upper tails.

The estimated GARCH parameters are all statistically significant. The $\alpha_1 + \beta_1$ measures the volatility persistence. The persistence will increase as $\alpha_1 + \beta_1$ approaches one.[2] Then, from table 1, the sample data exhibits high volatility persistence since $\alpha_1 + \beta_1$ is about 0.98. In addition, to capture the leverage effect that the GARCH model cannot reveal, the EGARCH model is estimated. From table 2, the parameter α_1 represents the coefficient for the leverage effect. The negative and significant estimated value of α_1 is consistent with the leverage effect revealed by Black (1976) and Christie (1982). Then, the sample data tends to respond more to bad news than good news.

3.2. Performance tests

3.2.1. Distribution test

Crnkovic and Drachman (1996) propose the distribution test procedure which is based on the entire distribution. Figure 1 presents the histograms of transformed returns of all four GARCH models while the results obtained from the models with EGARCH process are shown in figure 2.

[2] If $\alpha_1 + \beta_1$ is equal to one, the process will be IGARCH.

Figure 1

Histogram of Transformed Returns of the GARCH Models

This figure displays the histograms of the transformed returns under the distributions predicted by the four models: normal-GARCH distribution, student's *t*-GARCH distribution, bimodal-GARCH distribution, and trimodal-GARCH distribution. The transformed returns are plotted against the expected uniform distribution.

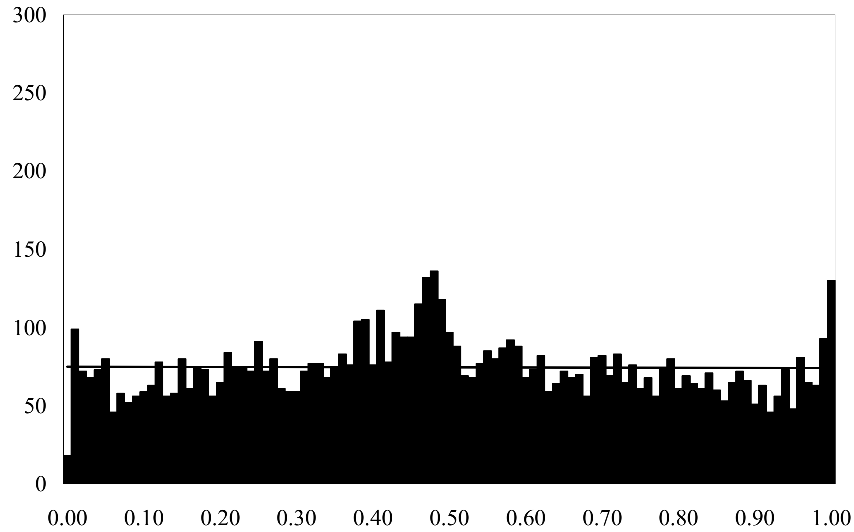

Fig. 1a. Normal-GARCH distribution

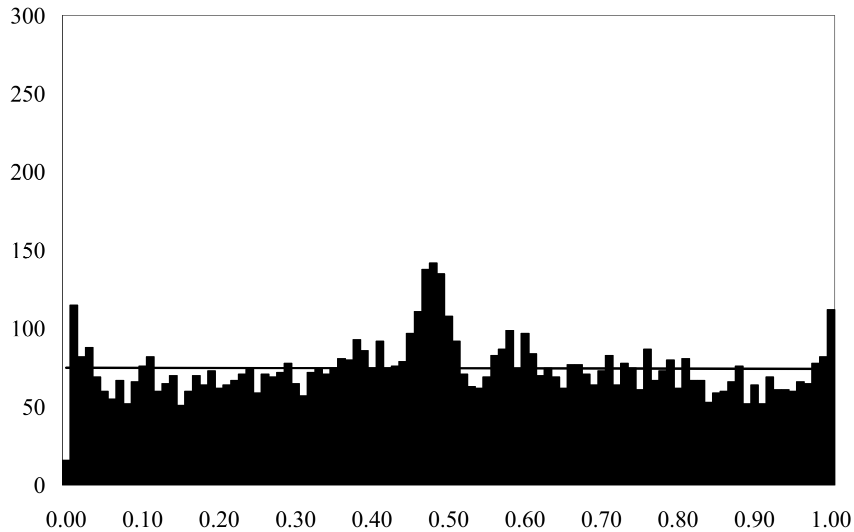

Fig. 1b. Student's *t*-GARCH distribution

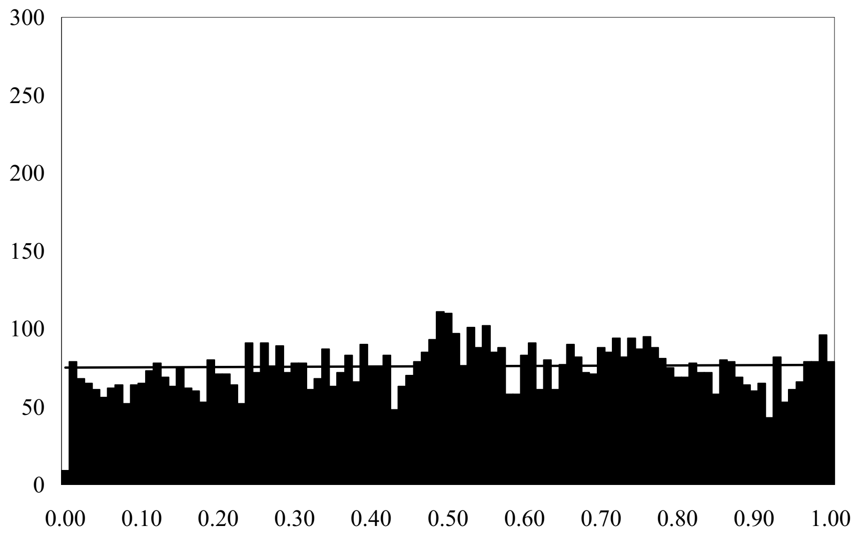

Fig. 1c. Bimodal-GARCH distribution

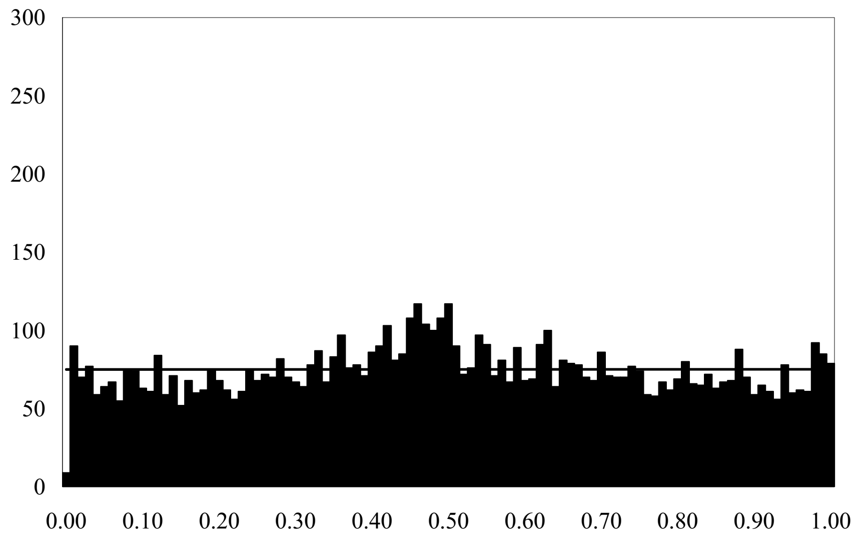

Fig. 1d. Trimodal-GARCH distribution

Figure 2

Histogram of Transformed Returns of the EGARCH Models

This figure displays the histograms of the transformed returns under the distributions predicted by the four models: normal-EGARCH distribution, student's *t*-EGARCH distribution, bimodal-EGARCH distribution, and trimodal-EGARCH distribution. The transformed returns are plotted against the expected uniform distribution.

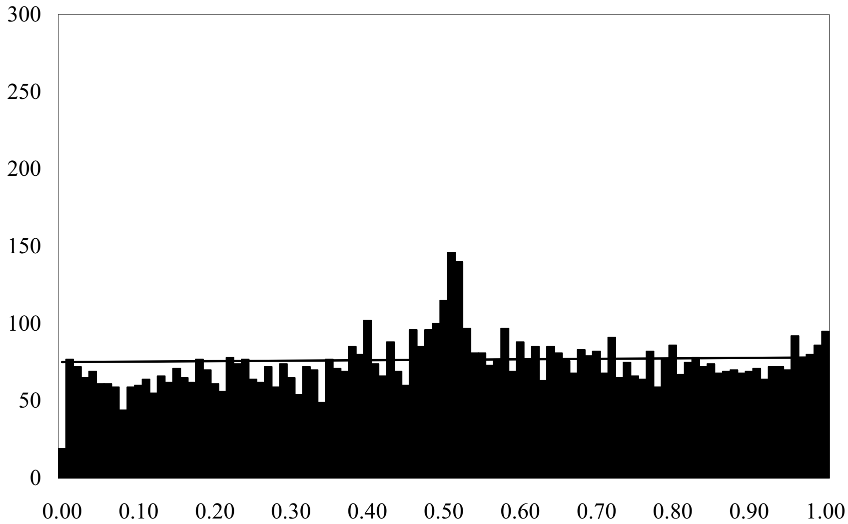

Fig. 2a. Normal-EGARCH distribution

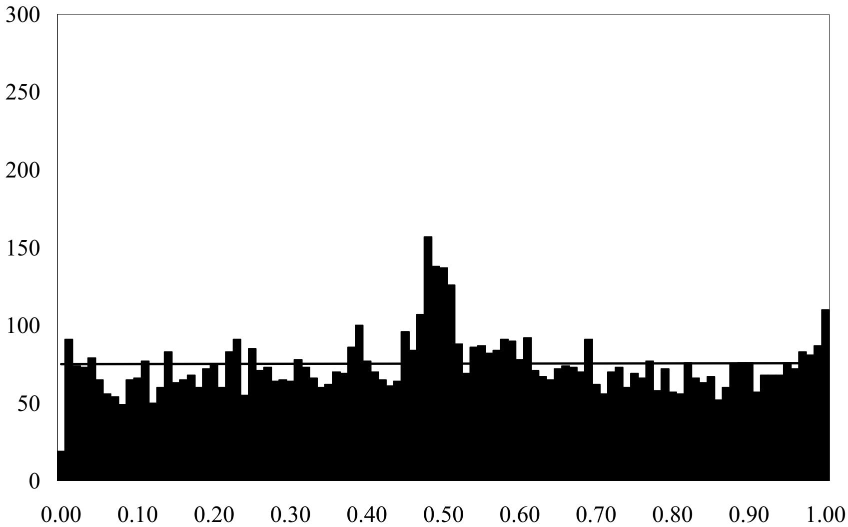

Fig. 2b. Student's *t*-EGARCH distribution

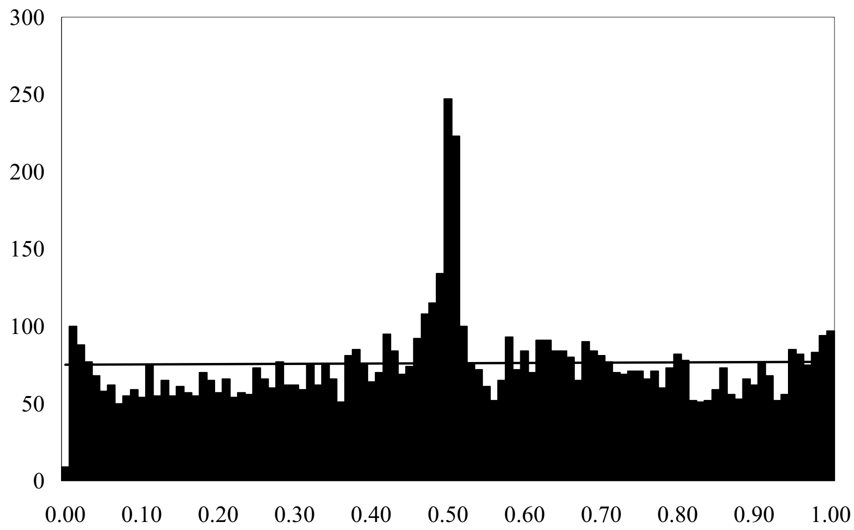

Fig. 2c. Bimodal-EGARCH distribution

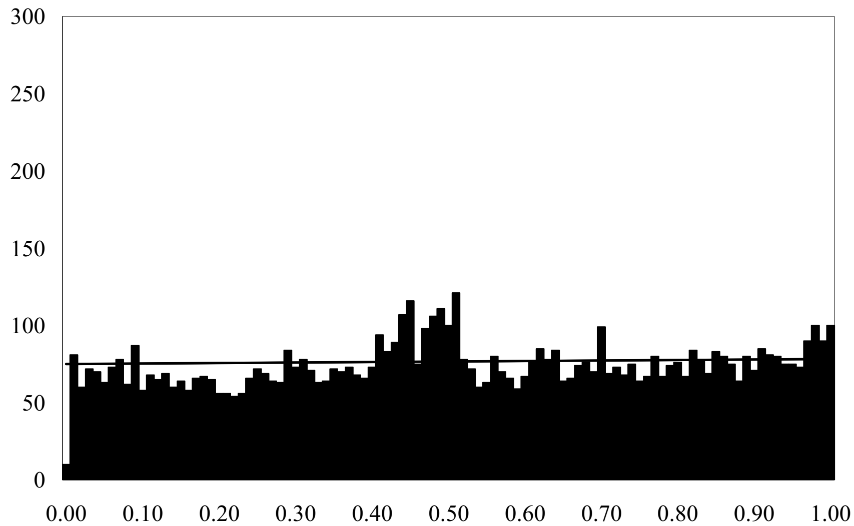

Fig. 2d. Trimodal-EGARCH distribution

Since the transformed data should be uniformly distributed, if the assumed model is correct, the histogram should be closed to flat. Figures 1 and 2 shows that the conditional normal models, both normal-GARCH and normal-EGARCH, and the two conditional student's *t* models, either with the GARCH or EGARCH innovations deviate significantly from the uniform distribution since there are higher probability mass in the center of the distribution and also higher numbers of observations in the tails. However, the conditional bimodal and the conditional trimodal models show higher number of observations in the center while less number of observations are presented in other areas, then these also make them to be different from the uniform distribution. This will be confirmed by the uniformity test. To check for uniformity, the test based on the

Kuiper statistic is performed. Tables 3 and 4 display the distribution test results of the GARCH and EGARCH models, respectively.

Table 3

Distribution Test of the GARCH Models

This table shows the results from the distribution tests on four models: normal-GARCH distribution, student's *t*-GARCH distribution, bimodal-GARCH distribution, and trimodal-GARCH distribution. Under the null hypothesis that the distribution is uniform, the Kuiper statistic of each model is displayed in the table. The *p*-value is given below in the parenthesis.

Model	Kuiper Statistic (*p* -value)
Normal-GARCH	0.0597
	(0.0000)
Student's t-GARCH	0.0526
	(0.0000)
Bimodal-GARCH	0.0419
	(0.0000)
Trimodal-GARCH	0.0529
	(0.0000)

Table 4

Distribution Test of the EGARCH Models

This table shows the results from the distribution tests on four models: normal-EGARCH distribution, student's *t*-EGARCH distribution, bimodal-EGARCH distribution, and trimodal-EGARCH distribution. Under the null hypothesis that the distribution is uniform, the Kuiper statistic of each model is displayed in the table. The *p*-value is given below in the parenthesis.

Model	Kuiper Statistic (*p*-value)
Normal-EGARCH	0.0500
	(0.0000)
Student's t-EGARCH	0.0554
	(0.0000)
Bimodal-EGARCH	0.0747
	(0.0000)
Trimodal-EGARCH	0.0416
	(0.0000)

The results show that the null hypotheses of uniformity are rejected for all approaches with either the GARCH or the EGARCH process. Therefore, according to the distribution test, our 8508 observations may be too large to avoid the rejection of the null hypothesis of uniformity.

3.2.2. Likelihood ratio test

From the backtesting results, the Kupiec (1995) likelihood ratio test based on proportions of failures is performed to test and compare the performance of the competing models. The likelihood ratio test statistics from the four models with the GARCH and the EGARCH processes are presented in tables 5 and 6, respectively.

Table 5

Likelihood Ratio Test of the GARCH Models

This table displays the results from the likelihood ratio tests based on the ratios of exceptions from the backtesting approach on four models: normal-GARCH distribution, student's *t*-GARCH distribution, bimodal-GARCH distribution, and trimodal-GARCH distribution. Panel A and B present the results from the rolling-window and the appending-window methods, respectively. The likelihood ratio test statistics are defined with the quantile. Four quantile estimates are considered: 0.99, 0.975, 0.95, and 0.90. The likelihood ratio test statistics are shown in the table. The *p*-values are given below in the parentheses.

Model	Lower tail				Upper tail			
	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
	Panel A: Rolling-window method							
Normal-GARCH	6.5711	1.1371	0.4188	2.2759	1.9367	1.0391	0.2212	3.2219
	(0.0104)	(0.2863)	(0.5175)	(0.1314)	(0.1640)	(0.3080)	(0.6381)	(0.0727)
Student's *t*-GARCH	16.1871	28.6199	36.7926	35.2253	25.0389	41.3628	37.2981	34.8923
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bimodal-GARCH	1.3870	19.8134	35.1856	31.3720	8.3880	32.9844	49.8254	49.2407
	(0.2389)	(0.0000)	(0.0000)	(0.0000)	(0.0038)	(0.0000)	(0.0000)	(0.0000)
Trimodal-GARCH	13.5098	32.0488	34.8213	17.6945	26.6561	50.5871	55.0465	40.5805
	(0.0002)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	Panel B: Appending-window Method							
Normal-GARCH	5.2602	0.7707	1.3985	4.4476	3.2862	1.6907	0.0004	1.3733
	(0.0218)	(0.3800)	(0.2370)	(0.0350)	(0.0699)	(0.1935)	(0.9833)	(0.2412)
Student's *t*-GARCH	16.1871	32.0446	39.8887	42.6335	25.0389	36.5010	34.3271	29.4978
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bimodal-GARCH	0.2220	0.6899	2.5468	0.7855	0.9243	4.1498	4.1246	3.0835
	(0.6375)	(0.4062)	(0.1105)	(0.3755)	(0.3364)	(0.0416)	(0.0423)	(0.0791)
Trimodal-GARCH	0.9243	4.1498	3.9904	0.3729	3.2862	10.5205	12.2922	6.3361
	(0.3364)	(0.0416)	(0.0458)	(0.5414)	(0.0699)	(0.0012)	(0.0005)	(0.0118)

Table 6

Likelihood Ratio Test of the EGARCH Models

This table displays the results from the likelihood ratio tests based on the ratios of exceptions from the backtesting approach on four models: normal-EGARCH distribution, student's *t*-EGARCH distribution, bimodal-EGARCH distribution, and trimodal-EGARCH distribution. Panel A and B present the results from the rolling-window and the appending-window methods, respectively. The likelihood ratio test statistics are defined with the quantile. Four quantile estimates are considered: 0.99, 0.975, 0.95, and 0.90. The likelihood ratio test statistics are shown in the table. The *p*-values are given below in the parentheses

Model	Lower tail				Upper tail			
	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
	Panel A: Rolling-window method							
Normal-EGARCH	3.8075	0.0661	1.3985	4.2291	3.0388	0.2474	0.9361	6.0072
	(0.0510)	(0.7972)	(0.2370)	(0.0397)	(0.0813)	(0.6189)	(0.3333)	(0.0142)
Student's *t*-EGARCH	16.1871	34.9720	43.1388	53.3536	30.0347	38.0750	37.8078	42.2626
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bimodal-EGARCH	3.0388	11.3903	14.6515	8.1694	5.2602	18.6950	27.8938	31.1101
	(0.0813)	(0.0007)	(0.0001)	(0.0043)	(0.0218)	(0.0000)	(0.0000)	(0.0000)
Trimodal-EGARCH	3.8075	11.0969	11.4024	6.2137	5.5758	14.5115	23.1550	24.1945
	(0.0510)	(0.0009)	(0.0007)	(0.0127)	(0.0182)	(0.0001)	(0.0000)	(0.0000)
	Panel B: Appending-window Method							
Normal-EGARCH	2.5706	0.0069	3.3668	9.2074	4.3632	0.8559	0.2926	2.8584
	(0.1089)	(0.9339)	(0.0665)	(0.0024)	(0.0367)	(0.3549)	(0.5885)	(0.0909)
Student's *t*-EGARCH	16.1871	39.6952	47.7193	62.6624	27.4399	32.0446	35.7940	35.5602
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bimodal-EGARCH	0.7551	0.1426	0.1113	2.5172	0.0068	0.8559	1.2602	0.1676
	(0.3849)	(0.7057)	(0.7386)	(0.1126)	(0.9340)	(0.3549)	(0.2616)	(0.6822)
Trimodal-EGARCH	0.1543	0.0069	0.1329	2.7710	0.0883	0.6135	0.3718	0.2352
	(0.6945)	(0.9339)	(0.7155)	(0.0960)	(0.7664)	(0.4335)	(0.5420)	(0.6277)

The conditional trimodal distribution, both for the GARCH and the EGARCH processes, reveal the better performance with the appending-window method than with the rolling-window method where the trimodal-EGARCH is superior than the trimodal-GARCH model. The null hypothesis of equality between the proportion of failures and the expected number cannot be rejected at all quantile both in the lower and upper tails. The results found for the conditional trimodal models are comparable to the conditional bimodal distributions but the better fit over the conditional student's *t* models which have the worst performance since it is rejected in all cases. This can be explained by the same reason that the conditional student's *t* models give the larger VaR numbers than others, then it is violated less frequent than other models resulting in the lower number of exceptions and lower proportion of failures. So, the likelihood ratio test which provides the test whether the proportion of failures is equal to the expected number gives the high test value for the conditional student's *t* models in which the proportion of failures is far from the expected number. On the other hand, comparing our conditional trimodal models with the conditional normal distributions, we find that, with the appending-window method, the trimodal-EGARCH performs better than the normal-EGARCH while the trimodal-GARCH reveals comparable performance to the normal-GARCH model in the lower tail but less preferable in the upper tail.

3.2.3. Information test

Following the information test suggested by Christoffersen et al. (2001), the specification testing results are summarized in tables 7 and 8.

Table 7

Information Test of the GARCH Models

This table presents the results from the information test on four models: normal-GARCH distribution, student's *t*-GARCH distribution, bimodal-GARCH distribution, and trimodal-GARCH distribution. Under the null hypothesis that the model is correctly specified, the K-test value is presented in the table. The *p*-value is given below in the parenthesis.

Model	**0.99 Quantile**	**0.975 Quantile**	**0.95 Quantile**	**0.90 Quantile**
	Panel A: Lower tail			
Normal-GARCH	2.8574	12.3850	8.2577	10.4856
	(0.2396)	(0.0020)	(0.0161)	(0.0053)
Student's *t*-GARCH	1.2860	0.5570	5.5476	8.7208
	(0.5257)	(0.7569)	(0.0624)	(0.0128)
Bimodal-GARCH	0.6166	0.8502	0.2142	1.2353
	(0.7347)	(0.6537)	(0.8984)	(0.5392)
Trimodal-GARCH	0.2767	0.1657	1.1611	1.0658
	(0.8708)	(0.9205)	(0.5596)	(0.5869)
	Panel B: Upper tail			
Normal-GARCH	5.3972	9.9579	2.5472	2.9360
	(0.0673)	(0.0069)	(0.2798)	(0.2304)
Student's *t*-GARCH	4.7202	8.9442	1.2952	1.0395
	(0.0944)	(0.0114)	(0.5233)	(0.5947)
Bimodal-GARCH	6.1806	3.0656	2.5179	0.7053
	(0.0455)	(0.2159)	(0.2840)	(0.7028)
Trimodal-GARCH	11.4312	8.9370	8.0613	2.4293
	(0.0033)	(0.0115)	(0.0178)	(0.2968)

Table 8

Information Test of the EGARCH Models

This table presents the results from the information test on four models: normal-EGARCH distribution, student's *t*-EGARCH distribution, bimodal-EGARCH distribution, and trimodal-EGARCH distribution. Under the null hypothesis that the model is correctly specified, the K-test value is presented in the table. The *p*-value is given below in the parenthesis.

Model	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
		Panel A: Lower tail		
Normal-EGARCH	3.0222	7.3443	5.1693	1.0766
	(0.2207)	(0.0254)	(0.0754)	(0.5837)
Student's *t*-EGARCH	6.0491	6.0797	4.9158	2.5533
	(0.0486)	(0.0478)	(0.0856)	(0.2790)
Bimodal-EGARCH	3.2719	9.5141	0.9952	4.6306
	(0.1948)	(0.0086)	(0.6080)	(0.0987)
Trimodal-EGARCH	6.7935	8.0266	4.8377	1.9617
	(0.0335)	(0.0181)	(0.0890)	(0.3750)
		Panel B: Upper tail		
Normal-EGARCH	3.9507	3.6938	6.5605	10.0211
	(0.1387)	(0.1577)	(0.0376)	(0.0067)
Student's *t*-EGARCH	5.4949	3.3787	4.8908	6.5101
	(0.0641)	(0.1846)	(0.0867)	(0.0386)
Bimodal-EGARCH	1.0040	5.3152	4.2108	1.9740
	(0.6053)	(0.0701)	(0.1218)	(0.3727)
Trimodal-EGARCH	0.6354	2.6088	5.0438	13.2854
	(0.7278)	(0.2713)	(0.0803)	(0.0013)

From the results in previous chapter, almost half of all cases are rejected since they are subjected to misspecification.[3] However, for the conditional models considered in this study, tables 7 and 8 show that about 70 percent of all cases pass the specification test. This means that the misspecifications of the models are partly corrected when the conditional variance is employed. Considering the results from the specification testing of the conditional models, we find that the trimodal distribution performs better in the lower tail than in the upper tail. The results indicate that there is no model that performs best in all cases. They reveal the comparable performance.

[3] See table 5 of previous chapter.

Further, the results from performing the pairwise comparison testing of the four GARCH models are shown in table 9 and the results of the EGARCH models are presented in table 10.

Table 9

Nonnested Comparison Test of the GARCH Models

This table demonstrates the results from the pairwise comparison testing based on the KLIC distances of the four models: normal-GARCH distribution, student's *t*-GARCH distribution, bimodal-GARCH distribution, and trimodal-GARCH distribution. Under the null hypothesis that the two models are equally suitable, the test values are shown in the table. The *p*-values are given below in the parentheses. If the null hypothesis is rejected, a positive value indicates that Model 1 is preferred while a negative value denotes that Model 2 is preferred.

Model		0.99	0.975	0.95	0.90
1	2	Quantile	Quantile	Quantile	Quantile
		Panel A: Lower tail			
Trimodal-GARCH	Normal-GARCH	0.7581	1.6853	1.1626	1.3651
		(0.4484)	(0.0919)	(0.2450)	(0.1722)
Trimodal-GARCH	Student's *t*-GARCH	0.4067	0.2322	0.8704	1.2234
		(0.6843)	(0.8164)	(0.3841)	(0.2212)
Trimodal-GARCH	Bimodal-GARCH	0.1841	0.3309	-0.3719	0.0556
		(0.8540)	(0.7407)	(0.7100)	(0.9557)
Bimodal-GARCH	Normal-GARCH	0.6227	1.5541	1.4193	1.3703
		(0.5335)	(0.1202)	(0.1558)	(0.1706)
Bimodal-GARCH	Student's *t*-GARCH	0.2455	-0.1219	1.1825	1.2287
		(0.8061)	(0.9030)	(0.2370)	(0.2192)
Student's *t*-GARCH	Normal-GARCH	0.0000	0.0000	0.0000	0.0000
		(1.0000)	(1.0000)	(1.0000)	(1.0000)
		Panel B: Upper tail			
Trimodal-GARCH	Normal-GARCH	-0.7116	0.1111	-0.8151	0.1007
		(0.4767)	(0.9115)	(0.4150)	(0.9198)
Trimodal-GARCH	Student's *t*-GARCH	-0.6501	-0.8424	-0.8440	-0.4701
		(0.5157)	(0.3996)	(0.3987)	(0.6383)
Trimodal-GARCH	Bimodal-GARCH	-0.8077	0.0008	-1.0391	-0.3616
		(0.4193)	(0.9994)	(0.2988)	(0.7176)
Bimodal-GARCH	Normal-GARCH	-0.1105	0.8988	0.0063	0.5147
		(0.9120)	(0.3688)	(0.9950)	(0.6068)
Bimodal-GARCH	Student's *t*-GARCH	-0.2103	0.8000	-0.2997	0.1173
		(0.8334)	(0.4237)	(0.7644)	(0.9066)
Student's *t*-GARCH	Normal-GARCH	0.0000	0.0000	0.0000	0.0000
		(1.0000)	(1.0000)	(1.0000)	(1.0000)

Table 10

Nonnested Comparison Test of the EGARCH Models

This table demonstrates the results from the pairwise comparison testing based on the KLIC distances of the four models: normal-EGARCH distribution, student's *t*-EGARCH distribution, bimodal-EGARCH distribution, and trimodal-EGARCH distribution. Under the null hypothesis that the two models are equally suitable, the test values are shown in the table. The *p*-values are given below in the parentheses. If the null hypothesis is rejected, a positive value indicates that Model 1 is preferred while a negative value denotes that Model 2 is preferred.

Model 1	Model 2	0.99 Quantile	0.975 Quantile	0.95 Quantile	0.90 Quantile
		Panel A: Lower tail			
Trimodal-EGARCH	**Normal-EGARCH**	-0.6565	-0.0936	0.0547	-0.2693
		(0.5115)	(0.9254)	(0.9563)	(0.7877)
Trimodal-EGARCH	**Student's t-EGARCH**	-0.1049	-0.2886	0.0131	0.1418
		(0.9164)	(0.7729)	(0.9895)	(0.8872)
Trimodal-EGARCH	**Bimodal-EGARCH**	-0.6111	0.1906	-0.8562	0.4907
		(0.5411)	(0.8488)	(0.3919)	(0.6236)
Bimodal-EGARCH	**Normal-EGARCH**	-0.0490	-0.2610	0.8107	-0.7274
		(0.9609)	(0.7941)	(0.4175)	(0.4670)
Bimodal-EGARCH	**Student's t-EGARCH**	0.4283	-0.4488	0.8352	-0.3909
		(0.6684)	(0.6536)	(0.4036)	(0.6959)
Student's t-EGARCH	**Normal-EGARCH**	0.0000	0.0000	0.0000	0.0000
		(1.0000)	(1.0000)	(1.0000)	(1.0000)
		Panel B: Upper tail			
Trimodal-EGARCH	**Normal-EGARCH**	0.7612	0.2162	0.2325	-0.3384
		(0.4465)	(0.8289)	(0.8162)	(0.7351)
Trimodal-EGARCH	**Student's t-EGARCH**	1.0626	0.1602	-0.0253	-0.7571
		(0.2880)	(0.8727)	(0.9799)	(0.4490)
Trimodal-EGARCH	**Bimodal-EGARCH**	0.1410	0.5053	-0.1420	-1.4573
		(0.8878)	(0.6134)	(0.8871)	(0.1450)
Bimodal-EGARCH	**Normal-EGARCH**	0.6398	-0.2809	0.3639	1.1650
		(0.5223)	(0.7787)	(0.7159)	(0.2440)
Bimodal-EGARCH	**Student's t-EGARCH**	0.9310	-0.3476	0.1149	0.8002
		(0.3518)	(0.7281)	(0.9085)	(0.4236)
Student's t-EGARCH	**Normal-EGARCH**	0.0000	0.0000	0.0000	0.0000
		(1.0000)	(1.0000)	(1.0000)	(1.0000)

From the pairwise comparison which tests whether one of the two models is better than one another. The model with smaller KLIC distance will be considered as the better model. From table 9, the trimodal-GARCH distribution is preferred to the three competing models in all cases in the lower tail with only one exceptional case at 0.95 quantile while showing worse performance in the upper tail. In contrast, from table 10, the trimodal-EGARCH performs better in the upper tail than in the lower tail. However, since some models are misspecified, then the significance tests of the nonnested comparisons reveal only one rejection. Although at the 10 percent significance level, the trimodal-GARCH distribution is significantly better than the normal-GARCH model at the 0.975 quantile of the lower tail.

4. Concluding remarks

This study is concerned with the application of the proposed distribution of returns in risk management. We propose the conditional trimodal distribution for the returns on S&P500 index and apply it with the estimation of the Value at Risk (VaR). Both the GARCH and EGARCH processes are assumed. We test and compare the performance of our model with the three competing models including the conditional normal distribution, the conditional student's *t* distribution, and the conditional bimodal distribution. The three different tests which are the distribution test, the likelihood ratio test, and the information test are employed.

The distribution test which utilizes the information on the entire distribution rejects all the models in consideration. Furthermore, according to the likelihood ratio test based on proportions of failures, the conditional trimodal distribution, both the GARCH and the EGARCH processes, reveal the better performance with the appending-window method than with the rolling-window method where the trimodal-EGARCH is superior to the trimodal-GARCH model. The results are comparable to the conditional bimodal distribution but the better fit over the conditional student's *t* models which have the worst performance. In addition, the information tests indicate the improved results over the unconditional models since more cases pass the specification testing. However, there is no model that performs best in all cases. From the nonnested comparison tests, although at the 10 percent significance level, the trimodal-GARCH distribution is significantly better than the normal-GARCH model at the 0.975 quantile of the lower tail.

Therefore, comparing with the results obtained from the unconditional trimodal distribution in previous chapter, we find that the unconditional trimodal model reveals the superior performance with respect to the distribution test while the trimodal-EGARCH performs best in the likelihood ratio test. Further, according to the results obtained from the information test, the conditional models give better performance than the unconditional case. The trimodal-GARCH is most preferable when dealing with the lower tail while the trimodal-EGARCH performs better in the upper tail.

Then, the model selection is inconclusive and we cannot conclude that the more complicated conditional models give better performance in some cases. Neither the GARCH nor the EGARCH model considered in this study can fully explain the variance process which may lead to the indication that the variance process has many features (Khanthavit, 1995). In the area of risk management, the choice between the conditional and the unconditional models is still be in doubt. Some previous studies on VaR analysis have proved the usefulness of incorporating the conditional variance in the model (e.g., Pownall and Koedijk, 1999; Cotter, 2000; McNeil and Frey, 2000; Mittnik et al., 2000) but Daníelsson and de Vries (2000) oppose that the unconditional model is more suitable in VaR estimation than the conditional volatility forecasts. Besides, apart from the problem of variance process, the main drawback of the proposed trimodal distribution is the large number of estimated parameters which may induce the estimation errors.

Acknowledgements

We would like to thank the Thailand Research Fund (TRF) for a research grant. We would also like to thank Peter Christoffersen and Roger Koenker for sharing their Gauss and Matlab source code.

References

Baillie, Richard T., and Tim Bollerslev, 1989, The message in daily exchange rates: A conditional-variance tale, Journal of Business and Economic Statistics 7, 297-305.

Baillie, Richard T., and de Gennaro, R. P., 1990, Stock returns and volatility, Journal of Financial and Quantitative Analysis 25, 203-214.

Ball, Clifford A., and Walter N. Torous, 1985, On jumps in common stock prices and their impact on call option pricing, Journal of Finance 40 (1:March), 155-173.

Barone-Adesi, Giovanni, Frederick Bourgoin, and Kostas Giannopoulos, 1998, Don't look back, Risk 11 (August), 100-104.

Bera, A. K., and M. L. Higgings, 1993, ARCH models: Properties, estimation, and testing, Journal of Economic Surveys 7, 305-366.

Black, Fischer, 1976, Studies of stock price volatility changes, Proceedings of the 1976 Business Meeting of the Business and Economic Statistics Section, American Statistical Association, 177-181.

Bollerslev, Tim, 1986, Generalized autoregressive conditional heteroskedasticity, Journal of Econometrics 31, 307-327.

Bollerslev, Tim, R. Y. Chou, and K. F. Kroner, 1992, ARCH modelling in finance: A review of the theory and empirical evidence, Journal of Econometrics 52, 5-59.

Bollerslev, Tim, Robert F. Engle, and Daniel B. Nelson, 1994, ARCH models, in: Robert F. Engle and D. McFadden (eds.), Handbook of econometrics, Vol. 4 (North-Holland, New York) 2959-3038.

Brailsford, T., and R. Faff, 1996, An evaluation of volatility forecasting techniques, Journal of Banking and Finance 20, 419-438.

Byström, Hans NE, 2001, Managing extreme risks in transquil and volatile markets using conditional extreme value theory, Working Paper, Lund University (October).

Campbell, John Y., Andrew W. Lo, and A. Craig MacKinlay, 1997, The econometrics of financial markets (Princeton University Press, New Jersey).

Christie, A., 1982, The stochastic behavior of common stock variances: Value, leverage, and interest rate effects, Journal of Financial Economics 10, 407-432.

Christoffersen, Peter, Jinyong Hahn, and Atsushi Inoue, 2001, Testing and comparing Value-at-Risk measures, Journal of Empirical Finance 8, 325-342.

Cotter, John, 2000, Conditional and unconditional risk management estimates for European stock index futures, Working Paper, University College Dublin.

Crnkovic, Cedomir, and Jordan Drachman, 1996, A universal tool to discriminate among risk measurement techniques, Risk 9, 138-143.

Daníelsson, Jón, and Casper G. de Vries, 2000, Value-at-risk and extreme returns, Working Paper (January).

Daníelsson, Jón, and Yuji Morimoto, 2000, Forecasting extreme financial risk: A critical analysis of practical methods for the Japanese market, IMES Discussion Paper Series 2000-E-8 (April), Bank of Japan.

Engle, Robert F., 1982, Autoregressive conditional heteroskedasticity with estimates of the variance of U. K. inflation, Econometrica 50, 987-1008.

Engle, Robert F., and Victor K. Ng, 1993, Measuring and testing the impact of news on volatility, Journal of Finance 48, 1749-1778.

Fama, Eugene F., 1963, Mandelbrot and the stable Paretian hypothesis, Journal of Business 36, 420-429.

Fama, Eugene F., 1965, The behavior of stock market prices, Journal of Business 38, 34-105.

Fiszeder, Piotr, Jerzy Romański, 1998, Looking for the pattern of GARCH type models in stock returns of polish banks listed on the Warsaw stock exchange, Working Paper, Nicholas Copernicus University in Toruń.

Franses, P., J. Neele, and D. Van Dijk, 1998, Forecasting volatility with switching persistence GARCH models, Working Paper, Erasmus University, Rotterdam.

Giot, Pierre, and Sébastien Laurent, 2001, Modelling daily value-at-risk using realized volatility and ARCH type models, Working Paper (April).

Huisman, Ronald, Kees G. Koedijk, and Rachel A. Pownall, 1998, VaR-x: fat tails in financial risk management, Journal of Risk 1 (Fall), 47-61.

Jorion, Philippe, 1989, On jump processes in the foreign exchange and stock markets, Review of Financial Studies 1 (4), 427-445.

Kearns, P., and Adrian Pagan, 1997, Estimating the density tail index for financial time series, Review of Economics and Statistics 79, 171-175.

Khanthavit, Anya, 1995, Alternative models for conditional volatility: Some evidence from Thailand's stock market, Working Paper, Thammasat University.

Kupiec, Paul H., 1995, Techniques for verifying the accuracy of risk measurement models, Journal of Derivatives 3, Winter, 73-84.

Lehar, Alfred, Martin Scheicher, and Christian Schittenkopf, 2002, GARCH vs. stochastic volatility: Option pricing and risk management, Journal of Banking and Finance 26, 323-345.

Loudon, G., W. Watt, and P. Yadav, 2000, An empirical analysis of alternative parametric ARCH models, Journal of Applied Econometrics 15, 117-136.

Lucas, Andre, 2000, A note on optimal estimation from a risk-management perspective under possibly misspecified tail behavior, Journal of Business & Economic Statistics 18 (1), 31-39.

Mandelbrot, Benoit, 1963, The variation of certain speculative prices, Journal of Business 36, 394-419.

McNeil, Alexander J., and Rüdiger Frey, 2000, Estimation of tail-related risk measures for heteroscedastic financial time series: An extreme value approach, Journal of Empirical Finance 7, 271-300.

Mittnik, Stefan, Marc S. Paolella, and Svetlozar T. Rachev, 2000, Diagnosing and treating the fat tails in financial returns data, Journal of Empirical Finance 7, 389-416.

Nelson, Daniel, 1990, Conditional heteroskedasticity in asset returns: A new approach, Econometrica 59, 347-370.

Pagan, Adrian, 1996, The econometrics of financial markets, Journal of Empirical Finance 3, 15-102.

Pagan, Adrian, and G. William Schwert, 1990, Alternative models for conditional stock volatility, Journal of Econometrics 45, 267-290.

Peters, Jean-Philippe, 2001, Estimating and forecasting volatility of stock indices using asymmetric GARCH models and (skewed) student-t densities, Working Paper, University of Liège (March).

Pownall, Rachel A. J., and Kees G. Koedijk, 1999, Capturing downside risk in financial markets: The case of the Asian crisis, Journal of International Money and Finance 18 (December), 853-870.

Vlaar, Peter J. G., and Franz C. Palm, 1993, The message in weekly exchange rates in the European monetary system: Mean reversion, conditional heteroscedasticity, and jumps, Journal of Business & Economic Statistics 11 (3:July), 351-360.

Zangari, Peter, 1996a, An improved methodology for measuring VaR, RiskMetrics Monitor 2Q96, 7-25.

Improving VaR Forecasts,

Using Information in Derivatives Prices

Anya Khanthavit, *Ph.D.**

Professor of Finance and Banking and TRF Senior Researcher

Faculty of Commerce and Accountnacy

Thammasat University

Bangkok 10200 Thailand

Natachai Boonyapropatrara

Risk Manager

KGI Securities (Thailand) Public Company

Bangkok 10500 Thailand

Somsak Tiraganant

Doctoral Candidate

Faculty of Commerce and Accountnacy

Thammasat University

Bangkok 10200 Thailand

---

* Corresponding author. Tel: (662) 613-2223, Fax: (662) 225-2109, E-mail: akhantha@tu.ac.th. We would like to thank Thailand Research Fund for the financial supports and CITIBANK (Thailand) for the data. We appreciate comments and suggestions from participants at Thammasat's Joint DBA Workshop.

ABSTRACT

Improving VaR Forecasts,

Using Information in Derivatives Prices

A VaR forecast is developed in a Bayesian framework to improve the performance over that of traditional ones. As opposed to the traditional forecasts, which assume risk manager knows the return distribution and that distribution is the same for the realized returns and next period's return, our return distribution is predictive and is derived for the next period's return in particular. Moreover, we are able to incorporate information in the volatilities implied by option prices, in addition to that in the return samples, into the estimation of the predictive distribution. We demonstrate its out-of-sample performance in the risk measurement of daily baht/dollar exchange rate from December 24, 2001 to January 15, 2003. Our Bayesian VaR forecast can outperform those from the traditional ones, which rely on historical or implied volatilities alone.

บทคัดย่อ

การพัฒนาความแม่นยำของการพยากรณ์มูลค่าความเสี่ยง

โดยใช้ข้อมูลเพิ่มเติมจากราคาของหลักทรัพย์อนุพันธ์

การศึกษาพัฒนาเทคนิคเพื่อปรับปรุงความแม่นยำของการพยากรณ์มูลค่าความเสี่ยง โดยใช้ข้อมูลเพิ่มเติมจากราคาของหลักทรัพย์อนุพันธ์ ตามแนวทางการประสานข้อมูลจากแหล่งต่างๆ ภายใต้ทฤษฎีบทของเบย์ ทั้งนี้เทคนิคที่พัฒนาขึ้นได้ใช้การแจกแจงที่เกิดจากการพยากรณ์ผลตอบแทนของการลงทุนในคาบถัดไป แล้วใช้การแจกแจงที่พยากรณ์นี้ไปพยากรณ์มูลค่าความเสี่ยงอีกต่อหนึ่ง การศึกษาใช้เทคนิคไปในการพยากรณ์มูลค่าความเสี่ยงของอัตราแลกเปลี่ยนระหว่างเงินบาทกับเงินดอลลาร์สหรัฐอมริกา โดยข้อมูลส่วนเพิ่มเป็นค่าความผันผวนของอัตราแลกเปลี่ยนที่ชี้โดยนัยจากราคาออปชัน การศึกษาพบว่า เทคนิคที่พัฒนาขึ้นได้ให้ผลการพยากรณ์ที่แม่นยำขึ้นอย่างมีนัยสำคัญ

Improving VaR Forecasts,

Using Information in Derivatives Prices

I. INTRODUCTION

Value at risk (VaR) methods have emerged as a standard tool for measuring market risk. A VaR is the largest loss, expected for the next investment horizon at a confidence level. In order to form a VaR forecast, risk manager must know the return distribution. Normal distributions are generally assumed because of convenience and familiarity. But they cannot capture skewness and fat-tailedness found for most asset returns. Their VaR forecasts are not very accurate. To improve the performance over that of the normal distributions, more realistic and flexible distributions have been proposed. Yet, the success is not clear. No single distribution dominates across assets or markets (Danielsson (2002)).

In this study, we propose an alternative approach to improve the performance of VaR forecasts. It is developed in a Bayesian framework. The approach is motivated by the success of Bayesian analyses to improve the performance of option pricing and price forecasting and by the unrealistic assumptions underlying the traditional VaR forecasts. For the performance improvement, Karolyi (1993) employed a Bayesian estimate of stock return volatility in the Black-Scholes option pricing formula and found that the resulting price was more accurate than the one with the historical volatility. Darsinos and Satchell (2001) derived a Bayesian forecast for option prices in the Black-Scholes framework, while Bauwens and Lubrano (2002) did a Bayesian forecast when the asset price followed a GARCH process. These forecasts outperformed the ones constructed from historical or implied volatilities.

As for the unrealistic assumptions, the traditional VaR forecasts assume that risk manager knows the return distribution and that distribution is the same for the realized return and the next period's return. The assumed known distribution is generally the one that can best fit the realized returns. Even if it were the true distribution of the realized returns, that distribution is not necessarily the one of the next period's return. In reality, moreover, the distribution is not known. It must be estimated using return samples.

Our Bayesian VaR forecasts are different and are based on a more natural and realistic structure. The forecasts rely on the predictive density derived in particular for the next period's return. We also recognize that return samples are not the only source of information for the distribution estimation. Like the previous studies, the Bayesian analysis enables us to incorporate additional useful information into the estimation in a systematic way. These Bayesian treatments should enhance accuracy of the distribution estimates and improve performance of VaR forecasts.

In the analysis, we assume the asset price follows a log-normal process and use this distribution assumption to derive the predictive distribution for the next period's return. We estimate the predictive distribution, using the sample returns and the volatilities implied by option prices. The information in the return samples is historical and it is the information being used by the traditional VaR forecast. The information in the implied volatilities is forward-looking and is reported, for example, by Szakmary et al. (2003) as being able to describe the return in the future very well. The Bayesian analysis enables us to incorporate the information from these two sources in a systematic way. The sample returns are used in the likelihood and the implied volatilities are used in the prior. We demonstrate the performance of our Bayesian VaR forecast in the risk measurement of the daily baht/U.S. dollar exchange rate from December 24, 2001 to January 15, 2003. The Bayesian VaR forecast can outperform those from the traditional ones, which rely on historical or implied volatilities alone.

II. METHODOLOGY

II.1 Derivation of the Predictive Density

Because a VaR is the largest possible loss of the investment in the next period, the underlying distribution must also be the one for the next period's return. But the next period's return cannot be observed. A Bayesian predictive density can naturally serve as the estimate.

In order to derive the predictive density, we first assume the asset price follows a log-normal process, whose mean and standard deviation is μ and σ, respectively. This assumption implies the return is distributed normally, with a $\mu - 0.5\sigma^2$ mean and a σ standard deviation.

We rely on the Bayes Theorem to derive the predictive density. Let $p(\mu, \sigma)$ and $\ell(r_T, r_{T-1},\ldots,r_1 | \mu, \sigma)$ be the prior of (μ, σ) and the likelihood of the return samples. The posterior density $p(\mu, \sigma | r_T, r_{T-1},\ldots,r_1)$ must be proportional to $p(\mu, \sigma)$ and $\ell(r_T, r_{T-1},\ldots,r_1 | \mu, \sigma)$.

$$p(\mu, \sigma | r_T, r_{T-1},\ldots,r_1) \quad \propto \quad p(\mu, \sigma) \times \ell(r_T, r_{T-1},\ldots,r_1 | \mu, \sigma). \qquad (1)$$

For the next period's return, r_{T+1}, its joint density with (μ, σ) is

$$p(r_{T+1}, \mu, \sigma | r_T, r_{T-1},\ldots,r_1) \propto p(r_{T+1} | \mu, \sigma, r_T, r_{T-1},\ldots,r_1) \times p(\mu, \sigma) \times \ell(r_T, r_{T-1},\ldots,r_1 | \mu, \sigma). \qquad (2)$$

Hence, the predictive density $p(r_{T+1} | r_T, r_{T-1},\ldots,r_1)$ can be obtained by integrating out (μ, σ) from equation (2).

$$p(r_{T+1} | r_T, r_{T-1},\ldots,r_1) \quad = \quad \iint p(r_{T+1}, \mu, \sigma | r_T, r_{T-1},\ldots,r_1)\, d\mu\, d\sigma. \qquad (3)$$

From equation (3), our Bayesian VaR forecast at a $(1-\alpha)$ confidence level is the quantity $\mathrm{VaR}(\alpha)$ that satisfies equation (4).

$$\int_{-\infty}^{-\mathrm{VaR}(\alpha)} p(r_{T+1} | r_T, r_{T-1},\ldots, r_1)\, d\, r_{T+1} \quad = \quad \alpha \qquad (4)$$

II.2 The Choices for Prior

As for the prior, we assume that μ and σ are independent, so that

$$p(\mu, \sigma) = p(\mu) \times p(\sigma). \tag{5}$$

We will discuss the choices for the prior densities $p(\mu)$ and $p(\sigma)$ in turn.

II.2.1 The Choices for $p(\mu)$

We propose three choices for the prior density $p(\mu)$. The first choice is a *diffuse prior*. It is appropriate when risk manager knows nothing about the governing parameter μ. The diffuse prior $p(\mu)$ is proportional to a constant. That is,

$$p(\mu) \propto \text{constant}. \tag{6}$$

However, in reality risk manager must know some thing about μ. At the least, μ must be grater than r_f--the rate of return on a risk-free asset, in the market where investors are risk-averse. $\mu > r_f$. This fact motivates our *semi-diffuse prior* for μ. In this case, we assume the prior distribution $p(\mu)$ is a negative exponential distribution. Its density function is

$$p(\mu) = \frac{1}{\sigma} exp\left(-\frac{\mu - r_f}{\sigma}\right). \tag{7}$$

This specification imposes $\mu > r_f$, satisfying the positive risk-premium constraint. The density is peak at r_f and declines as μ grows.

Finally, we consider a case in which the asset return is known and equal to zero. That is,

$$\mu - \frac{\sigma^2}{2} = 0. \tag{8.1}$$

Or,

$$\mu = \frac{\sigma^2}{2}. \tag{8.2}$$

This specification is motivated by the fact that the investment horizon for a VaR forecast is generally short about 1 day or not more than 10 days. So, the expected return for that short investment horizon should be small and effectively zero.

II.2.2 The Choice for $p(\sigma)$

We assume the prior $p(\sigma)$ for σ is an inverted gamma distribution. It is a natural conjugate density. Zellner (1971) suggests that this choice for the prior makes the problem relatively simple and mathematically tractable. The density has the form

$$p(\sigma) = \frac{2}{\Gamma\left(\frac{v}{2}\right)}\left(\frac{vs^2}{2}\right)^{\frac{v}{2}} \frac{1}{\sigma^{v+1}} exp\left(-\frac{vs^2}{2\sigma^2}\right), \tag{9}$$

where $\Gamma(.)$ is a gamma function and v and s are positive parameters.

We acknowledge that the parameters v and s are unknown. They must be estimated. Here is when the volatilities implied by today's option prices play an important role. And this is how we incorporate the information in the option prices into the estimation of predictive density.

To estimate v and s, firstly we compute the implied volatilities from the observed option prices. Secondly, we treat these implied volatilities as being our sample in an ML estimation. Finally, we treat the ML estimates of v and s as known parameters of the prior in equation (9).

II.3 The Likelihood

In this study, it is assumed the asset price follows a log-normal process. Under this assumption, the likelihood $\ell(r_T, r_{T-1},...,r_1| \mu, \sigma)$ for the return samples is

$$\ell(r_T, r_{T-1},...,r_1| \mu, \sigma) = \frac{1}{\left(\sigma\sqrt{2\pi}\right)^T} exp\left[-\frac{1}{2\sigma^2}\sum_{t=1}^{T}\left\{r_t - \left(\mu - \frac{\sigma^2}{2}\right)\right\}^2\right] \quad (10.1)$$

Let V = T-1, $S = \frac{1}{V}\sum_{t=1}^{T}(r_t - \bar{r})$ and $\bar{r} = \frac{1}{T}\sum_{t=1}^{T} r_t$. As Zellner (1971, p 22) shows, equation (10.1) can be rewritten as

$$\ell(r_T, r_{T-1},...,r_1| \mu, \sigma) = \frac{1}{\left(\sigma\sqrt{2\pi}\right)^T} exp\left[-\frac{1}{2\sigma^2}\left\{VS^2 + T\left(\left(\mu - \frac{\sigma^2}{2}\right) - \bar{r}\right)^2\right\}\right] \quad (10.2)$$

II.4 The Posterior and Predictive Densities

We will base our VaR forecasts on the predictive density. Because the choice for the likelihood is common, the form of the predictive density will depend on our choice for the prior density. We will derive the predictive densities for each choice of the priors in turn.

II.4.1 The Case of A Diffuse Prior for μ

If we have a diffuse prior for μ, equations (1), (6), (9) and (10.2) dictate that the posterior density is proportional to

$$p(\mu, \sigma| r_T, r_{T-1},...,r_1) \propto$$
$$\frac{1}{\sigma^{T+V+1}} exp\left[-\frac{1}{2\sigma^2}\left\{vs^2 + VS^2 + T\left(\mu - \frac{\sigma^2}{2} - \bar{r}\right)^2\right\}\right]. \quad (11)$$

Applying equations (2) and (11) and integrating over μ and σ gives the predictive distribution for the diffuse prior case of the form[1]

$$p(r_{T+1} | r_T, r_{T-1},\ldots,r_1) = \frac{1}{k_1}\left[\frac{vs^2 + VS^2 + \frac{T}{T+1}\left(r_{T+1} - \bar{r}\right)^2}{2\,w}\right]^{-\frac{w}{2}}, \qquad (12)$$

where

$$k_1 = \int\left[\frac{vs^2 + VS^2 + \frac{T}{T+1}\left(r_{T+1} - \bar{r}\right)^2}{2\,w}\right]^{-\frac{w}{2}} d\, r_{T+1}$$ is the constant of the integration and

$w = T + V.$

Finally, we apply equation (4) to compute the VaR forecast. The integration in equation (4) and the constant of the integration (k) are computed, using the Kloek and van Dijk (1978) method.

II.4.2 The Case of A Semi-Diffuse Prior for μ

If risk manager utilizes the information that $\mu > r_f$, equation (7) must substitute for equation (6) in the derivation. Following the same steps as we did in the preceding section, we have the predictive density for the semi-diffuse prior case of exactly the same form as that of the diffuse prior case in equation (12). Although we have some information about μ, the predictive density remains unchanged after this information has been applied. The result suggests that the information $\mu > r_f$ is not very useful and cannot help to improve the VaR forecast over the one for the diffuse prior case.

[1] Detailed derivation for this case and the following two cases can be obtained from the corresponding author upon request.

II.4.3 The Case of A Known Prior for μ

If the investment horizon is short as it usually is the case when a VaR forecast is made, the mean return is effectively zero. Risk manager may impose it as a constraint for a VaR forecast. When the constraint $\mu - \frac{\sigma^2}{2} = 0$ is imposed, our derivation of the predictive density must be modified accordingly. Applying this constraint, the likelihood in equation (10.2) becomes

$$\ell(r_T, r_{T-1}, \ldots, r_1 | \mu, \sigma) = \frac{1}{\left(\sigma\sqrt{2\pi}\right)^T} exp\left[-\frac{1}{2\sigma^2}\left\{VS^2 + T\bar{r}^2\right\}\right]. \tag{10.3}$$

Hence, the predictive density in this known prior case is

$$p(r_{T+1} | r_T, r_{T-1}, \ldots, r_1) = \frac{1}{k_2}\left(\frac{vs^2 + VS^2 + T\bar{r}^2 + r_{T+1}^2}{w}\right)^{-\frac{w}{2}} \tag{13}$$

where $k_2 = \int \left(\frac{vs^2 + VS^2 + T\bar{r}^2 + r_{T+1}^2}{w}\right)^{-\frac{w}{2}} d\, r_{T+1}$ is the constant of the integration.

III. Performance Tests

III.1 Competing Models

We empirically evaluate the performance of the Bayesian VaR forecasts against the normality forecasts. The general form of the normality forecasts is

$$VaR_{N(i)}(\alpha) = -\left(\bar{r} + z_\alpha \hat{\sigma}_i\right), \tag{14}$$

where z_α is the standard z score evaluated at α and $\hat{\sigma}_i$ is the volatility estimate of a competing model i. We propose three choices for $\hat{\sigma}_i$--historical volatility $\hat{\sigma}_{HV}$, Beckers' (1981) implied volatility $\hat{\sigma}_{BV}$ and Latane and Rendleman's (1976) implied volitility $\hat{\sigma}_{LV}$.

The historical volatility is the ML estimate of the standard deviation of asset return.

$$\hat{\sigma}_{HV} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(r_t - \bar{r}\right)^2} . \quad (15)$$

We consider $\hat{\sigma}_{HV}$ because the normality forecast based on the ML estimates are widely used in practice. The implied violatilites $\hat{\sigma}_{BV}$ and $\hat{\sigma}_{LV}$ are considered because, for example, Szakmary et al. (2003) reports that implied volatility can forecast the future volatility much better than the historical volatility does. In addition, we use two specifications of the implied volatility because previous studies report that these two specifications can lead to more accurate option prices.

$\hat{\sigma}_{BV}$ and $\hat{\sigma}_{LV}$ are the implied volatilities, derived from the option prices on day T when the forecasts are made. $\hat{\sigma}_{BV}$ is the implied volatility of the option with the highest vega, while $\hat{\sigma}_{LV}$ is the vega-weighted-average implied volatility.

III.2 Empirical Tests

III.2.1 Validity Tests

We check for validity of the competing forecasts, using the approaches developed by the Bank for International Settlements (BIS, 1996) and Kupiec (1995). A successful forecast must describe the maximum possible loss in the next period very well and it must not be rejected by either test.

The BIS test counts the number of times the realized return violates the VaR forecasts and assesses that number against α. The forecasting model falls into a red zone and is rejected if the probability of committing a type-I error is lower than 0.001. The model falls into a green zone and it can be accepted if the probability is grater than 0.10. Otherwise, the model is in a yellow zone and must be revised. We consider the BIS test first because it is the test that financial institutions must observe under the BIS guideline.

The BIS test is conservative and biased for a model, which give larger VaRs correctly or incorrectly. To reconcile the BIS test results, we consider a likelihood ratio (LR) test, proposed by Kupiec (1995). Let N be the number of the test samples and n be the number of times the realized returns violate the VaR. For a 1-α confidence level, Kupiec shows that the following LR statistic is distributed as a chi-squared variable with one degree of freedom.

$$LR = 2ln\left\{(1-\alpha)^{N-n}(\alpha)^{n}\right\} + 2ln\left\{\left(1-\frac{n}{N}\right)^{N-n}\left(\frac{n}{N}\right)^{n}\right\} \quad (16)$$

III.2.2 Model Comparison

It is possible that more than one model can pass the two validity tests or that none will pass the tests. If this is the case, we cannot conclude which model gives the best VaR forecast. In order to identify the best (better) model, we conduct a test proposed by Christoffersen et al. (2001) in addition. The test is based on the information criterion. It measures the distance of the interesting model from the true but unobserved model and compares the distance with that of the competing model. The distance is measured with respect to the violation days and their numbers over the test period vis-a-vis the information variables.

Let $f_D(r_i) = I\{r_i \leq -VaR_D(\alpha)\} - \alpha$ be a function of the realized return r_i on the test date i for a competing model D. $I\{r_i \leq -VaR_D(\alpha)\}$ is the indicator function, where I {.} is one if the condition in the curly brackets is true. Otherwise, I {.} is zero. Next, define a statistic M_D

$$M_D = \frac{1}{N}\sum_{i=1}^{N} exp\left\{\sum_{j=1}^{J} a_j f_D(r_i) Z_{j,i-1}\right\}, \quad (17)$$

where $Z_{j,i-1}$ is the information variable j in the preceding period i-1. If models D = 1 and 2 can perform equally well in terms of the quality of VaR forecasts, the difference $\sqrt{N}\,(M_{D=1}-M_{D=2})$ must be asymptotically distributed normally with a zero mean. The standard deviation of the difference can be estimated from the series of $exp\left\{\sum_{j=1}^{J} a_j f_D(r_i) Z_{j,i-1}\right\}$, where i = 1, 2, ... , N and D = 1, 2, in a straightforward way. If model D = 1 has a better performance, the difference must be negative and significant. But if model D = 2 is better, the difference will be positive and significant.[2]

In this study, for model comparison we will consider a set of five information variables $Z_{j,i-1}$ including a constant, r_{i-1}, r_{i-1}^2, r_{i-1}^3, and r_{i-1}^4. The constant is considered as an information variable to acknowledge the fact that the mean of the function $f_D(r_i)$ is zero. The lagged return r_{i-1} is used because the return in the past period should not have the information about the error from the VaR forecast made by the correct model. The returns r_{i-1}^2, r_{i-1}^3, and r_{i-1}^4 are considered also in order to capture the information about the second, third and fourth moments, respectively.

IV. THE DATA

The data we consider are implied volatilities of at-the-money 1-, 3- and 6-month call options on baht/U.S. dollar exchange rate. The data are daily and cover a period from December 24, 2001 to January, 15 2003 (249 daily observations). These implied volatilities as well as the exchange rates and the Thai and U.S. interest rates for the period are obtained from CITIBANK (Thailand).

The implied volatilities are quoted with respect to the Garman and Kohlhagen (1983) pricing model for foreign exchange options. The model extends the Black-Scholes (1972) model to price a foreign exchange option by interpreted the interest rate in the foreign market as the continuous dividend payment of the underlying stock. The Garman-Kohlhagen formula for a call price is

$$C \quad = \quad FN(d+\sigma\sqrt{T}) - exp\{-T(r_f - r_{US})\}XN(d) \qquad (17)$$

[2] The quantity $-ln(M_D)$ is interpreted as the distance of the interesting model from the true model so that a better model is associated with a smaller statistic M_D.

where F is the implied forward exchange rate and N(x) is the cumulative standard normal density function value evaluated at x. d = $\frac{ln\left(\frac{F}{X}\right) - T\frac{\sigma^2}{2}}{\sigma\sqrt{T}}$. Finally, r_f and r_{US} are the riskless rates in the Thai and the U.S. markets, respectively.

We notice that for the same options, the numbers of calendar days to expiration are not necessarily the same due to practical day counts and month of the year, while the implied volatilities are reported in percentage per year. So, the adjustment must be made. We first compute the corresponding call prices on each day. We then use these prices to recover the implied volatilities in percentage per day, based upon the actual calendar day counts.

Finally, we append the time series of the exchange rate prior to December 24, 2001 by the data from Datastream. These appended data are needed for the Bayesian and (historical) normality forecasts to form the likelihood and to estimate the historical volatility, respectively.

For this data set, we can form a sample set of 249 observations for the test of out-of-sample forecasts. For the Bayesian forecast, we set T equal to 250 and 50 observations for the likelihood. The choice of 250 observations follows the BIS (1996) guideline. The choice of fewer observations is made because Zellner (1971) points out that the sample information in the likelihood will dominate the prior information and the Bayesian VaR forecast converges to the historical normality forecast, when T becomes large.

Table 1 reports the descriptive statistics of the rate of change of the baht/U.S. dollar exchange rate for the test period. From the table, the mean return is very small, compared to the standard deviation. The *t*-test for a zero mean return cannot reject the hypothesis. This finding supports the known prior specification in which the mean return is pre-set to zero. The skewness is 2.09 and the kurtosis is 13.34, suggesting that the distribution is skewed to the right and has extremely fat tails. The Jarque-Bera test rejects the normality hypothesis with probability 1.00.

TABLE 1

DESCRIPTIVE STATISTICS

The table reports the descriptive statistics of the rate of change of daily baht/U.S. dollar exchange rate from December 24, 2001 to January 15, 2003 (249 daily observations). * denotes significance at 1%.

Statistics	Value
Number (N) of test samples	249
Mean	-0.000113
Median	-0.000240
Maximum	0.022295
Minimum	-0.011015
Standard Deviation	0.003354
Skewness	2.090958
Kurtosis	13.337461
t-test for a zero mean	0.2975
Jarque-Bera test for normality	1945.617*

The fact that normality has been rejected for the return sample does not necessarily imply that the normality VaR forecast will perform poorly. In previuos studies such as Khanthavit (2003), even though more realistic and flexible distributions that can accommodate the skewness and fat-tailedness can describe the in-sample return well, their out-of-sample VaR forecasts do not perform significantly better and sometimes poorer than a normality forecast does.

V. EMPIRICAL RESULTS

In this study, we set α at 99% and 95% for VaR forecasts. These choices are common in the literature and are adopted in practice. For the performance comparison, let's turn first to the BIS' three-zone test. Table 2 reports the number of days, which the realized returns violate the VaR forecasts. Because the test samples are 249 observations, at α of 99% and 95% the expected number of violation days should be 2.49 and 12.25, respectively. The table has 2 panels. Panel 2.1 is for T = 50 and panel 2.2 is for T = 250.

TABLE 2

BIS' THREE-ZONE TESTS

The table reports the number of violation days and the results for the BIS' three zone tests of the competing VaR forecasts. The test sample covers a period from December 24, 2001 to January 15, 2003 (249 observation). At 1-α = 0.99 (0.95) and the test sample of 249 observations, the red zone begins at the n violation days of 10 (25) and the yellow zone covers n from 6 to 9 (18 to 24). The green zone corresponds with n of 5 (17) or fewer. * and ** indicate the model falls into the red and yellow zones, respectively.

PANEL 2.1

T = 50

Forecasting Model	Confidence level (1-α)	
	99%	95%
Bayesian--diffuse and semi-diffuse priors	4	11
Bayesian--known prior	4	12
Normality--historical	9**	19**
Normality--Beckers' IV	5	14
Normality--Latane and Rendleman's IV	16*	35*

PANEL 2.1

T = 250

Forecasting Model	Confidence level (1-α)	
	99%	95%
Bayesian--diffuse and semi-diffuse priors	3	10
Bayesian--known prior	3	10
Normality--historical	7**	14**
Normality--Beckers' IV	3	13
Normality--Latane and Rendleman's IV	16*	32*

The two panels give similar results. The historical normality and Latane and Rendleman's IV forecasts cannot pass the BIS tests. The former falls into the yellow zone, while the latter falls into the red zone. The Bayesian forecasts of all the choices for prior can perform very well and are in the green zone. The Beckers' IV forecast is in the green zone as well. Because the Bayesian forecasts and Beckers' IV forecast fall into the green zone, based on the BIS test we can conclude only that they both are valid. But we cannot conclude which model gives a better forecast.

The fact that the Bayesian forecasts and the Beckers' IV forecast cannot be rejected by the BIS test may come from the fact that their VaR forecasts are biased upward so that the number of their violation days are small. In order to ensure that the performance is not from the bias of the BIS test, we conduct the LR test for model validity, proposed by Kupiec (1995). The results are reported in Table 3. The results of the Kupiec test, both for T = 50 and 250, support the results of the BIS tests. The historical normality forecast and the Latane and Rendleman's IV forecast are rejected at conventional confidence levels. The Bayesian forecasts and the Beckers' IN forecast cannot be rejected. The results from the two tests lead us to conclude that the Bayesian and Beckers' IV forecasts are valid and can be used to measure the risk of the baht/U.S. dollar exchange rate.

TABLE 3

KUPIEC's (1995) LIKELIHOOD RATIO TESTS

The table reports the results of Kupiec's (1995) likelihood ratio tests for the competing VaR forecasts. The statistics on the first lines are the LR statistics, distributed as a chi-squared variable of one degree of freedom if the model is correct. The numbers in the parentheses on the second lines are their corresponding *p* values. *, **, and *** indicate significance at 1%, 5%, and 10%, respectively.

PANEL 3.1

T = 50

Forecasting Model	Confidence level (1-α)	
	99%	95%
Bayesian--diffuse and semi-diffuse priors	0.7937 (0.3730)	0.1727 (0.6777)
Bayesian--known prior	0.7937 (0.3730)	0.0137 (0.9067)
Normality--historical	10.3361* (0.0013)	3.2029** (0.0735)
Normality--Beckers' IV	1.9977 (0.1575)	0.2090 (0.6476)
Normality--Latane and Rendleman's IV	33.3771* (0.0000)	29.6764* (0.0000)

PANEL 3.1

T = 250

Forecasting Model	Confidence level (1-α)	
	99%	95%
Bayesian--diffuse and semi-diffuse priors	0.1032 (0.7480)	0.5221 (0.4699)
Bayesian--known prior	0.1032 (0.7480)	0.5221 (0.4699)
Normality--historical	5.5709** (0.0183)	0.2090 (0.6476)
Normality--Beckers' IV	0.1032 (0.7480)	0.0301 (0.8623)
Normality--Latane and Rendleman's IV	33.3771* (0.0000)	23.1523* (0.0000)

Although the Bayesian and Beckers' IV forecasts are both valid, it is interesting to ask which model can give better performance. To answer this question, we turn to the Christoffersen et al. information test for model comparison. We report the results in Table 4.

TABLE 4

MODEL COMPARISON

The table reports the information tests for model comparison of the Bayesian VaR forecasts against the normality forecasts. The numbers on the first lines are the difference statistics. A significantly negative (positive) statistic suggests that model 1 (2) is preferred. The numbers in the parentheses on the second lines are *p* values. *, **, and *** indicate significance at 1%, 5% and 10%, respectively.

PANEL 4.1

T = 50

Competing Models		Confidence Levels	
Model 1	Model 2	99%	95%
Bayesian--known prior	Bayesian--diffuse and semi-diffuse priors	0.0002* (0.0000)	0.9973* (0.0061)
Bayesian--known prior	Normality--historical	-4.7139** (0.0242)	-7.5059** (0.0268)
Bayesian--known prior	Normality--Beckers' IV	-2.9043** (0.0147)	-0.3171*** (0.0568)
Bayesian--known prior	Normality--Latane and Rendleman's IV	-2.2901*** (0.0541)	-2.8775*** (0.0664)
Bayesian--diffuse and semi-diffuse priors	Normality--historical	-4.7175** (0.0242)	-8.0607*** (0.0257)
Bayesian--diffuse and semi-diffuse priors	Normality--Beckers' IV	-2.9070** (0.0147)	-0.4234*** (0.0569)
Bayesian--diffuse and semi-diffuse priors	Normality--Latane and Rendleman's IV	-2.2893*** (0.0541)	-2.9716*** (0.0663)

PANEL 4.2

T = 250

Competing Models		Confidence Levels	
Model 1	Model 2	99%	95%
Bayesian--known prior	Bayesian--diffuse and semi-diffuse priors	0.0000 (N.A.)	0.0000 (N.A.)
Bayesian--known prior	Normality--historical	-0.8887** (0.0349)	1.6218** (0.0401)
Bayesian--known prior	Normality--Beckers' IV	-0.0050* (0.0000)	2.3653** (0.0378)
Bayesian--known prior	Normality--Latane and Rendleman's IV	-2.8380*** (0.0517)	-2.2536*** (0.0527)
Bayesian--diffuse and semi-diffuse priors	Normality--historical	-0.8887** (0.0349)	1.6218** (0.0401)
Bayesian--diffuse and semi-diffuse priors	Normality--Beckers' IV	-0.0050* (0.0000)	2.3653** (0.0378)
Bayesian--diffuse and semi-diffuse priors	Normality--Latane and Rendleman's IV	-2.8380*** (0.0517)	-2.2536*** (0.0527)

Let's turn to the case in which T = 50. We first compare the Bayesian forecasts with a (semi-) diffuse prior with the one with a known prior. If the known prior is correct, its resulting VaR forecast must perform better than the one under the (semi-) diffuse prior. However, the test indicates that this is not the case. The forecast with a (semi-) diffuse prior can perform significantly better than the one with a known prior for VaR(1%) and VaR(5%). This finding suggests that the constraint $\mu - \frac{\sigma^2}{2} = 0$ imposed on the prior may be incorrect. We compare the two Bayesian forecasts against the normality forecasts and find that the Bayesian forecasts perform significantly better than all the normality forecasts, including the Beckers' IV forecast.

The results for the case in which T = 250 are different. Here, the two Bayesian forecasts give the same violation days, so the difference is zero and the statistical test cannot be conducted. For VaR(1%), the Bayesian forecasts are superior to all the normality forecasts. For VaR(5%), however, the normalty forecasts are preferred except for the Latane and Rendleman's IV forecast. The fact that the Bayesian forecasts perform poorer when T grows to 250 observation may result from the dominance of the sample information over the prior information.

VI. CONCLUSION

In this study, we develop a VaR forecast in a Bayesian framework. As opposed to the traditional forecasts, which assume risk manager knows the return distribution and that distribution is the same for the realized returns and next period's return, our return distribution is predictive and is derived for the next period's return in particular. Moreover, we are able to incorporate information in the volatilities implied by option prices, in addition to that in the return samples, into the estimation of the predictive distribution. We demonstrate its out-of-sample performance in the risk measurement of daily baht/dollar exchange rate from December 24, 2001 to January 15, 2003. Our Bayesian VaR forecast can outperform those from the traditional ones, which rely on historical or implied volatilities alone. We plan to examine if the performance of the Bayesian forecast is robust across assets and national markets.

REFERENCES

Bank for International Settlements, 1996, Supervisory framework for the use of "backtesting" in conjunction with the internal models approach to market risk capital requirements, Bank for International Settlements, Basle.

Bauwens, L., and M. Lubrano 2002, Bayesian option pricing using asymmetric GARCH models, **Journal of Empirical Finance** 9, 321-342.

Beckers, S., 1981, Standard deviations in option prices as predictors of future stock price variablity, **Journal of Banking and Finance** 5, 363-382.

Black, F., and M. Scholes, 1973, The Pricing of Options and Corporate Liabilities, **Journal of Political Economy** 81, 637-59.

Christoffersen, P., J. Hahn, and A. Inoue, Testing and comparing Value-at-Risk measures, **Journal of Empirical Finance** 8, 325-342.

Danielsson, Jon, 2002, The emperor has no clothes: Limits to risk modeling, **Journal of**

Banking and Finance 26, 1273-1296

Darsinos T. and S. Satchell, 2001, Bayesian Forecasting of Options Prices: A Natural Framework for Pooling Historical and Implied Volatility Information, Manuscript, University of Cambridge, Cambridge.

Garman, M., and S. Kohlhagen, 1983, Foreign currency option values, **Journal of International Money and Finance** 2, 239-253.

Karolyi, G., 1993, A Bayesian approach to modeling stock return volatility for option valuation, **Journal of Financial and Quantitative Analysis** 28, 579-594.

Khanthavit, A., 2003, A performance comparison of alternative risk models: A case for Thailand, Manuscript, Faculty of Commerce and Facultancy, Thammasat University, Bangkok (in Thai).

Kloek, T. and H. K. van Dijk., 1978, Bayesian estimates of equation system parameters: An application of integration by Monte Carlo**, Econometrica** 46, 1-19.

Kupiec, P., 1995, techniques for verifying the accuracy of risk management models **Journal of Derivatives** 3, 73-84.

Latane, H., and R. Rendleman, Jr., 1976, Standard deviations of stock price ratios implied in option prices, **Journal of Finance** 31, 369-381.

Szakmary, A., E. Ors, J. Kim, and D. Davidson, III, 2003, The predictive power of implied volatility: Evidence from 35 futures markets, **Journal of Banking and Finance** 27, 2151-2175.

Zellner, A., 1971, **An Introduction to Bayesian Inference in Econometrics**, John Wiley, New York.

Outside Directors, Audit Committee Structure, and Firm Performance: Evidence from Thailand

Anya Khanthavit, Ph.D.*

Professor of Finance and Banking and TRF Senior Researcher

Faculty of Commerce and Accountancy,

Thammasat University, Bangkok, Thailand

Tel: (662) 613 2223; Fax: (662) 225 2109

Seksak Jumreornvong, Ph.D.

Assistant Professor of Finance and Banking

Faculty of Commerce and Accountancy,

Thammasat University, Bangkok, Thailand

Tel: (662) 613 2234; Fax: (662) 225 2109

Sorasart Sukcharoensin

Doctoral Candidate

Faculty of Commerce and Accountancy,

Thammasat University, Bangkok, Thailand

Tel: (662) 671 9061-2; Fax: (662) 249-7371

---

* Corresponding author. The authors would like to thank Thailand Research Fund for the financial supports.

ABSTRACT

Outside Directors, Audit Committee Structure, and Firm Performance: Evidence from Thailand

We examine the relationship of the firm's performance with the independence structure of audit committee and other corporate governance mechanisms of Thai firms listed on the Stock Exchange of Thailand in the year 2000. We apply the simultaneous-equations approach to acknowledge the possible endogeneity relationship among the variables in order to avoid inconsistency problems. We test for exogeneity and endogeneity of the firm's performance and governance mechanisms, so that the relationship is interpreted correctly. This test has never been conducted by any other study and we consider it as our contribution.

We find that the independence structure of audit committee and the level of debt financing are determined simultaneously with the firm's performance. As opposed to previous studies, we find that the firm's performance, debt financing and audit committee independence are exogenous to and are determinants of certain corporate governance mechanisms.

JEL classification: G32; G34; C31

Keywords: Audit committee; Corporate governance; Firm performance; Outside directors; Thailand

บทคัดย่อ

โครงสร้างของคณะกรรมการตรวจสอบกับความสำเร็จของบริษัทจดทะเบียนไทย

การศึกษาตรวจสอบลักษณะของโครงสร้างของคณะกรรมการตรวจสอบในด้านความเป็นอิสระอย่างแท้จริงที่จะมีผลต่อความสำเร็จในการดำเนินงานของบริษัทจดทะเบียนไทย โดยการศึกษาได้พิจารณามาตรการอื่นด้านบรรษัทภิบาลร่วมด้วย การศึกษาพบว่า สำหรับปี พ.ศ. 2543 บริษัทที่มีผลการดำเนินงานดี มีความสำเร็จ มักมีโครงสร้างของคณะกรรมการตรวจสอบที่เป็นอิสระจริง และมักระดมทุนโดยการก่อหนี้ ลักษณะกลุ่มนี้ได้รับการกำหนดร่วมกันในดุลยภาพและโครงสร้างของคณะกรรมการตรวจสอบไม่ใช้ตัวแปรซึ่งกำหนดความสำเร็จของบริษัท

Outside Directors, Audit Committee Structure, and Firm Performance: Evidence from Thailand

1. Introduction

It is believed that good corporate governance can bring about certain benefits to a firm for at least two reasons. One, good governance leads to closer and careful internal monitoring of the firm's management, thereby ensuring the management's operational and investment decisions that lead to a maximized firm value. Two, it improves quality and transparency of information disclosure to the market. Stakeholders--major and minor shareholders, creditors, employees, suppliers, regulators, for example, now have sufficient and accurate information about the firm to assess its performance and plans *vis-à-vis* their expectations. Stakeholders can be very influential. Their monitoring of and corrective feedback to the firm are market discipline, being sought after by regulators in all national markets.

Corporate governance mechanisms can come in various forms. An audit committee is designed recently as a governance mechanism to reduce potential conflicts of interests and moral hazards within a firm. The audit committee monitors activities of the firm's top management, reviews the firm's financial statements, and provide the firm's stakeholders with internal audit investigations over transactions that may be subject to conflict of interests or may be in favor of the top executives (Wallace (1985), Klein (1998)). In addition, the audit committee can reduce contractual costs, resulting from information asymmetry between the firm and external stakeholders by providing certification on financial statements and by ensuring timely release of unbiased accounting information (Deli and Gillan (2000)).

An audit committee in the structure of the firm's board of directors is well-received in developed and emerging markets around the world. In Thailand, in particular, good governance is so important that the government has set it as a national agenda for social and economic development.

In 1993, the Stock Exchange of Thailand (SET) required its listed firms to elect at least two independent directors to the boards. In addition, the audit committee structure has been imposed recently in late 1999 as being its new governance mechanism. This new rule is more stringent. At least three independent directors on the board must serve in the audit committee. It is hoped that the newly imposed audit committee structure can ensure a high standard of the information disclosure and the monitoring process.

Verschoor (1993) and Vicknar et al. (1993) warn that the audit committee can hardly serve as a very effective governance mechanism, unless its members are truly independent of the firm's top management and major shareholders. Yet independence of the audit committee members is practically the firm's choice, because candidates are searched and nominated by the firm's top management. Furthermore, major shareholders with decisive votes generally have a close tie with the top management, so the management's nominees tend to be elected.

We use the information in the year 2000 for the SET's 264 listed firms in Table 1 to demonstrate this fact.

Table 1

The Structure of Audit Committees

of the SET's Listed Firms in 2000

This table presents the summary statistics for the audit committee structure. The sample consists of 264 firms listed on the Stock Exchange of Thailan in 2000. Financial firms are not included in the sample.

Audit committee information	No. of firms	(%)
Sample size	264	
All audit committee members are independent	160	(60.61%)
No audit committee	3	(1.14%)
At least one audit committee is		
Inside directors:		
Employee of the firm, its subsidiary, or associated firm	4	(1.52%)
Representing major / controlling shareholders		
Employee of the major / controlling shareholder's firm	9	(3.41%)
Business group	22	(8.33%)
Affiliated /Gray area directors:		
Relative of the management	2	(0.76%)
Former employee	16	(6.06%)
Representing stakeholders:		
Other blockholders	25	(9.47%)
Bank affiliated	14	(5.30%)
Other business relationship*	10	(3.79%)
Holding more than 0.5% of the company's shares	7	(2.65%)

Note: * representing firms' suppliers, customers, lawyers, or business consultants.

In Table 1, we have inside directors, affiliated directors, and independent directors. This classification is consistent with the SET's *Code of Best Practice for Directors of Listed Companies* (1999). But our definitions differ. We refer the inside directors to executive directors, employees or advisors, who receive regular salary or any other benefits from the firm or its subsidiaries. We also refer the inside directors to the directors who work in other firms but owned by the firm's major shareholders.

We define the affiliated directors as the directors who represent stakeholders of the firm. For example, they are the relatives of top executives, former employees, and the representatives of the firm's customers, suppliers, creditors, or blockholders. Next, we define independent outside directors as those directors who have no affiliation with the firm beyond being a member of the board or the audit committee. We follow the SET by adding that independent directors must hold less than 0.5% of the firm's equity stocks. Examples of independent directors are academic professions, government officers, and top executives from truly independent firms.

Under the SET's rule, all the directors who serve in the audit committees must be independent directors and all the firms must have an audit committee. Because the rule was relatively new then in the year 2000, three firms in our sample still did not have audit committees and four firms appointed their executives to serve in the committees. We believe these seven cases were unintentional.

It is interesting to note that 40% (105 firms) of the sample firms have at least one inside director or affiliated director serving in the audit committee. Most of these seemingly dependent directors represent the firms' major shareholders, other blockhoders, creditors or they are former employees of the firms. This finding is similar with what was found earlier for U.S. firms by Verschoor (1993) and Klein (1998).

Table 1 points to the fact that the independence structure can be manipulated. So, it is possible the firm's performance is jointly determined with--not by, audit committee's independence and other control mechanisms, as is suggested by Agrawal and Knoeber (1996) and Hermalin and Weisbach (1998). It is the empirical question as to how the firm's performance and the audit committee independence are related.

Despite the significance of this question, empirical studies on the relationship of the audit committee and firm's performance are limited. Moreover, some are conducted improperly, so their results are not very reliable. For example, using an OLS regression in her test, Klein (1998) reports that the independence structure of audit committees cannot affect the firm's performance. As is pointed out by Hermalin and Weisbach (1991, 2000) Agrawal and Knoeber (1996), and Mishra and Nielsen (2000), the independence structure may not be exogenous to the firm's performance. If these two variables are endogenous, Klein's OLS results are necessarily inconsistent and are potentially incorrect.[1]

---

[1] This failure of the OLS regression is sometimes labeled simultaneous-equations bias.

In this study, we test for the relationship between the firm's performance and the independence structure of audit committee against existing literature. We are aware of the possible endogeneity relationship between the two variables and we recognize the OLS' simultaneous-equations bias under such a relationship.

We propose a simultaneous-equations model to respond with the possible endogeneity problem. This econometric model classifies the firm's performance and the independence structure as being endogenous variables. This model always gives consistent parameter estimates, even though in reality the independence structure is exogenous.

We are also aware that alternative governance mechanisms are available to the firm such as debt issuance or independent directors. These mechanisms can be use with or serve as complement or as substitute mechanisms of the independence structure. Our model considers these alternative governance mechanisms, in addition to the independence structure, in order to ensure that our system of equations is complete.

It is important that we conclude governance mechanisms are endogenous or exogenous to the firm's performance in order for us to interpret their relationship correctly. The simultaneous-equations model enables us to conduct such a test for exogeneity. In this study, therefore, we propose a two-step procedure. In the first step we do not assume but test for exogeneity of governance mechanisms to the firm's performance. Then, we examine how the firm's performance and the governance mechanisms relate with one another in the second step.

In her recent study, Klein (2002) acknowledges such a possible endogeneity relationship among corporate governance mechanisms. She uses the simultaneous-equations model to respond to this possibility. Although our study and hers apply the same technique, the two studies differ in significant ways. Firstly, our study examines the relationship of the firm's performance and governance mechanisms. The Klein study considers only the relationship of independence composition of audit committee and board of directors. It does not examine how these two governance mechanisms and the firm's performance are related. Secondly, our study tests for exogeneity so that the revealed relationship is interpreted correctly. The Klein study does not. It interprets the results, assuming the variables are endogenous.

Our study is similar to Prevost et al. (2002). We both consider the firm's performance and the control mechanisms as being endogenous and we apply the simultaneous-equations approach to correct the possible inconsistency problems. However, in the Prevost et al. study, other control mechanisms--such as insider directors, blockholders and debt financing, are treated as exogenous, although these control mechanisms are potentially endogenous. If these control mechanisms are endogenous, the results from the Prevost et al. will still incur the problems. Our study considers all these control mechanisms as endogenous and test for their exogeneity before it interprets the results; hence all the inconsistency problems are hardly possible.

Using cross-sectional data for 264 firms listed on the SET in the year 2000, we find that the firm's performance is endogenous to the independence structure of audit committee and the level of debt financing. That is, audit committee independence and debt level are determined simultaneously with the firm's performance. We also find that the firm's performance, debt financing and audit committee independence are exogenous to and are determinants of blockholdings, insider holdings, and independent directors. The finding is important because it gives policy makers the correct understanding of the role of audit committee and other governance mechanisms. In general, it suggests that the firm's performance cannot be improved by good corporate governance mechanisms. In fact, they are jointly and simultaneously determined. In particular, it points to the fact that the SET's 1993 rule, that requires listed firms to appoint independent directors, has not been effective.

The organization of this study is as follows. In section 2, we construct a simultaneous-equations model to describe the endogeneity structure of the firm's performance and governance mechanisms against exogenous variables considered in the literature on good corporate governance. This structure is quite general. By parameter restrictions, it can accommodate the structure under which the governance mechanisms are exogenous to the firm's performance. We then use this fact to test for exogeneity. Section 3 briefly describes the data. Section 4 reports the empirical results and Section 5 concludes.

2. The Simultaneous-Equations Model

2.1 The Construction of the Model

In this study, we examine the relationship of the firm's performance with the independence structure of audit committee (*ACOMPO*) and four other corporate governance mechanisms, including the independence structure of the board of directors (*BCOMPO*), the insider ownership (*OWN*), the blockholder ownership (*BLOCK*), and the firm's leverage (*DEBT*).

We measure the firm's performance by its Tobin's *Q* ratio. The ratio is the market capitalization of the firm's equity stocks and debt securities over the market, replacement value of the firm's assets. This variable reflects the market expectations of the firm's value net of the agency costs. Hermalin and Weisbach (1991) point out that, in absence of the firm's market power, a divergence of the ratio from 1.00 indicates the firm's value over or under the accounting assets, probably resulting from the value of the internal organization or the value of the expected agency costs. A ratio above one indicates that the market views the firm's internal organization as exceptionally good and/or its expected agency costs as particularly small. Hence, the Q ratio is appropriate because it is consistent with the design of corporate governance mechanisms for reducing agency costs resulting from a separation of ownership and control.

Due to inactive markets for corporate debts and assets in place, we have to replace the market value of debt securities and assets by their book values. This modified ratio is widely used in the corporate governance literature, for example, by Morck et al. (1988), McConnell and Servaes (1990), Yermack (1996). Moreover, Perfect and Wiles (1994) find that this simple approximation such as the one we use here is highly correlated with the correct ratio.

The relationship of the firm's performance with the five interesting governance mechanisms can be described by the system of equations (1) to (6), written in matrices as follows.

$$
\begin{bmatrix} Tobin's\,Q_i \\ ACOMPO_i \\ BCOMPO_i \\ OWN_i \\ BLOCK_i \\ DEBT_i \end{bmatrix} = \begin{bmatrix} \gamma_{10} \\ \gamma_{20} \\ \gamma_{30} \\ \gamma_{40} \\ \gamma_{50} \\ \gamma_{60} \end{bmatrix} + \begin{bmatrix} 0 & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} \\ \beta_{21} & 0 & \beta_{23} & \beta_{24} & \beta_{25} & \beta_{26} \\ \beta_{31} & \beta_{32} & 0 & \beta_{34} & \beta_{35} & \beta_{36} \\ \beta_{41} & \beta_{42} & \beta_{43} & 0 & \beta_{45} & \beta_{46} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & 0 & \beta_{56} \\ \beta_{61} & \beta_{62} & \beta_{63} & \beta_{64} & \beta_{65} & 0 \end{bmatrix} \begin{bmatrix} Tobin's\,Q_i \\ ACOMPO_i \\ BCOMPO_i \\ OWN_i \\ BLOCK_i \\ DEBT_i \end{bmatrix}
$$

$$
+ \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdot & \cdot & \cdot & \gamma_{1k} \\ \gamma_{21} & \gamma_{22} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & & & & \cdot \\ \cdot & & \cdot & & & \cdot \\ \cdot & & & \cdot & \cdot & \cdot \\ \gamma_{61} & \cdot & \cdot & \cdot & \cdot & \gamma_{6k} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_k \end{bmatrix} + \begin{bmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \\ \varepsilon_{3i} \\ \varepsilon_{4i} \\ \varepsilon_{5i} \\ \varepsilon_{6i} \end{bmatrix} \quad \begin{matrix} (1) \\ (2) \\ (3) \\ (4) \\ (5) \\ (6) \end{matrix}
$$

In the system, we treat the variables Tobin's *Q*, *ACOMPO*, *BCOMPO*, *OWN*, *BLOCK*, and *DEBT* as endogenous variables. Subscript *i* indicates that the variables are for firm *i*. These variables appear on the left- and right-hand sides of the equations, meaning they explain and are explained by the others as they are jointly determined by the factors exogenous to the system. The coefficients β describe the exact relationship among these variables. The coefficients β_{jj}, where j = 1, 2,.., 6, are necessarily zero to avoid the obvious identity.

We add independent/exogenous variables X_1 to X_k in equations (1) to (6) as control variables. The coefficients γ_{js} indicate the reaction of the endogenous variables *j* to the independent variable *s*. Each equation needs not have the same set of independent variables. We restrict γ_{js} to 0.00 if independent variable *s* is not considered in equation (j) for the endogenous variable *j*. We will discuss the choices for the independent variables and their reaction coefficients in Section 2.4. Finally, the variables ε_{ji} are regression errors in equation (j) for firm *i*.

2.2 Test for Exogeneity

If corporate governance mechanisms are exogenous to the firm's performance, these mechanisms must not be explained directly or indirectly by the firm's performance. So, if governance mechanism j, for some j $\geq$ 2, is exogenous to the firm's performance, the parameters must obey these two regularity conditions.

(i) β_{j1} **=** 0.00, i.e. the firm's performance cannot explain governance mechanism j directly.

(ii) If $\beta_{m1} \neq 0.00$ for some $m \geq 2$ and $m \neq j$, i.e. if mechanism m is explained by the firm's performance, then β_{jm} **=** 0.00, i.e. mechanism j must not be explained by mechanism m. Or, mechanism j is not explained indirectly by the firm's performance through mechanism m.

An exogenous governance mechanism j determines the firm's performance if its relevant coefficients satisfy conditions (i) and (ii) above *and* its coefficient $\beta_{1j} \neq 0.00$.

2.3 The Endogeneity relationship of Corporate Governance Mechanisms with the Firm's Performance

Before we proceed to discuss the role of independent variables, it is important that we understand the relationship of the firm's performance with corporate governance mechanisms.

Let us turn first to equation (1). Klein (1998) suggests that the *ACOMPO* is an effective governance mechanism that can raise the firm's value. So, we expect a positive β_{12}. We will measure the *ACOMPO* by the percentage of audit committee members held by independent outside directors.

We consider the *BCOMPO* in the system because Baysinger and Butler (1985) suggest that outside directors offer monitoring services so that agency costs of the firm is reduced. Here, the *BCOMPO* is the ratio of the number of independent directors and the number of all the directors on the board. With respect to Baysinger and Butler (1985), we expect β_{13} is greater than 0.00.

The *OWN* is the sum of all shareholdings of the management and the board members. We consider this governance mechanism with respect to Jensen and Meckling (1976), who argue firms with more insider ownership tend to incur lower agency costs. So, β_{14} should be positive.

The *BLOCK* is motivated by Shleifer and Vishny, (1986, 1997), who propose that large shareholders monitor the management of firm quite effectively. It is measured by the summed percentage holding of large shareholders with more than 5% holding of the firm's equity stocks. If Morck et al. is correct, then $\beta_{15} > 0.00$.

Finally, the *DEBT* is included because, according to Jensen and Meckling (1976), debt serves as a discipline mechanism to reduce agency problems between the management and shareholders. Hence, β_{16} should be positive. In this study, the *DEBT* is measured by the ratio of the book values of total debt to total assets.

In equations (2) to (6), the governance mechanisms can be endogenous to one another because the firm may use one with the others to enhance performance even more. Or, the firm may use a mechanism as complement or substitute of other mechanisms. So, β_{js} for $s \geq 2$, can be positive or negative. It can be zero, if mechanism j and s are irrelevant.

The firm's performance may explain the corporate mechanisms too (Hermalin and Weisbach (1998)). Because the firm can choose types of the mechanisms and their degree of intensity, it may make its choice *vis-à-vis* the firm's performance in equilibrium with respect to the optimization behavior. Hence, β_{j1} can be different from zero.

We will interpret the relationship of these variables from the parameter estimates after the exogeneity hypothesis has been tested for.

2.4 Independent Variables

2.4.1 Equation (1): The Firm's Performance (Tobin's Q)

We turn next to the independent variables *X*. In equation (1), the independent variables are the asset size (*ASSET*), the firm's investment in research and development (*RD*), the growth opportunity (*CAPEX*), the firm's age (*AGE*), and the industry dummies.

The *ASSET*--measured by the logged book value of the firm's assets, is to control for size differences across the sample firms. The effect can be positive or negative. On the one hand, Fama and Jensen (1983) note that the agency costs tend to increase with firm size. So, based on this argument, a negative coefficient is expected for this variable. On the other hand, however, Booth and Deli (1996) suggest that large firms tend to have more investment opportunities, resulting in a positive effect on the firm's performance. Hence, a positive relation can also be found.

The *RD* variable is measured by a dummy variable to indicate the fact that the firm spends or does not spend for research and development. This variable can affect the firm's performance in two aspects. One, it reflects the firm's growth opportunity, so the *RD* variable is positively related with the firm's performance (Morck et al. (1988)). Two, however, the *RD* variable can proxy the scope of discretionary spending, which are difficult to be monitored (Himmelberg et al. (1999)). Hence, the agency costs are high and the firm's performance is lower with a rising *RD*. Because the first and second effects are in opposite directions, the coefficient of the *RD* can be negative or positive. Or, the effects can cancel, resulting in a zero coefficient.

As noted by Lang et al. (1989), because the Tobin’s *Q* ratio is a measure of firm performance, it should reflect the discounted value of future growth opportunities. In this study we use the ratio of net capital expenditure scaling by the book value of assets to proxy the *CAPEX*. Lang et al. (1989) note that *Tobin's Q* grows with the firm's growth opportunity, so the coefficient for the *CAPEX* should be positive.

Finally, for equation (1), we recognize we employ the book value of assets as the denomination of *Tobin's Q*. But the book value is historical. It tends to understate more the true asset value as the firm ages increase. So, we control for this upward bias of our *Tobin's Q* by the *AGE* measured by the logged number of years counting from the firm's inception. If the bias exists, the coefficient should be positive and significant.

We also recognize a different growth rate in each stage of the firm's life cycle. A younger firm has a larger growth opportunity, while an older firm has a smaller one. The *AGE* variable can also reflect this growth opportunity too. For the life-cycle hypothesis, the *AGE* will vary negatively with the *Tobin's Q* ratio. Its resulting coefficient is the net effect of the bias and the growth opportunity.

In addition to these independent variables, we also include the industry dummy variables to remove the industry effects.[2]

---

[2] The industry dummies will be added to all the equations. So, in the following equations, we will not repeat this information.

2.4.2 Equation (2): The Independence Structure of Audit Committee (ACOMPO)

We choose the *ASSET*, the ratio of the firm's fixed assets to its total assets (*CAPINT)*, and the reputation of audit-committee members (*REP*) to be independent variables for equation (2). Klein (2002) documents that larger firms with a high *ASSET* may require lower levels of audit committee independence because they tend to have stronger internal auditing system. So, they require fewer independent directors to verify the information and the coefficient should be negative.

As for the *CAPINT*, Himmelberg et al. (1999) point out that investment in fixed assets can be observed and can be monitored quite easily from the outside. Firms with more fixed assets (high *CAPINT*) need less monitoring. The relationship between the *CAPINT* and *ACOMPO* should be negative.

In order to measure the *REP*, we notice that a more reputable director will serve many more firms than does a less reputable one. So, we set the *REP* variable to the sum of the numbers of all firms served by the firm's audit committee members, divided by the number of members in that audit committee. Effectively, the *REP* is the average number of firms, served by a member of the firm's audit committee. A higher *REP* variable should reflect its members' reputation. Fama (1980) and Fama and Jensen (1983) argue that directors have incentive to maintain their reputation in the labor market. Because it is costly for a reputable director to behave in an appropriate way, the independence structure of the audit committee tends to be less important. We expect the *REP* is negatively related with the *ACOMPO*.

2.4.3 Equation (3): The Independence Structure of Board of Directors (BCOMPO)

The independent variables for the *BCOMPO* equation are the *ASSET*, the diversified-business dummy (*MSEG*), the intensity of executives on the board (*INSIDER*), and the *CAPINT.* As for the *ASSET* variable, Agrawal and Knoeber (1996) assert that large firms have greater visibility and can attract independent directors from the outside. The *MSEG* variable captures the firm's diversification of its businesses to several segments as it is disclosed in the annual report. A more diversified firm needs many independent directors to give guidance for unique business lines. If these reasons are correct, the coefficients for these two variables must be positive.

However, it should be noted that the given reasons are from a perspective in a developed market. In an emerging market such as Thailand, independence of board directors is relatively new. Although it is true for Thailand that larger firms or conglomerate firms tend to have more directors on the board, the number of independent directors is small around its required minimum as has been shown earlier in Table 1. So, it is possible that the sign of the coefficients may be the opposite to what has been expected in a more developed market.

Next, the *INSIDER* variable is proxied by a ratio of the number of the firm's executives on the board and the total number of the directors. On the one hand, more executives on the board induce entrenchment, i.e., to avoid monitoring from the outside directors and to lessen their number, thereby resulting in a negative coefficient. On the other hand, however, these executives have more information about the firm than the other board members. Because the *BCOMPO* monitors entrenchment, a high *INSIDER* can be associated with a high *BCOMPO* so that the entrenchment is controlled, while the board retains the insightful information from its executive directors.

The *CAPINT* variable captures the investment in fixed assets. Himmelberg et al. (1999) find that, because fixed assets are visible, firms with more fixed assets needs less monitoring from the outside, including the one from outside directors. For this reason, its coefficient should be negative.

2.4.4 Equation (4): The Inside Ownership (OWN)

Jensen et al. (1992) proposes that the firm's attributes affect the *OWN* variable. We follow this proposition to identify the independent variables for this equation. Firstly, we choose the *RD* and *MSEG* variables. It is difficult for external investors to monitor a firm that spends for research and development or a firm that has many divisions. This difficulty benefits insider owners and should induce more of them. So, the coefficients of these two variables should be positive.

For Thailand, it is important to note that research and development are considered luxurious by most firms. Firms that spend on research and development are usually large technology-oriented firms with more disperse ownership. As we will discuss in the next paragraph, a large firm tends to have a low *OWN*. For this reason, the coefficient of the *RD* can as well be negative.

Secondly, we acknowledge that the wealth of insider owners is limited. For large firms, these insider owners tend to hold fewer equity stocks due to the insufficient-fund and risk-diversification reasons. So, we add the *ASSET* variable as an independent variable in this equation and expect its negative coefficient.

Thirdly, most of the sample firms began from family-owned businesses. Although these firms become public firms today, the founding families can maintain their control power by appointing their family members to serve on the boards. The more family members there are on the board, the higher should the *OWN* be. We set the *FAM* variable, measured by the number of members of founding families on the board, as an additional control variable for this equation and expect its positive relationship with the *OWN* variable.

Finally, the size of the board should affect the *OWN* variable. The *OWN* variable measures the wealth of the firm's management and board directors in equity stocks. Fewer directors on the board imply more holding per person, thereby constituting risk concentration. The risk spreads out if the board has more directors. The *OWN* should rise with the number of the board directors (*NDIR*).

For this matter, John and Senbet (1993) make an important observation that more directors on the board can raise the board’s monitoring capability. Insider owners have less chance to earn more than their fair shares from the firm. So, their holdings reduce and the coefficient is negative.

2.4.5 Equation (5): The Blockholder Ownership (BLOCK)

The role of the *BLOCK* variable to the firm's blockholders is similar to the role of the *OWN* variable to the firm's insider owners. That is, it reflects risk concentration. So, we put the *ASSET* and *NBLOCK* variables as control variables in the fifth equation, where the *NBLOCK* variable is the number of the firm's blockholders. We expect the same signs for their coefficient as the comparable ones in equation (4).

We also consider the *RD* variable, but its relationship with the *BLOCK* should be negative rather than positive. This is because blockholders are outside not inside owners. The difficulty to monitor research and development works against them.

The firm's riskiness (*STDV*) can significantly affect the *BLOCK*. According to Demsetz and Lehn (1985), it is difficult to monitor a firm whose risk is unique. Blockholders concentrate their investment in the firm. Hence, a very risky firm will be less attractive for holding shares in blocks. So, the effect is negative. However, Cho (1998) has a different opinion on the effect. He believes the effects can be positive. Cho argues that, because it is more difficult to monitor a more risky firm, large shareholders have opportunities to exploit the firm's resources for their own interests while other stakeholders of the firms bear the costs (Shleifer and Vishney (1997), La Porta et al. (1999), Johnson et al. (2000)). To absorb more of this benefit, the *BLOCK* rises with the *STDV*. We will measure the *STDV* variable by a three-year average standard deviation of the firm's stock return.

2.4.6 Equation (6): The Leverage (DEBT)

Due to tax deductibility of its interest expenses and coupons, debt is an inexpensive source of funds to the firm. It has been the rule that creditors examine certain qualifications of the firm before they approve loans or purchase debt securities. So, we consider the variables, which can estimate those qualifications, as the independent variables for this equation. They are the *ASSET*, non-debt tax shield (*NDTS*), *CAPINT*, earnings before depreciation expenses, interests, and taxes (*EBDA*), and *RD* variables. We explain why these variables are relevant with the *DEBT* variable in turn.

The *DEBT* should be positively related with *ASSET* for two reasons. One, given a leverage level, the chance to go into bankruptcy should be smaller for larger firms. Two, Bradley, Jarrell, and Kim (1984) argue that asset can be used as collateral for debt. So, more assets are favorable to debt issuance.

We consider the Bradley et al. argument a bit further. Usually, collateral assets are fixed assets. Therefore, we add the *CAPINT* in the equation and expect the same positive sign.

The *NDTS* variable measures the firm's non-debt tax benefits, equal to the sum of depreciation and amortization over the firm's total assets. We expect that firms with a high non-debt tax shield will use low level of debt because the tax shield from interest expenses and coupons is relatively less important to reduce the firm's taxable income. The *NDTS*' coefficient should be negative (DeAngelo and Masulis (1980)).

It should be noted that debt can vary positively with the *NDTS* too. We notice that the amortization component in the calculation of the *NDTS* is quite small. So, the *NDTS* is dominated by the depreciation. With respect to the secured-debt hypothesis, high depreciation reflects the firm's high fixed assets and these fixed assets are favorable to debt issuance (Scott (1977)).

We expect the *DEBT* variable to vary negatively with the *EBDA* variable. The *EBDA* is defined here by the ratio of earnings before depreciation expenses, interests, and taxes to the firm's total assets. The *EBDA* reflects cash earnings for the year. Myers and Majluf (1984) relate the firm's profitability to the choice of debt by the pecking-order hypothesis. That is, a profitable firm accumulates retained earnings. So, it uses its internal source of fund first. The choice for debt is deferred.

There are at least two competing hypotheses that explain how research and development can affect the firm's *DEBT*. Firstly, the *RD* variable can proxy the firm's growth opportunities. With respect to Myers' (1977) under-investment hypothesis, a firm with growth opportunities will experience an under-investment problem if it finances the projects by debt. So, the firm with a high *RD* tends to rely less on debt financing. Secondly, nonetheless, Ross' (1977) signaling hypothesis suggests that a firm that spends more on research and development should employ more debt because a high *RD* will eventually result in good performance. High debt signals that the firm is a good firm. Therefore, the positive coefficient is expected.

2.5 The Estimation Technique

At this stage, we proceed to the econometrics for the estimation of the model. We noted in the first place that the firm's performance and governance mechanisms could be endogenous. If that is the case, the OLS regression will give inconsistent coefficient estimates. The statistics will not converge in probability to their correct values. We propose a two-stage least squares (2SLS) regression to correct this possible econometric problem. As we have shown earlier, the model is still correct even though the governance variables are exogenous. Consistency is maintained.

The 2SLS regression requires independent variables to serve as instrument variables (IVs) in each equation. The set of our IVs consists of all the independent variables in Section 2. We use this full IV set in the regressions in the first stage for all the equations so that all the information we have is employed in estimation. The coefficients that we report are from the regressions in the second stage.

3. Data Descriptions

The data used in this study are cross-sectional of 264 non-financial firms being listed in the year 2000 on the SET. We choose the Thai data because audit committee has been recently implemented in the country. Our findings will give insightful understanding for Thailand about the role audit committees actually play and will fill the gap in the literature for emerging markets.

We choose the year 2000 as our sample period because it is the only available data set. The year 2000 is the first year all the SET's listed firms had to appoint independent board members to serve in the audit committees, after this rule had been implemented in late 1999.

These 264 sample firms exclude the firms with incomplete data on the variables we described in Section 2. They also exclude financial firms because financial firms are in a regulated industry and therefore their governance mechanisms can differ from the others. Booth et al. (2002) report for the U.S.A. market that internal monitoring mechanisms of regulated firms such as banks and utilities are significantly less than those of unregulated firms.

We collect accounting and financial variables from the DATASTREAM INTERNATIONAL database. These variables are year-end, including stock prices, total assets, tangible assets, net capital expenditure, and total debt.

Blockholdings and director descriptions are obtained from the I-SIMS database provided by the SET. Shareholdings of executives and board directors are manually collected from Form 56-1 submitted by listed firms to the SET. Classifications of members to the firm's audit committee are based on the information in Form 56-1, which reports the directors' current professions, past experiences, and their relations with the firms.

4. Empirical Results

4.1. Descriptive Statistics

Table 2 reports descriptive statistics of the firm's performance, corporate governance mechanisms, and certain independent variables. From the table, the average *Tobin's Q* ratio is 0.89, indicating that our sample firms have small growth opportunity or large agency costs. The average ratio of independent audit committee members to all members in the committee is 81.04%, although the SET imposes that the ratio is 100%. This number suggests that the independence structure can be managed with respect to the firm's choice.

The average board size has about 12 directors, while the largest board has 24 directors and the smallest has 6. The ratio of independent directors to the total number of board directors is 27.58%. This ratio, when it is analyzed with the average 12 directors on the board, results in about three independent directors on the board. It should be noted that three is also the minimum number of independent directors to serve in the audit committee. This analysis supports our conjecture in Section 2.3.3 that firms tend to appoint independent directors to meet the SET's minimum requirement.

The average holdings of executives and directors are 16.7%, while those of blockholders are 53.2%. Their sum is 69.9%, thereby suggesting that the SET's listed firms still exhibit ownership concentration.

Table 2

Descriptive Statistics

The summary statistics in this table are the mean, median, maximum, and minimum of the dependent and explanatory variables.

	Mean	Median	Max	Min
Tobin's Q	0.864	0.857	1.730	0.223
ACOMPO	0.810	1.000	1.000	0.000
BCOMPO	0.276	0.267	0.643	0.000
OWN	0.171	0.091	0.943	0.000
BLOCK	0.530	0.538	0.985	0.085
DEBT	0.393	0.380	2.142	0.000
ASSET	8,889.084	2,250.948	260,309.120	207.537
AGE	23.672	21.000	118.000	7.000
CAPEX	0.042	0.025	0.274	0.000
REP	1.023	0.667	6.500	0.000
INSIDER	0.375	0.385	0.857	0.000
CAPINT	0.426	0.419	0.971	0.000
NFAM	0.235	0.227	0.750	0.000
NDIR	12.050	12.000	24.000	6.000
STDV	0.055	0.051	0.251	0.009
NBLOCK	3.656	4.000	10.000	1.000
EBDA	0.060	0.102	1.475	-10.301
NDTS	0.053	0.042	0.498	0.000

Our model in the system of equations (1) to (6) is based on the premise that relationship of the firm's performance with corporate governance mechanisms exists. So, before we proceed to estimate the model, we compute the correlation matrix and report the results in Table 3.

Table 3

Correlation Matrix of Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 Tobin's Q	1.00																			
2 ACOMPO	0.21 *	1.00																		
3 BCOMPO	0.13 **	0.45 *	1.00																	
4 OWN	-0.07	0.17 *	0.17 *	1.00																
5 BLOCK	0.13 **	-0.04	0.02	-0.04	1.00															
6 DEBT	0.27 *	0.07	0.07	-0.08	-0.04	1.00														
7 ASSET	0.34 *	0.02	-0.05	-0.30 *	0.00	0.23 *	1.00													
8 AGE	-0.19 *	-0.23 *	-0.15 **	-0.04	0.04	-0.03	-0.12 **	1.00												
9 CAPEX	-0.04	-0.10	-0.12 **	-0.06	0.23 *	0.02	-0.08	0.05	1.00											
10 REP	0.02	-0.15 **	-0.22 *	-0.14 **	-0.04	0.03	0.20 *	0.12 ***	0.09	1.00										
11 INSIDER	-0.03	0.15 **	-0.07	0.20 *	-0.20 *	0.03	0.01	-0.09	-0.03	-0.10	1.00									
12 CAPINT	-0.05	-0.27 *	-0.17 *	-0.20 *	0.15 **	-0.09	0.18 *	0.00	0.13 **	0.02	-0.06	1.00								
13 NFAM	-0.09	0.09	-0.02	0.39 *	-0.18 *	0.01	-0.21 *	0.04	-0.08	-0.25 *	0.08	-0.13 **	1.00							
14 NDIR	0.08	-0.03	-0.01	0.06	0.14 **	0.05	0.03	-0.09	-0.37 *	-0.02	-0.15 **	-0.07	0.06	1.00						
15 STDV	-0.05	0.10	0.08	0.03	-0.11 ***	0.23 *	-0.07	-0.07	-0.05	-0.10	0.07	-0.13 **	0.09	-0.08	1.00					
16 NBLOCK	0.09	0.13 **	0.12 **	0.23 *	0.10	0.00	-0.08	-0.10	-0.57 *	-0.27 *	0.03	-0.15 **	0.24 *	0.58 *	0.11 ***	1.00				
17 EBDA	-0.04	0.03	-0.01	-0.09	0.09	-0.36 *	0.03	-0.06	-0.03	-0.03	-0.03	0.03	0.05	0.07	-0.07	0.03	1.00			
18 NDTS	0.03	0.00	0.02	-0.06	0.00	0.10 ***	-0.06	0.01	-0.10	-0.03	-0.01	0.05	0.06	0.23 *	0.05	0.11 ***	0.05	1.00		
19 RD	0.03	-0.05	-0.07	-0.18 *	0.09	0.07	0.10	0.03	-0.16 *	0.04	-0.10	0.06	-0.08	0.10	-0.04	0.14 **	-0.04	0.12 ***	1.00	
20 MSEG	0.07	-0.03	-0.01	0.03	-0.01	0.12 ***	0.25 *	0.02	0.04	0.04	0.07	0.13 **	-0.06	0.03	0.04	-0.03	-0.08	0.10	0.07	1.00

We focus our attention to the first column of the correlation matrix. Significant correlation implies that the relationship exists, but we cannot infer its direction from the significant correlation alone.

From the table, we find that all the correlation coefficients of all the governance mechanisms, except for the *OWN*, with the firm's performance are significant. As for our focused *ACOMPO* variable, the correlation is very high at 0.21 and significant at a 99% confidence level.

4.2. Model Estimation

4.2.1 An Overview

We estimate the simultaneous-equations model in equations (1) to (6), using two stage least squares, and report the results in Table 4. The coefficient estimates are in the first lines and their *t*-statistics are in parentheses in the second line.[3]

[3] The coefficients of the industry dummies are not reported to save space, but they are available upon request. We do not report the R^2 statistics here because they have no natural interpretation when IV variables serve as regressors as in this 2SLS case (Wooldridge (2000)).

Table 4

Simultaneous-Equations Analysis of

Firm's Performance and Corporate Governance Mechanisms

Regression results estimated by the 2SLS procedure are shown. The dependent variables are Tobin’s *Q* ratio and other five corporate governance variables in a system of six equations. Industry dummy variables are included for all models but not shown in the table. The *t*-statistics are given below in the parentheses.

	Tobin's Q	ACOMPO	BCOMPO	OWN	BLOCK	DEBT
Constant	-0.3834	1.3421 **	1.0075 ***	1.4669 ***	0.6056 ***	-2.8276 **
	(-0.7246)	(2.4472)	(1.9195)	(1.9434)	(1.7251)	(-2.1078)
Tobin's Q		0.7539 **	0.7619 **	0.2513	0.4167	-0.7821
		(2.0283)	(2.1934)	(0.6406)	(1.2645)	(-0.9249)
ACOMPO	0.2069		-0.3537	0.4647 ***	-0.3981 **	0.9539 ***
	(1.0871)		(-1.4362)	(1.8287)	(-2.3094)	(1.7372)
BCOMPO	0.2917	-0.4702		-1.2830	0.3306	0.4911
	(1.3575)	(-1.3762)		(-1.4915)	(1.3781)	(0.8593)
OWN	-0.1642	0.2481	0.1885		-0.3160	0.3163
	(-0.6895)	(0.9949)	(0.8589)		(-1.5835)	(0.8581)
BLOCK	0.3010	-0.2730	-0.1439	-0.0294		0.4549
	(1.5684)	(-1.0204)	(-0.6084)	(-0.1413)		(0.9485)
DEBT	0.1999 **	-0.1087	-0.0741	-0.0901	-0.2258 **	
	(2.2954)	(-0.8011)	(-0.6535)	(-0.7819)	(-2.5160)	
ASSET	0.1101 *	-0.0814	-0.1020 ***	-0.0749	-0.0322	0.2715 **
	(2.9831)	(-1.2111)	(-1.8271)	(-1.4287)	(-0.7056)	(1.9865)
RD	0.0068			-0.0529 ***	-0.0101	0.0689
	(0.1823)			(-1.7836)	(-0.3569)	(1.0537)
REP		-0.0408 **				
		(-2.3506)				
STDV					0.3916	
					(0.4514)	
INSIDER			0.0114			
			(0.1156)			
AGE	-0.1485 ***					
	(-1.9214)					
NFAM				0.2061 **		
				(2.2337)		
EBDA						-0.2272 *
						(-4.4057)
CAPINT		-0.1537	-0.1318 ***			0.2793
		(-1.5656)	(-1.8057)			(1.6039)
CAPEX	0.0001					
	(0.8110)					
NBLOCK					0.0461 *	
					(4.7115)	
NDTS						0.6266
						(1.2254)
NDIR				-0.8122 ***		
				(-1.7954)		
MSEG			-0.0085	0.0832 *		
			(-0.2542)	(2.8446)		

Note: * Parameter estimate is significantly different from zero at 1% level
** Parameter estimate is significantly different from zero at 5% level
*** Parameter estimate is significantly different from zero at 10% level

4.2.2 The Roles of Independent Variables

Before we test for exogeneity and analyze the relationship among the interesting variables, we examine the resulting coefficients of the independent variables in each equation to reconcile the results with our expectations and to understand how these variables function with our interesting variables.

In the first equation for the *Tobin's Q* variable, the coefficients of the *ASSET* and *AGE* are positive and negative. Both are significant. The significantly positive coefficient of the *ASSET* is expected. The significantly negative coefficient of the *AGE* supports the life-cycle hypothesis, as opposed to the bias resulting from the use of low historical asset values. The coefficient of the *CAPEX* has a correct sign. but it is not significant. Finally, the coefficient of the *RD* is positive but it is not significant, probably due to the canceling effects of the growth opportunity and the agency costs proxied by this variable.

In the second equation for the *ACOMPO* variable, all the coefficients of the independent variables--*ASSET*, *REP*, and *CAPINT*, assume the correct negative sign. But only that of the *REP* is significant, leading to an important implication that reputation can substitute independence.

In equation (3) for the *BCOMPO* variable, we argue that the coefficients of the *ASSET* and *MSEG* variables may not have the same sign as they are usually expected in more developed market. It turns out that the results support our argument that the sample firms simply meet the minimum requirement for independent directors, while their board sizes grow with asset sizes and business lines. The coefficient of the *CAPINT* has the expected sign and significant. However, the coefficient for the *INSIDER* is not significant, probably due to the conflicting contribution of the *INSIDER* from insightful information against agency costs.

Equation (4) for the *OWN* variable shows an interesting result for the *RD* variable. Its coefficient is negative and significant, which is the opposite to what is expected in a more developed market. We argued earlier that this result was possible because in Thailand the *RD* was associated with large firms.

As for the *ASSET*, *NFAM*, and *MSEG*, their coefficients have the expected signs. But only those of the first two variables are significant. The result for the *NDIR* helps to clarify how the decision to hold more shares of insider directors is affected by the number of board directors. A significantly negative coefficient refutes the hypothesis that additional directors help to reduce concentration risk incurred by the *OWN*. It supports the hypothesis that more board directors raise the board's monitoring capability as was proposed by John and Senbet (1998).

Finally, all the results of equations (5) and (6) for the *BLOCK* and *DEBT* variables are as expected. The positive and significant coefficient for the *STDV* variable in equation (5) supports Cho (1998), who proposes that volatility increases benefits to the *OWN* because it makes the firm more difficult to be monitored.

4.2.3 Test for Exogeneity

In previous studies, it is assumed that the governance mechanisms are exogenous to the firm's governance. So, they employ the OLS regression to test for the existence of the relationship. This test gives incorrect results due to the inconsistent estimates, if in fact the firm's performance and governance mechanisms are endogenous. It is our contribution to the literature to propose the exogeneity is tested first, so the results can be interpreted correctly.

From Table 4, it is clear from equations (2) and (3) that the *ACOMPO* and *BCOMPO* are not exogenous to the firm's performance. These two variables are explained by the firm's performance. The results are significant statistically at a 95% confidence level.

As for the *OWN*, *BLOCK*, and *DEBT* variables, even though they are not explained directly by the firm's performance, i.e. the coefficients of the *Tobin's Q* variable in their equations are not significant, they are explained indirectly through the

ACOMPO variable. The coefficients of the *ACOMPO* in their respective equations (3), (4) and (5) are significant and the *ACOMPO* is explained by the *Tobin's Q* variable in equation (2).

Based on these findings, we conclude that the corporate governance mechanisms are not exogenous to the firm's performance. This fact has an important implication. Good governance mechanisms do not particularly improve the firm's performance.

Given the results, it is interesting to explore further whether the firm's performance is exogenous to any of these governance mechanisms. We begin by examining the coefficients β_{1j} in the first equation. From Table 4, β_{16} of the *DEBT* variable is significant. So, the firm's performance cannot be exogenous to the *DEBT* mechanism. Moreover, we recall that the *DEBT* is explained significantly by the *ACOMPO* variable. So, the firm's performance is not exogenous to the *ACOMPO* mechanism either.

Because the firm's performance explains and is explained by the *ACOMPO* and *DEBT* mechanisms, we conclude that the three variables are endogenous to one another.

Finally, we notice from Table 4 that the *DEBT* is the only significant explanatory variable of the *Tobin's Q* variable and that the *DEBT* is not explained by the *BCOMPO*, *OWN*, and *BLOCK* variables. We conclude that the firm's performance is exogenous to the *BCOMPO*, *OWN*, and *BLOCK* mechanisms. Moreover, because the firm's performance, the *ACOMPO* mechanism, and the *DEBT* mechanism are endogenous, the *ACOMPO* and *DEBT* mechanisms must be exogenous to the *BCOMPO*, *OWN*, and *BLOCK* mechanisms too.

4.3.4 Relationship of the Firm's Performance with Corporate Governance Mechanisms

From Section 4.3.3, we find that the firm's performance is endogenous to the *ACOMPO* and *DEBT* mechanisms and that it is exogenous to the *BCOMPO*, *OWN*, and *BLOCK* mechanisms. We examine the endogeneity and exogeneity relationship in turn.

4.3.4.1 The Endogeneity Relationship

From Table 4, the firm's performance, the *ACOMPO* mechanism and the *DEBT* mechanism have endogeneity relationship. Simultaneously, the firm's performance positively explains the *ACOMPO* mechanism in equation (2), the *ACOMPO* mechanism positively explains the *DEBT* mechanism in equation (6), and the *DEBT* mechanism positively explains the firm's performance in equation (1). These variables do not determine or are not determined by one another. This result suggests that they are jointly determined in equilibrium by the firm's optimization behavior (Demsetz and Lehn (1985), Agrawal and Knoeber (1996) and Hermalin and Weisbach (1998)). We interpret this circular relationship as follows.

In equation (2), there are at least two reasons to explain why the *ACOMPO* mechanism increases with the firm's performance. Firstly, an outperforming firm is willing to elect truly independent directors to serve on its audit committee. This result is consistent with the signaling theory (Ross (1977)). An outperforming firm may choose independent audit committee members to signal its performance. The independence structure promotes effective monitoring and improves quality of information disclosure. For this reason, an independence structure is a convincing signal because it is more costly to poorly performing firms to maintain one. Secondly, Todhanakasem (2002) makes an important observation for Thai listed firms that it is very difficult generally for those firms to have qualified independent directors to serve in their audit committees. Outperforming firms are more visible. These firms tend to be more successful to invite independent directors to serve on their boards and audit committees (Agrawal and Knoeber (1996)).

It is not difficult to explain why the *DEBT* rises with the *ACOMPO* mechanism in equation (6). Independent audit committee members are favorable to debt issuance because they lessen asymmetric information problems between the firm and its creditors (Deli and Gilan (2000)). Moreover, independent audit committee members serve all the firm's stakeholders and the public. The fact that they can monitor the firm's management effectively benefits the creditors too. The *ACOMPO* ensures that the firm is not mismanaged and that the creditors' wealth in the firm's debt securities is not siphoned to its equity holders (Watt and Zimmerman (1986)).

In equation (1), the firm's performance rises with debt. We follow Jensen and Meckling (1976) to explain this finding that debt serves as a discipline mechanism to reduce agency problems, thereby increasing the firm's value.

We also notice that debt is an inexpensive source of funds. The fact that the coefficient for the non-debt tax shield (*NDTS*) in equation (6) is positive implies that the firm is able to issue debt as we pointed out earlier, and that debt is preferred even though the firm has a non-debt tax shield. Our findings in equations (2) and (6) suggest that an outperforming firm can afford more debt, through the *ACOMPO* mechanism. Its reduced cost of funds is then fed in to raise the firm's performance.

4.3.4.2 The Exogeneity Relationship

In Section 4.2, we conclude from our exogenetity tests that the firm's performance, the *ACOMPO* mechanism, and the *DEBT* mechanism are exogenous to the *BCOMPO*, *OWN*, and *BLOCK* mechanisms.

As opposed to what is generally believed (e.g., Baysinger and Butler (1985)), for our sample firms in equation (3) the firm's performance determines the *BCOMPO* mechanism. The relationship is positive and significant at a 95% confidence level. Certo et al. (2001) explains that the firm's performance can determine the *BCOMPO* because it is the concern of independent directors to accept the invitation to sit on the board. Sitting on the board of an under-performance firm can jeopardize their reputation.

This finding has an important policy implication. It points to the fact that the SET's 1993 good governance rule, that requires its listed firms to elect at least two independent directors to the boards, has been ineffective. The mechanism has never served as the determinant of performance. Rather, the independent-directors mechanism is a choice chosen by a well performing firm and avoided by a poorly performing firm.

In equation (4), the *OWN* mechanism is positively determined by the *ACOMPO* mechanism. Independent members of the audit committee are usually experts in the business, whose guidance can contribute to the firm's successful operations. In addition, from equation (2), we see that the *ACOMPO* mechanism is associated with the firm's good performance. So, the insider owners raise their holdings to benefit from the performance.

Finally, in equation (5) the *BLOCK* is negatively related with the *ACOMPO* and *DEBT* mechanisms. The relationship is significant at a 95% confidence level. Benefits to blockholders can be more than a fair share, resulting from their exploitation of the firm's resources (Shleifer and Vishny (1997), La Porta et al. (1999)). This is possible because blockholders have control power from their decisive voting rights. We find that the *ACOMPO* and *DEBT* mechanisms lead to low blockholdings, probably reflecting a lessened opportunity for blockholders to earn more than their fair shares.

5. Conclusions

In this study, we examine the relationship of the firm's performance with the independence structure of audit committee and other corporate governance mechanisms of Thai firms listed on the Stock Exchange of Thailand in the year 2000. We apply the simultaneous-equations approach to acknowledge the possible endogeneity relationship among these variables in order to avoid inconsistency problems. We test for exogeneity and endogeneity of variables, before the relationship is interpreted. This test has never been conducted by any other study and we consider it as our contribution.

We find that the firm's performance is endogenous to the independence structure of audit committee and the level of debt financing. That is, audit committee independence and debt level are determined simultaneously with the firm's performance. We find that the firm's performance, debt financing and audit committee independence are exogenous to and are determinants of blockholdings, insider holdings, and independent directors.

The finding is important because it gives policy makers the correct understanding of the role of audit committee and other governance mechanisms. In general, it suggests that performance cannot be improved by good corporate governance mechanisms. Rather, they are determined jointly and simultaneously. In particular, it points to the fact that the SET's 1993 rule, that requires listed firms to appoint independent directors, has not been effective.

Acknowledgement

The authors are grateful to the Thailand Research Fund (TRF) for financial supports. They thank Sudipto Dasgupta, Yuen Teen Mak, Steven Todd, Yin-Hua Yeh, and seminar participants at the 2002 APFA/PACAP/FMA Finance Conference, Tokyo, Japan, for their helpful comments.

References

Agrawal, A., and C. R. Knoeber, 1996, Firm performance and mechanisms to control agency problems between managers and shareholders, Journal of Financial and Quantitative Analysis 31, 377-397.

Baysinger, B. D., and H. Butler, 1985, Corporate governance and the boards of directors: Performance effects of changes in board composition, Journal of Law, Economics and Organizations 1, 101-124.

Bhagat, S., and B. S. Black, 1997, Board independence and long-term firm performance, Working Paper 143, Columbia Law School, Columbia University, New York.

Bhagat, S., and B. S. Black, 1998, The uncertain relationship between board composition and firm performance, in: K. Hopt, M. Roe, and E. Wymeersch (eds.), Comparative corporate Governance: The State of the Art and Emerging Research (Oxford University Press, London), 301-326.

Booth, J. R., M. M. Cornett, and H. Tehranian, 2002, Boards of directors, ownership, and regulation, Journal of Banking and Finance 26, 1973-1996.

Booth, J. R., and D. N. Deli, 1996, Factors affecting the number of outside directorships held by CEOs, Journal of Financial Economics 40, 81-104.

Byrd J. W., and K. A. Hickman, 1992, Do outside directors monitor managers? Evidence from tender offer bids, Journal of Financial Economics, 195-221.

Certo, S. T., C. M. Daily, and D. R. Dalton, 2001, Signaling firm value through board structure: An investigation of initial public offerings, Entrepreneurship Theory and Practice, 26 (2), 2001.

Cho, M., 1998, Ownership structure, investment, and the corporate value: An empirical analysis, Journal of Financial Economics 47 (1), 103-121.

Chung, K. H., and S. W. Pruitt, 1994, Executive ownership, corporate value, and executive compensation: A unifying framework, Journal of Banking and Finance 20, 1135-1159.

DaDalt, P. J., W. N. Davidson III, and B. Xie, 2001, Earnings management and corporate governance: The roles of the board and the audit committee, Working Paper, Southern Illinois University.

Davidson, W. N. III, T. Pilger, and A. Szakmary, 1998, Golden parachutes, board and committee composition, and shareholder wealth, Financial Review 33, 17-32.

Deli, D. N., and S. L. Gillan, 2000, On the demand for independent and active audit committees, Journal of Corporate Finance 6, 427-445.

Demsetz, H., and K. Lehn, 1985, The structure of corporate ownership: Causes and consequences, Journal of Political Economy 93, 1155-1177.

Fama, E. F., 1980, Agency problems and the theory of the firm, Journal of Political Economy 88, 134-145.

Fama, E. F., and M. C. Jensen, 1983, Separation of ownership and control, Journal of Law and Economics 26, 301-349.

Greene, W., 2000, Econometric Analysis (3rd ed.), Prentice Hall, New Jersey.

Hermalin, B., and M. Weisbach, 1991, The effect of board composition and direct incentives on firm performance, Financial management 21, 101-112.

Himmelberg, C. P., R. G. Hubbard, and D. Palia, 1999, Understanding the determinants of managerial ownership and the link between ownership and performance, Journal of Financial Economics 53, 353-384.

Jensen, M. C., 1986, Agency costs of free cash flow, corporate finance, and takeovers, American Economic Review 76, 323-329.

Jensen, M. C., and W. H. Meckling, 1976, Theory of the firm: Managerial behavior, agency costs and ownership structure, Journal of Financial Economics 13, 305-360.

Klein, A., 1998, Firm performance and board committee structure, Journal of Law and Economics 41, 275-303.

Klein, A., 2002, Economic Determinants of audit committee independence, The Accounting Review 77 (2), 435-452.

La Porta, R., F. Lopez-de-Silanes, and A. Shleifer, 1999, Corporate ownership around the world, Journal of Finance 54 (2), 471-517.

Loderer, C., and K. Martin, 1997, Executive Stock Ownership and performance: Tracking faint traces, Journal of Financial Economics 45(2), 223-255.

McConnell, J. J., and H. Servaes, 1990, Additional evidence on equity ownership and corporate value, Journal of Financial Economics 27, 595-612.

Mishra, C. S., and J. F. Nielsen, 2000, Board independence and compensation policies in large bank holding companies, Financial Management (Autumn), 51-70.

Morck, R., A. Shleifer, and R. W. Vishny, 1988, Management ownership and market valuation, Journal of Financial Economics 20, 293-315.

Perfect, S. B., and K. W. Wiles, 1994, Alternative constructions of Tobin's Q: An empirical comparison, Journal of Empirical Finance 1, 313-341.

Prevost, A.K., R.P. Rao, and M. Hossain, 2002, Determinants of board composition in New Zealand: A simultaneous equations approach, Journal of Empirical Finance 9, 373-397.

Rosenstein, R., and J. G. Wyatt, 1990, Outside directors, board independence, and shareholder wealth, Journal of Financial Economics 26, 175-192.

Shivdasani, A., 1993, Board composition, ownership structure, and hostile takeovers, Journal of Accounting and Economics 16, 167-198.

Shleifer, A., and R. W. Vishny, 1986, Large shareholders and corporate control, Journal of Political Economy 94, 461-488.

Shleifer, A., and R. W. Vishny, 1997, A survey of corporate governance, Journal of Finance 52,737-783.

Short, H., and K. Keasey, 1999, Managerial ownership and the performance of firms: Evidence from the UK, Journal of Corporate Finance 5, 79-101.

Stock Exchange of Thailand, 1999, The Code of Best Practice for Directors of Listed Companies, Stock Exchange of Thailand, Bangkok.

Todhanakasem, W., 2002, Are corporate governance reforms in Southeast Asia real? A case study of Thailand, A speech given at ASEM and the Changing World Economy Seminar, Tokyo, Japan.

Verschoor, C. C., 1993, Benchmarking the audit committee, Journal of Accountancy (September), 59-64.

Vicknar, D., K. Hickman, and K. C. Carnes, 1993, A note on audit committee independence: Evidence from the NYSE on gray area directors, Accounting Horizons 7, 53-57.

Watts, R. L., and J. L. Zimmerman, 1990, Positive accounting theory: A ten-year perspective, The Accounting Review 65, 131-156.

Whidbee, D. A., 1997, Board composition and control of shareholder voting rights in the banking industry, Financial Management, 26 (4), 27-41.

Wiwattanakantang, Y., 2001, Controlling shareholders and corporate value: Evidence from Thailand, Pacific-Basin Finance Journal 9, 323-362.

Wooldridge, J. M., 2000, Introductory Econometrics: A Modern Approach, South-Western College Publishing, Ohio.

Yermack, D., 1996, Higher market valuation of companies with a small board of directors, Journal of Financial Economics 40, 185-211.

Appendix

Variable Description

Tobin's Q	The ratio of the market value of the firm's equity plus book value of total debt divided by the book value of the firm's assets.
ACOMPO	The percentage of audit committee members held by independent outside directors.
BCOMPO	The ratio of the number of independent directors and the number of all the directors on the board.
OWN	The sum of all shareholdings of the management and the board members.
BLOCK	The summed percentage holding of large shareholders with more than 5% holding of the firm's equity stocks.
DEBT	The ratio of the book values of total debt to total assets.
ASSET	The logged book value of the firm's assets.
AGE	The logged number of years counting from the firm's inception.
CAPEX	The ratio of net capital expenditure on fixed assets scaling by the book value of assets.
REP	The sum of the numbers of all firms served by the firm's audit committee members.
INSIDER	The ratio of the number of the firm's executives on the board and the total number of the directors.
CAPINT	The ratio of fixed assets to the firm’s total assets.
NFAM	The number of members of founding families on the board.
NDIR	The number of directors on the board.
STDV	Three-year average standard deviation of the firm's stock return.
NBLOCK	The number of the firm's blockholders.
EBDA	The earnings before depreciation expenses, interests, and taxes.
NDTS	The sum of depreciation and amortization over the firm's total assets.
RD	The dummy variable to indicate that the firm spends or does not spend for research and development.
MSEG	The dummy variable to indicate that the firm has multiple lines of business.

Did Families Lose or Gain Control?

Thai Firms after the East Asian Financial Crisis

Anya Khanthavit*

Piruna Polsiri **

and

Yupana Wiwattanakantang ***

Key Words: Ownership; Controlling Shareholder; Corporate Governance; East Asian Financial Crisis; Thailand

JEL Classification: G32

---

* Corresponding author. Department of Finance, Thammasat University, Bangkok 10200, THAILAND. Tel: +66-2- 613-2223 Fax: +66-2 225-2109, E-mail: akhantha@tu.ac.th. **Department of Finance, University of Melbourne, Parkville, VIC 3010, Australia, and Department of Finance, Dhurakijpundit University, Thailand. Tel.: +61-3-8344-0804; e-mail: piruna@yahoo.com. ***Center for Economic Institutions, Institute of Economic Research, Hitotsubashi University, 2-1 Naka, Kunitachi, Tokyo 186-8602, Japan. Tel.: +81-42-580-8374; fax: +81-42-580-8333; e-mail: yupanaw@yahoo.com. The authors acknowledge financial supports from Thailand Research Fund with thanks.

Abstract

Did Families Lose or Gain Control?

Thai Firms after the East Asian Financial Crisis

This paper investigates the ownership and control of Thai public firms in the period after the East Asian financial crisis, compared to those in the pre-crisis period. Using the comprehensive unique database of ownership and board structures, we find that the ownership and control appear to be more concentrated in the hands of controlling shareholders subsequent to the crisis. Interestingly, even though families remain the most prevalent owners of Thai firms and are still actively involved in the management after the financial crisis, their role as the controlling shareholder becomes less significant. In addition, our results show that direct shareholdings are most frequently used as a means of control in both periods. Pyramids and cross-shareholdings, however, are employed to the lesser extent following the crisis.

บทคัดย่อ

การประเมินระดับการควบคุมบริษัทจดทะเบียนในประเทศไทย

โดยบุคคลในครอบครัวผู้ก่อตั้ง ภายหลังจากวิกฤตการเงินเอเซีย

การศึกษาตรวจสอบและประเมินระดับของการควบคุมบริษัทจดทะเบียนในประเทศไทยโดยบุคคลในครอบครัวผู้ก่อตั้ง เพื่อเปรียบเทียบระดับการควบคุมในช่วงก่อนและหลังจากวิกฤตการเงินเอเซีย การศึกษาพบว่า ภายหลังวิกฤตการเงิน บุคคลในครอบครัวผู้ก่อตั้งยังคงเป็นผู้ถือหุ้นใหญ่ของบริษัทและมีอำนาจในการออกเสียง แต่บุคคลเหล่านี้กลับมีบทบาทลดลงในฐานะผู้ถือหุ้นใหญ่

Did Families Lose or Gain Control?

Thai Firms after the East Asian Financial Crisis

1. Introduction

Financial crises have been frequent phenomenon in recent years. During the past decade, there have been major crises in East Asia, Eastern Europe, and Latin America. It is well documented that a macroeconomic and financial crisis has caused tremendous changes in the economy and financial system, which in turn affect the micro firm level and force firms to undertake various restructuring activities to survive. This study investigates the impact of a macroeconomic shock on ownership and board structures using the comprehensive unique data from Thailand.

Previous studies document that changes in ownership and board structures of firms in the US occur in response to changes in the business or industry conditions of the firms due to changes in regulations, input costs, technology and financial system (Mitchell and Mulherin, 1996; Holderness et al., 1999; Kole and Lehn, 1999). In addition, ownership and board changes might be attributable to past stock price returns, top executives changes, and corporate control threats (Denis and Sarin, 1999). However, little evidence on ownership structure changes following a macroeconomic shock or crisis has been documented.

Although recently studies focusing on how firms respond to an economy-wide shock have been increasing, to our knowledge there is no study that directly investigates an impact of a macroeconomic shock on ownership and board structures. For example, Baek et al. (2002) focus only on the effects of the East Asian financial crisis on restructuring activities using data on Korean firms. They assume that ownership structure is predetermined, and document the negative relation between ownership by owner-managers and the likelihood that firms undertake downsizing activities. Unlike Baek et al. (2002), we investigate changes in ownership as a part of the restructuring process in response to the macroeconomic shock. Similar to most research on the ownership structure literature, our analysis is best viewed as an exploratory data study.

The 1997 East Asian crisis and hence Thailand provide a spectacular opportunity to explore this issue. Thailand was the first casualty of the crisis, experiencing the first wave of serious speculative attacks on its currency in July, 1997, followed by a sharp decline in its stock market, after which South Korea, Malaysia, Indonesia and the Philippines were also affected. The East Asian financial crisis has not only caused a large shock to economies across the region but also brought out economic inefficiencies all over the region. Consequently, many of financial institutions as well as non-financial corporations have been in distress (Claessens et al., 1998 and 2000a; Krugman, 1998).

To survive rises in debt burden and declines in profitability, many firms in East Asia have been actively restructuring (Gilson, 2001). The restructuring activities include selling off some of the affiliates/subsidiaries in order to save the core businesses. More severely, the controlling shareholders might be forced to sell off their shares and/or issue new equity to raise more funds to keep their main business alive. It is a thus general thought that these activities might affect the controlling power of a corporate ultimate owner, resulting in changes in corporate ownership and control structure.

Our study focuses on Thai non-financial publicly traded firms in 2000 compared to those of 1996, which is one year before the crisis. This comparison allows us to address three principal issues. First, how corporate ownership structure changes as the economy, the financial system and the regulation on foreign ownership have changed. Second, whether there are any variations in mechanisms used by the owners to control the firms before and after the crisis. Finally, to what extent the degree of controlling shareholders' participation in management changes, subsequent to the economic shock.

Our study is based on comprehensive data sources of ownership. Previous research on ownership structure of firms in East Asian countries (for example, Claessens et al., 2000b; Lemmon and Lins, 2001; Lins, 2002; Mitton, 2002) typically employs data sources that include shareholders with shareholdings of at least 5 percent, while our database includes more detailed information. More precisely, our database provides the information on shareholders who hold at least 0.5 percent of a firm's shares. Additionally, we are able to trace the ownership beyond shareholder names for at least two reasons. First, our database allows us to identify ultimate owners of privately owned companies that in turn hold shares in the publicly traded firms in our focus. Second, we cover more information on family relationships than other studies on Thai corporate ownership, using various sources of documents in Thai.

Surprisingly, we find that the ownership and control appear to be more concentrated in the hands of controlling shareholders, subsequent to the crisis. Interestingly, even though families are still the most prevalent owners of Thai firms, their role is reduced. Similar to the pre-crisis period, the controlling shareholders are typically involved in management in the majority of firms. Especially in family-owned firms, the participation of controlling families' members in the board is even greater after the crisis. In addition, our results show that direct shareholdings are the most common means of control used in more than two-third of the firms in both periods. Rather than direct ownership, pyramidal structures and cross-shareholdings are employed. These control-enhancing mechanisms, nevertheless, are used less often, reflected in the lower degree of separation between ownership and control following the macroeconomic shock.

The paper is organized as followed. In Section 2, we describe data sources, data collection, and data definition. In Section 3, we examine who control Thai firms in the period after the crisis. Section 4 provides analyses of the deviation between ownership and control of the firms' ultimate owners and the means they use to enhance their voting rights from associated cash-flow rights. We also investigate the separation between ownership and management in this Section. In Section 5, we explore the concentration of ownership and control in firms that have no controlling shareholder. Finally, our conclusion is drawn in Section 6.

2. Data construction

2.1 Data sources

Our sample includes all non-financial companies listed in the Stock Exchange of Thailand. The data of 1996 and 2000 are used to represent the pre- and post-crisis periods, respectively. The choices of these two years are arbitrary, however. We do not investigate banks and other financial companies here because unlike non-financial companies, there are ownership restrictions imposed on banks and financial institutions by the Bank of Thailand[1].

---

[1] No shareholder is allowed to own more than 5 and 10 percent of the shares of commercial banks and finance companies, respectively.

The major source of the ownership and board data is the I-SIMS database produced by the Stock Exchange of Thailand. This database provides the information of shareholders who own at least 0.5 percent of a firm's outstanding shares and lists of a firm's board members. Additional information on the ownership and board data, such as lists of a company's affiliates and shareholdings by these companies as well as family relationships among board members, is manually collected from company files (FM 56-1) available at the library and the website of the Stock Exchange of Thailand. Besides Johnstone et al. (2001), we also search various books written in Thai to trace the family relationships beyond their surnames (Pornkulwat, 1996; Sappaiboon, 2000a, 2000b, and 2001).

We use the BOL database provided by BusinessOnLine Ltd. to trace the ownership of private companies that appear as corporate shareholders of our sample firms. The BOL has the license from the Ministry of Commerce to reproduce the company information from the Ministry's databank. Basically, this databank includes major information of all registered companies in Thailand that is reported annually to the Ministry.

With all the above data sources, we are able to trace the ultimate owners of all privately owned companies that are the (domestic corporate) shareholders of firms in our focus. As will be shown later, one would underestimate equity stakes held by the firm's shareholders without searching for the owners of these private companies.

2.2 Definition of controlling shareholder

We define a controlling shareholder or an ultimate owner following the definition of the Stock Exchange of Thailand (Stock Exchange of Thailand, 1998). More precisely, a controlling shareholder is a shareholder who *directly* or *indirectly* owns more than 25 percent of a company's votes. We are aware that the cut-off levels of 10 percent and 20 percent are more commonly used in the literature (La Porta et al., 1999; Claessens et al., 2000b; Faccio and Lang, 2002). However, due to differences in law and legislation across countries, the 25 percent cut-off should be more appropriate as far as Thailand is concerned[2]. The shareholder with more than 25 percent stakes can control a firm because in which case no other single shareholder would own enough voting

[2] See also Wiwattanakantang (2000 and 2001) for the argument of this issue.

rights to have the absolute power over the firm to challenge him. Under the Public Limited Companies Act B.E. 2535, to have the absolute power over a firm, a shareholder needs to own at least 75 percent of a firm's votes.

More ironically, a shareholder with the 25 percent of votes has sufficient legal rights to perform the following actions under the Thai corporate law. First, he has the right to ask the court to withdraw a resolution that fails to comply with or that is in contravention of the articles of the company's association or the provisions of the Public Limited Companies Act. Second, he has the right to demand an inspection of the company's business operation and financial condition. Third, he has the right to call an extraordinary general meeting at any time. Fourth, he has the right to request the court to dissolute the company if he expects that further business operation will bring in only losses and that the company has no chance to be recovered (Sersansie and Nimmansomboon, 1996).

2.3 Definition of ownership and control

Direct ownership means that a shareholder owns shares under his own name or via a private company owned by him. Indirect ownership is when a company is owned via other public firms or a chain of public firms. This chain of controls is in the form of pyramidal structures and/or cross-shareholdings, which can include many layers of firms. In which case, we search for the controlling shareholder(s) of these firms. Following the literature, we also calculate both cash-flow and voting rights by following the standard approach used in Claessens et al. (2000b) and Faccio and Lang (2002). Regarding the definition of pyramidal structures and cross-shareholdings, we use the conventional method of La Porta et al. (1999).

Unlike many countries in Europe, multiple voting shares do not exist in Thailand. The law prohibits the issuance of such shares. Therefore, we focus only on the three control mechanisms, namely, direct, pyramidal, and cross-shareholdings, here. Previous studies suggest that while direct shareholdings do not create discrepancies between voting and cash-flow rights, pyramids and cross-shareholdings do (Grossman and Hart, 1988; Harris and Raviv, 1988; Wolfenzon, 1998; Bebchuk et al., 1999). Appendix 1 provides the definition of these control-enhancing mechanisms.

We classify an *ultimate owner* or a *controlling shareholder* into eight types as follow:

1. *A group of related families*, which is defined as an individual, a family, and members of a group of families that are relatives, including in-law families. Regarding family relationship, we treat members of a family as a single shareholder assuming that they vote as a coalition. Members of a family include those who have the same family name, those who are close relatives, and those who are relatives of in-laws of a family.

2. *The state*, which is the Thai government.

3. *Domestic financial institution*, which is defined as a financial (and securities)company as well as a mutual fund that is owned by domestic investors.

4. *Foreign investor*, which is defined as a foreign individual, family, and corporations. Note here that similar to the literature, we do not search for the ultimate owner of the parent companies of foreign corporate shareholders. So it might be the case that firms that have foreign corporations as their controlling shareholders, and hence defined as foreign-controlled firms, are actually widely held if their parent companies in the home based countries are dispersedly owned.

5. *Foreign institutional investor*, which is defined as a financial (and securities), insurance company as well as a mutual fund that is owned by foreign investors.

6. *A group of unrelated families*, which is defined as members of a group of families that are not related but jointly own a private company, which in turn ultimately controls the sample firms.

7. *Multiple controlling shareholders*, which is defined as a firm in which the number of controlling shareholders is more than one.

8. *No controlling shareholder*, which is defined as a firm that does not have an ultimate controlling shareholder.

2.4 Comparability with Claessens et al. (2000b)

There are a number of issues that might affect the comparability of our results and those of Claessens et al. (2000b) who investigate the ownership of East Asian firms using 1996 data. First, the sample firms are different. Their sample includes financial companies and banks, while ours does not. Furthermore, while our sample covers all non-financial listed firms, their sample covers only 36.78 percent of all listed companies. Second, their definition of controlling shareholder differs from ours. Specifically, they use the 20 percent cut-off in defining the controlling shareholder, while we employ the 25 percent cut-off. Third, their ownership data might not be as comprehensive as ours in that their database provides only shareholders with stakes of at least 5 percent, while our database includes more detailed information of shareholders who hold at least 0.5 percent. Also, they only trace the ownership within publicly traded firms. Consequently, their ownership calculation could give some biased results. For example, firms that were classified as widely held in their sample might not truly represent firms with no controlling shareholder. Perhaps these firms are classified into such category simply because their ownership could not be traced.

3. Results: Who Control Thai Firms after the East Asian financial Crisis

We begin our exploration by investigating who ultimately own and control Thai listed companies based on 2000 data, and then compare the results with the pre-crisis structure. Table 1 shows that the existence of controlling shareholders has been typical for Thai firms during the pre- and post-crisis periods. More than three quarters of our sample firms have at least one controlling shareholder. Specifically, in 2000, about 79.19 percent of the firms have controlling shareholders. Among these firms, 67.05 percent (209 firms) have a single controlling block, while 14.29 percent (46 firms) are ultimately owned by a group of controlling shareholders. When compared to the pre-crisis data, the ownership appears to be slightly more concentrated. In 1996, controlling shareholders exist in 78.69 percent of the sample firms. The proportion of firms in which the controlling shareholder exists is not statistically different between both periods.

We compare our results with those of Claessens et al. (2000b) while keeping the facts stated in Section 2.4 in mind. To be comparable, we extend the calculation of the ownership and control by using the 20 percent cut-off. Our findings show that around 10.25 and 11.65 percent of our sample firms have no controlling shareholder in 2000 and 1996, respectively. Claessens et al. (2000b), however, document that in 1996 only 6.6 percent of Thai firms in their sample are widely held[3]. The comparison, using either 25 percent or 20 percent cut-off level, gives the consistent results that the ownership happens to be marginally more concentrated in the post-crisis period.

Changes in the ownership structure should be seen more clearly when investigating the percentage of firms associated with a particular type of controlling shareholders. After the crisis, firms that are controlled by a group of single family still appear to be the most prevalent in Thai

[3] A plausible reason why Claessens et al. (2000b) find smaller number of widely held firms than our calculation might be that their samples exclude firms that are difficult to trace the ultimate owners (see Section 2.4).

stock market. However, the percentage of such firms has declined. That is, a single family controls about 45.65 percent of the firms in the sample in 2000, while such a group controls about 51.4 percent of the firms in 1996. The fraction of single family-controlled firms in the post-crisis period is, nevertheless, not significantly different at the conventional levels from that in the pre-crisis period.

Family controlling ownership seems to be substituted by other types of shareholders. Particularly, we find that foreign ownership increases from 13.07 percent in 1996 to 15.22 percent in 2000. Moreover, the fraction of firms owned by domestic financial institutions rises from 0.57 percent to 1.24 percent. In addition, the fraction of firms owned by a group of controlling shareholders increases from 11.65 percent to 14.29 percent. The Thai government remains as the controlling shareholder of nine firms after the crisis, while it controls eight firms before the crisis. These firms account for 2.48 percent of the 2000 sample. Among firms with a group of controlling shareholders, the proportion of firms that are controlled by a group of unrelated families slightly declines from 5.97 percent in 1996 to 5.59 percent in 2000, while the proportion of firms with multiple controlling shareholders increases from 5.68 percent to 8.70 percent.

Although none of the changes in the fraction of firms with each type of controlling shareholders between both periods is statistically significant, the decline in the fraction of single family-controlled firms and the rise in the fraction of firms with multiple controlling shareholders have the highest t-statistics of 1.43 and 1.57, respectively.

We further investigate the ownership characteristics of firms with multiple controlling shareholders. Consistent with the main results, Table 2 shows a decreasing role of single families as the controlling shareholders following the crisis. To be specific, in 1996, single controlling families appear in 95 percent of firms with multiple controlling shareholders. In 2000, these families exist in only 67.86 percent of these firms. In contrast, other categories of controlling shareholders, namely, the Thai government, domestic institutions, foreign investors, and a group of unrelated families play greater role in such firms after the economic shock.

4. Ownership and Control of Controlling Shareholders

4.1 Control Mechanisms

We investigate how the controlling shareholder owns and controls the firms in this section. As discussed in Section 2, we consider three types of control mechanisms: Direct ownership, pyramidal structures, and cross-shareholdings. Table 3 shows that direct ownership is used most often in Thai public firms during the pre- and post-crisis years. In 2000, in approximately 78.04 percent of the firms, their controlling shareholders use simply direct shareholdings, compared to 76.53 percent in 1996. In other words, controlling shareholders in more than two-third of the firms own the shares using their own names and/or through their private companies. Based on our comprehensive database, we find that, on average, 35.8 and 35.5 percent of the direct shareholdings are done via companies that are privately owned in 1996 and 2000, respectively. Hence, without tracing the ownership of these private companies, one would underestimate the actual cash-flow and control rights held by the controlling shareholders.

Interestingly, in almost all the firms, controlling shareholders do not use either pyramids or cross-shareholdings alone to control the firms. In 2000, there are only two instances of using simply pyramids, while there is no single case where the controlling shareholders employ cross-shareholdings alone. The combinations of pyramids with direct shareholdings and pyramids with direct and cross shareholdings are more common. Specifically, in about 14.9 percent of the firms, direct shareholdings are used with pyramids, and in about 6.27 percent of the firms, direct shareholdings are used with pyramids and cross-shareholdings.

The combination of direct shareholdings with pyramids and cross-shareholdings is used most often in firms controlled by single families. Statistically, out of 38 firms that use direct shareholdings-cum-pyramids, 21 firms belong to a group of related families, seven firms are multiple controlling shareholders-owned, six firms are foreign-owned, three firms belong to a group of unrelated families, and the rest one firm is state-owned. A similar picture emerges regarding the use of direct shareholdings-cum-pyramids-cum-cross-shareholdings.

Interestingly, compared to the pre-crisis period, the exercise of pyramidal structures slightly decreases. Overall, our results show that pyramids are used in 21.96 and 23.47 percent of the firms with controlling shareholders in 2000 and 1996, respectively.

Compared to other countries in East Asia (Claessens et al., 2000b) and more developed economies (La Porta et al., 1999; Faccio and Lang, 2002)[4], pyramids are less commonly used in Thailand. Pyramids are employed in about 38.17 percent of companies in East Asia (Claessens et al., 2000b) and 26 percent of firms in the 27 wealthiest countries (La Porta et al., 1999). Thai firms appear to use pyramids slightly more frequently when compared to firms in Western European countries, however. Faccio and Lang (2002) reveal that pyramids are found in approximately 19.13 percent of the European firms in their sample.

Consistent with findings from other countries, cross-shareholdings happen to be used much less often by the controlling shareholders of Thai firms. In 2000, only about 6.27 percent of the firms with controlling shareholders (16 firms) employ cross-shareholdings, being most prevalent in firms controlled by a group of related families. Specifically, out of these 16 firms, 12 companies[5] are owned by a group of related families, accounting for 8.39 percent of all single family-controlled firms. Cross-shareholdings also appear in firms that are controlled by domestic financial institutions (two firms) and a group of unrelated families (two firms).

The proportion of firms using cross-shareholding structures marginally decreases from that of the pre-crisis period. In 1996, there exist 20 firms, accounting for 7.22 percent of all firms with controlling shareholders, in which cross-shareholdings are employed. Again, cross-shareholdings appear most in the firms controlled by a group of related families (16 firms).

When compared with more developed countries, the proportion of Thai firms exercising cross-shareholdings is relatively more prevalent. Cross-shareholdings are used in about 3.15 percent of the sample firms in La Porta et al. (1999) and 6.25 percent of the Western European firms in Faccio and Lang (2002).

---

[4] La Porta et al. (1999) use the data of 20 largest firms in the 27 wealthiest countries in 1995. Faccio and Lang (2002) use the data of 5,232 publicly traded companies in 13 Western European countries for the period between 1996 and 1999. Both studies include shareholder with at least 5 percent of the firms' shares and employ the 20 percent cut-off to define the controlling shareholders.

[5] Among these 12 companies, nine companies belong to a single family, Chokwatana, who is one of the biggest business groups.

When compared with those in other East Asian economies, controlling shareholders in Thailand, however, employ cross-shareholdings in the lesser degree. In particular, Claessens et al. (2000b) document that in 1996, approximately 10.1 percent of firms in nine East Asian countries use cross-shareholdings. Regarding Thailand, they find that only 0.8 percent of Thai firms in their sample use cross-shareholdings, which are the least prevalent among all East Asian firms. We suspect, however, that their results might be underestimated since their sample coverage is small. More precisely, 232 firms are excluded probably because these firms are controlled by private companies in which ultimate owners are difficult to be identified (see Claessens et al., 2000b, p. 88). In fact, we find that pyramids and cross-shareholdings are often used in this type of firms.

4.2 Ownership concentration

In this section, we investigate ownership concentration in the hands of controlling shareholders, measured by cash-flow and voting rights. The results are shown in Panel A and B of Table 4. In 2000, a controlling shareholder owns, on average, 45.27 percent of the firm's cash-flow rights, and 48.18 percent of the firm's voting rights, with the median values of 44.41 percent and 46.99 percent, respectively. The cash-flow rights held by controlling shareholders range from 12.38 percent to 92.85 percent, while their voting rights range from 25.03 percent to 92.85 percent.

Among all types of firms with controlling shareholders, the Thai government holds the highest mean value of cash-flow rights (52.71 percent), followed by the controlling shareholders in firms that are owned by related families (47.11 percent), unrelated families (46.47 percent), foreign investors (46.02 percent), and foreign institutional investors (43.03 percent). In firms controlled by domestic financial institutions and firms with multiple controlling shareholders[6], the controlling shareholders hold the lowest average cash-flow rights of 34.2 percent and 36.09 percent, respectively.

Regarding the control, the most concentrated voting rights appear in firms owned by the Thai government of 52.83 percent. The mean values of voting rights held by controlling shareholders in firms owned by related families (50.41 percent), unrelated families (48.05 percent),

[6] Note that cash-flow and voting rights in firms owned by multiple controlling shareholders are the rights held by the largest controlling shareholder.

foreign investors (47.31 percent), and foreign institutional investors (43.03 percent) are also relatively high. The lowest mean values of controlling shareholders' voting rights are shown in firms owned by domestic financial institutions (40.3 percent) and firms with multiple controlling shareholders (40.13 percent).

Compared to the results of the pre-crisis period, the concentration of ownership and control in the hands of controlling shareholders slightly increases. Specifically, the average cash-flow rights (voting rights) held by controlling shareholders rise from 44.66 percent (47.75 percent) in 1996, to 45.27 percent (48.18 percent) in 2000. The median value of cash-flow rights increases from 44.1 percent to 44.41 percent, while the median value of voting rights declines from 47.75 percent to 46.99 percent.

Except the Thai government, cash-flow and voting rights of all groups of controlling shareholders increase after the crisis. Specifically, in firms owned by a group of related families, the controlling families hold, on average, 46 percent of the firms' cash-flow rights in 1996, compared to 47.11 percent in 2000. The mean value of cash-flow rights owned by the controlling shareholders in firms owned by domestic financial institutions rises from 27.26 percent in 1996 to 34.2 percent in 2000. The average cash-flow rights held by controlling foreign investors also increase from 42.85 percent to 44.77 percent.

Ownership concentration in firms controlled by a group of controlling shareholders is also higher. More precisely, a group of unrelated controlling families holds, on average, 43.75 percent of the firm's cash-flow rights in 1996, relative to 47.16 percent in 2000. Likewise, in firms owned by multiple controlling blocks, the mean value of cash-flow rights held by the controlling shareholders rises from 35.41 percent to 36.63 percent.

In contrast, the Thai government holds less cash-flow rights in 2000 than in 1996. Specifically, the average cash-flow rights held by the Thai government decline from 54.68 percent to 52.71 percent.

Regarding voting rights, we find that the controlling shareholders of firms that are owned by families (both related and unrelated), domestic financial institutions, and foreign investors have greater control after the crisis. The Thai government and multiple controlling blocks, however, hold less voting rights in 2000, relative to those in 1996.

Even if there are changes in the controlling shareholder's cash-flow and voting rights following the crisis, our results show that the mean and median values of these two rights in the hands of all types of controlling shareholders are not significantly different between the two periods.

In Panel C, the results support our findings in Section 4.1. As direct shareholdings are the most commonly used means of control, the deviation of control from ownership is small. Overall, the average ratio of cash-flow to voting rights is 0.939, meaning that a controlling shareholder holds 100 ultimate votes for each 93.9 direct shares owned. The median value of the ratio is one, however. This is relatively high when compared to the average ratio of firms in nine East Asian countries (0.746) documented in Claessens et al. (2000b) and that of firms in 13 Western European countries (0.868) documented in Faccio and Lang (2002).

The largest separation between ownership and control occurs in firms that are controlled by domestic financial institutions (0.843). In contrast, firms controlled by the State and foreign institutional investors show almost no separation. In the middle of these two extreme cases are firms that are controlled by multiple controlling blocks (0.919), single families (0.926), , foreign investors (0.967), and by a group of unrelated families (0.97).

The degree of the separation between ownership and control appears to be slightly lower after the crisis. Specifically, the mean ratio of cash-flow to voting rights held by controlling shareholders is 0.931 in 1996 and 0.939 in 2000. The median values of the ratio for both periods are one, however. Among all types of firms with controlling shareholders, firms owned by a group of controlling shareholders have the greatest change in the mean ratio of cash-flow to voting rights. To be specific, the mean ratio increases from 0.938 in 1996 to 0.97 in 2000 in firms controlled by a group of unrelated families, and from 0.871 to 0.919 in firms with multiple controlling shareholders. To a lesser extent, in foreign-owned firms, the mean ratio increases from 0.955 to 0.967. There are, however, no changes in the ratio of cash-flow to voting rights in single family-owned and state-owned firms during the two periods.

Following Claessens et al. (2002), we also calculate the difference between voting and cash-flow rights, by deducting the controlling shareholders' cash-flow rights from the voting rights they hold. The outcome reported in Panel D is consistent with the results in Panel C.

However, similar to changes in the controlling shareholder's cash-flow and voting rights, we do not find any significant changes in the ratio of cash-flow to voting rights as well as the difference between these two rights in all types of controlling shareholders, during the pre- and post-crisis periods.

4.3 Discrepancy between Ownership and Management

We investigate how often the controlling shareholders and their family members are involved in management in this section. We categorize management into two groups: Executive and non-executive directors. An executive director is a person who holds one of the following positions: Honorary chairman, chairman, executive chairman, vice chairman, president, vice president, chief executive officer, managing director, deputy managing director, and assistant managing director. A non-executive director is a board member who does not hold an executive position.

Consistent with the previous literature, our results in Panel A of Table 5 show that controlling shareholders in about two-third of the firms are involved in management. Specifically, in about 67.84 percent and percent 60.78of the firms with controlling shareholders in 2000, there is at least one member of the controlling family sitting in the board at top executive and non-executive levels, respectively.

As expected, the controlling shareholders' participation in the board is most prevalent in firms controlled by families, including related and unrelated families. Statistically, the incidence of controlling families holding top executive positions occurs in 85.71 percent and 88.89 percent of the firms that are controlled by related families and unrelated families respectively. Similar picture emerges regarding the controlling shareholders' participation in non-executive positions. Specifically, this incidence appears in 76.19 percent and 94.44 percent of the firms controlled by related families and unrelated families, respectively.

Controlling shareholders in the firms with multiple controlling blocks are also highly involved in management. In 75 percent and 67.86 percent of such firms, their controlling shareholders sit in the executive and non-executive boards, respectively.

To a lesser degree, controlling shareholders in foreign-owned firms serve as executive and non-executive directors. This incidence is found in about 21.28 percent and 14.89 percent of these firms. Board representation by the controlling shareholders does not occur in the firms that are owned by foreign institutional investors, however.

Compared to the pre-crisis results, the controlling shareholders' involvement in management as executives slightly decreases from 68.95 percent in 1996 to 67.84 percent in 2000. The declining in the board representation by controlling shareholders is more pronounced at the non-executive level. The proportion of firms where controlling shareholders and their family members serve as non-executive directors declines from 65.7 percent in 1996 to 60.78 percent in 2000. However, in overall the incidence that controlling shareholders participate as both executive and non-executive directors does not differ significantly between these two periods.

Regarding each type of controlling shareholders, we find the interesting results that the proportion of firms where controlling shareholders serve as executives increases after the crisis in firms that are owned by families, namely a group of related and unrelated families. In related family-controlled firms, this proportion increases from 84.44 percent in 1996 to 85.71 percent in 2000, while in unrelated family-controlled firms the proportion increases from 66.67 percent to 88.89 percent. The percentage of firms with the controlling shareholders' involvement as top managers is also greater in firms owned by multiple controlling blocks, from 70 percent in 1996 to 75 percent in 2000. The fraction, however, is lower, from 23.91 percent to 21.28 percent, in foreignowned firms.

Concerning the controlling shareholders' participation as non-executive directors, it turns out that after the crisis controlling shareholders in all types of firms hold fewer board positions.

Our investigation also reveals that for each group of controlling shareholders, the differences in the percentage of firms where controlling shareholders sit in the board between the pre- and post-crisis periods are not statistically significant at the conventional levels. However, in firms owned by a group of unrelated families, the difference in the proportion of firms where controlling shareholders and their family members serve as executive directors is most pronounced, with the t-statistics of –1.56.

Considering the number of board positions held by controlling shareholders, we find that the controlling shareholder often holds more than one position. Panel B shows that in 2000, the average numbers of executive and non-executive directors held by controlling shareholders are 1.23 and 1.37 respectively. As expected, the incidence of having more than one person from the controlling shareholder's family on the board happens more often in family-owned firms. Statistically, in firms that are controlled by related families, the average (median) executive positions held by the controlling families are 1.68 (2), while the average (median) numbers of non-executive positions are 1.75 (1). Likewise, in firms owned by unrelated families, members of the controlling families hold the average executive positions of 1.39, with the median value of 1, and the average non-executive positions of 2.89, with the median value of 2. This evidence is consistent with the study of the US majority-owned firms with majority-ownership by Denis and Denis (1994). They find that in 79 percent of their sample firms, more than two members of the controlling families sit in the top management team.

Compared with the pre-crisis results, the controlling shareholders hold a smaller number of board positions at both executive and non-executive levels. More precisely, the mean value of executive positions served by controlling shareholders decreases from 1.29 in 1996 to 1.23 in 2000. The average number of non-executive positions held by the controlling shareholders also declines from 1.59 to 1.37.

When considering what happen in each type of firms regarding the controlling shareholders' participation as non-executives, we find that except in the firms that are controlled by related and unrelated families, controlling shareholders hold less positions in 2000 than in 1996.

Again, our results show that the differences in both the mean and median values of board positions held by controlling shareholders between the pre- and post-crisis periods are not statistically significant from zero. In firms with multiple controlling shareholders, the differences in the mean and median values of non-executive board seats held by controlling shareholders before and after the crisis are greatest with the t-statistics of 1.54 and z-statistics of 1.3, respectively.

We further investigate the controlling shareholders' involvement in management by controlling the board size effect. Panel C shows the ratio of board positions held by controlling shareholders divided by board size. The results reveal that controlling shareholders occupy about one-third of the firm's boards. The average ratios are 0.33 in both periods, while the median ratio is 0.29 in 1996 and 0.3 in 2000.

Consistent with the previous findings, the board representation by controlling shareholders is remarkably high in firms that are owned by families, and low in firms that are owned by foreign investors. To be specific, in related family-owned firms, the average ratio of board positions held by the controlling family to board size is 0.43, with the median value of 0.4. Similarly, in firms owned by a group of unrelated families, members of the families hold the mean ratio of 0.5, with the median value of 0.48. On the contrary, in foreign-owned firms, the average ratio of board position served by controlling shareholders to the total number of board positions is only 0.09, with the median value of zero.

When compared to the pre-crisis results, in firms owned by families, both related and unrelated, the controlling families' members hold a higher fraction of board positions. In contrast, in firms owned by multiple controlling blocks, the controlling shareholders have fewer positions in the board. The ratio of board positions held by any type of controlling shareholders to board size does not differ significantly in the periods before and after the crisis, although the differences in the mean and median values of this ratio are most pronounced in firms owned by unrelated families with the t-statistics of –1.65 and z-statistics of -1.63, respectively.

4.4 Managerial Ownership: The case of non-controlling shareholders

In this section, we analyze the ownership by executive and non-executive directors who are not the firm's controlling shareholders. Ownership here is measured by aggregating percentages of shares held by all the board members who are not the firm's controlling shareholders or members of the controlling families.

Table 6 shows that overall management that is not from the controlling shareholders or their families almost holds no shares. The median shareholdings of both groups of these directors are zero percent in both pre- and post-crisis periods. The average shareholdings of the executives, however, are 2.26 percent in 1996 and 2.54 percent in 2000. As for non-executives, their shareholdings are, on average, 3.18 percent in 1996 and 3.85 percent in 2000. There are no significant differences in the shareholdings of these directors between both periods, however.

In the post-crisis period, the top executives in firms owned by a group of unrelated families have the highest average shareholdings of 4.08 percent with the median value of 1.99 percent, while the non-executive directors in firms owned by foreign institutional investors hold the greatest mean and median values of the shareholdings of 17.43 percent. In the pre-crisis year, however, the executives in foreign-controlled firms own more shares than those in other types of firms. Their average shareholdings are 3.3 percent, with the median value of zero percent. The non-executives in firms owned by domestic institutions hold the highest mean and median values of equity stakes of 11.29 percent. As one might expect, directors in firms that are controlled by multiple controlling blocks and by single families hold the lowest shares in both periods.

5. Ownership structure in firms with no controlling shareholder

In this Section, we investigate the ownership of the firms that are defined as firms with no controlling shareholder. These firms account for 20.81 percent and 21.31 percent in our 1996 and 2000 samples, respectively. We examine whether such firms are really dispersedly owned, as described in the model of the UK and the US.

Panel A of Table 7 presents the cash-flow and voting rights held by the largest shareholder of these firms. The results show that the ownership of these firms is quite concentrated in both periods. In 2000, the largest shareholder holds, on average, 16.74 percent of the firm’s cash-flow rights with the median value of 16.49 percent. The average voting rights held by this largest shareholder is 18.16 percent with the median value of 19.51 percent. The maximum level of both rights is 25 percent, and the minimum is 5.57 percent. When compared with the pre-crisis results, the mean value of cash-flow rights held by the largest shareholder slightly increases from 16.38

percent in 1996 to 16.74 percent in 2000, while the mean values of voting rights are the same in these two periods.

Panel B provides further information on the distribution of the ownership and control. In 2000, in 37.31 percent (25 firms) of all firms with no controlling shareholder, the largest shareholder has between 20 percent and 25 percent of cash-flow rights. Regarding the voting rights, in 29 firms (43.28 percent), the shareholder owns the range of 20 percent to 25 percent. So, if we relax the definition of controlling shareholdings from those with the voting rights of 25 percent to 20 percent, which is the threshold commonly used in the literature, then these 29 firms would be classified as firms with the controlling shareholder. This issue is also addressed in Section 3.

Interestingly, if we use the cut-off level of 10 percent[7], another commonly used threshold to define controlling shareholding, only seven firms in 1996 and six firms in 2000 can be classified as having no controlling shareholder or widely held. These firms account for only about 2 percent of the overall samples. These findings are consistent with those documented in Claessens et al. (2000b) for the pre-crisis period. They find that 2.2 percent of Thai firms in their sample are widely held at the 10 percent cut-off.

If we lower the cut-off level further to 5 percent, then there would be no firm that can be classified as widely held in both periods.

Viewed collectively, our results show that, only a small fraction of firms in our sample can be considered as dispersedly held by atomistic shareholders in the same way as described in the US and UK model. In other words, the ownership of Thai publicly traded companies is very concentrated.

We also investigate the degree of discrepancy between ownership and control in these firms. The mean value of the ratio of cash-flow to voting rights is 0.93, with the median value of 1,

---

[7] In fact, at this level of ownership, a shareholder is defined as a major shareholder. According to the Thai corporate law, he has the right to ask the court for the company's dissolution and to demand the company to claim compensation from any misbehaved managers.

suggesting that the control-enhancing means such as pyramiding and cross-shareholding are not commonly used. This is similar to the case of firms with controlling shareholders documented in Section 4. In fact, our evidence reveals that the largest shareholder in 11 firms employs pyramidal structures, and in one firm uses cross-shareholdings. After the crisis, the degree of separation between ownership and control held by the largest shareholder is reduced, as measured by an increase in the ratio of cash-flow to voting rights from 0.91 in 1996 to 0.93 in 2000. The degree of separation is, however, not significantly different between the pre- and post-crisis periods. This is again consistent with the case of firms with controlling shareholders.

6. Conclusion

This study documents the corporate ownership and board structures after the East Asian financial crisis. We compare the structure with those before the crisis to address the effects of an economic downturn on the ownership and board structures. The results reveal that the post-crisis ownership structure indicates a decline of the role of families in controlling publicly traded firms. The controlling families are replaced mainly by foreign investors and domestic financial institutions. We also find the greater fraction of firms controlled by multiple controlling shareholders after the crisis.

Controlling shareholders appear to use less complicated shareholdings, in the forms of pyramidal structures and cross-shareholdings, to enhance their control after the crisis. This is reflected in the lower deviation of control from ownership, as computed by the ratio of cash-flow to voting rights held by controlling shareholders, and by the simple difference between the two rights. Interestingly, we find that overall, the ownership and control in the hands of controlling shareholders become more concentrated subsequent to the crisis.

The degree of separation between ownership and management, measured by the incidence that controlling shareholders participate in the board, is not significantly different during the pre- and post- crisis periods. Nevertheless, families appear to participate more, while foreign investors seem to be involved less often in management.

Viewed collectively, although we do not find any statistically significant differences in the ownership and board structure of Thai publicly traded corporations between the pre- and post-crisis periods, it might still be hard to deny that the macroeconomic shock has no effect on the firms. The related issue on what factors determine the ownership and board changes after the crisis, however, is left for future research.

References

Baek, J.S., Kang, J.K., Park, K.S., 2002. Economic shock, business group, and determinants of firm value and restructuring: Evidence from the Korean financial crisis, mimeo.

Bebchuk, L., Kraakman, R., Triantis, G., 1999. Stock pyramids, cross-ownership, and dual class equity: The creation and agency costs of separating control from cash flow rights. Working Paper 6951, National Bureau of Economic Research.

Claessens, S., Djankov, S., Lang, L., 1998. Corporate growth, financing, and risks in the decade before East Asia's financial crisis. Policy Research Working Paper 2017. World Bank, Washington, D.C.

Claessens, S., Djankov, S., Klapper, L., 2000a. Resolution of corporate distress: Evidence from East Asia's financial crisis. Policy Research Working Paper 2133. World Bank, Washington D.C.

Claessens, S., Djankov, S., Lang, L., 2000b. The separation of ownership and control in East Asian corporations. Journal of Financial Economics 58, 81-112.

Claessens, S., Djankov, S., Fan, J., Lang, L., 2002. Disentangling the incentive and entrenchment effects of large shareholdings. Journal of Finance, forthcoming.

Denis, D., Denis, D., 1994. Majority owner-managers and organizational efficiency. Journal of Corporate Finance 1, 91-118.

Denis, D., Sarin, A., 1999. Ownership and board structures in publicly traded corporations. Journal of Financial Economics 52, 187-223.

Faccio, M., Lang, L., 2002. The ultimate ownership of Western European corporations. Journal of Financial Economics, Forthcoming.

Gilson, S., 2001. Creating value through corporate restructuring: Case studies in bankruptcies, buyouts, and breakups. John Wiley & Sons, Inc.

Grossman, S., Hart, O., 1988. One share-one vote and the market for corporate control. Journal of Financial Economics 20, 175-202.

Harris, M., Raviv, A., 1988. Corporate governance: Voting rights and majority rules. Journal of Financial Economics 20, 203-235.

Holderness, C., Kroszner, R., Sheehan, D., 1999. Were the good old days that good? Changes in managerial stock ownership since the great depression. Journal of Finance 54, 435-469.

Johnstone, W., Neilsen, D., Henderson, A., 2001. Thai business groups 2001: A unique guide to who owns what. Bangkok: The Brooker Group Public Company Limited.

Kole, S., Lehn, K., 1999. Deregulation and the adaptation of governance structure: The case of the US airline industry. Journal of Financial Economics 52, 79-117.

Krugman, P., 1998. What Happened to Asia?, Mimeo. MIT, Cambridge, M.A.

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., Vishny, R., 1998. Law and Finance. Journal of Political Economy 106, 1113-1155.

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., Vishny, R., 1999. Corporate ownership around the world. Journal of Finance 54, 471-517.

Lemmon, M., Lins, K., 2001. Ownership structure, corporate governance, and firm value: Evidence from the East Asian financial crisis. Unpublished working paper.

Lins, K., 2002. Equity ownership and firm value in emerging markets. Unpublished working paper, University of North Carolina at Chapel Hill.

Mitchell, M., Mulherin, H., 1996. The impact of industry shocks on takeover and restructuring activity. Journal of Financial Economics 41, 193-229.

Mitton, T., 2002. A cross-firm analysis of the impact of corporate governance on the East Asian financial crisis. Journal of Financial Economics, Forthcoming.

Pornkulwat, S., 1996. The development of business strategies of overseas Chinese: A case study of two families, Master's thesis, Thammasat University (in Thai).

Sappaiboon, T., 2000a. The Lamsam Family, Nation Multi Media Group, Bangkok, (in Thai).

Sappaiboon, T., 2000b. The Fifty-five Most Well-Known Families Version 1, Nation Multi Media Group, Bangkok, (in Thai).

Sappaiboon, T., 2001. The Fifty-five Most Well-Known Families Version 2, Nation Multi Media Group, Bangkok, (in Thai).

Sersansie, S., Nimmansomboon, W., 1996. Public Limited Companies Act B.E. 2535, 2nd edn. Nititham Publishing House, Bangkok, Thailand.

Stock Exchange of Thailand, 1998. Rules of Stock Exchange of Thailand.

Wiwattanakantang, Y., 2000. The equity ownership structure of Thai firms. Unpublished working paper, Institute of Economic Research, Hitotsubashi University, Japan.

Wiwattanakantang, Y., 2001, Controlling Shareholders and Corporate Value: Evidence from Thailand. Pacific Basin Finance Journal 9, 323-362.

Wolfenzon, D., 1998. A theory of pyramidal ownership. Unpublished working paper, Harvard University, Cambridge, MA.

Appendix 1: Definition of pyramiding and cross-shareholding, and calculation of cash-flow rights and control rights

Definition of pyramidal structure and cross-shareholding

Pyramidal corporate structures are most commonly used to enhance ultimate owners' control (La Porta et al., 1999). It is a process in which a shareholder exercises control over the firm through tiers of companies. According to La Porta et al. (1999), *Shareholder X* controls *Company Z* via a pyramid if he ultimately owns *Public Company Y*, which in turn controls *Company Z*. We do not place a limit on the number of companies between the sample firm and its ultimate owner. However, companies along the chain of control are required to be publicly traded. If *Company Y* is privately owned by *Shareholder X*, we will not consider this ownership structure as a pyramid. In which case, the ultimate owner cannot separate cash-flow and control rights.

While in pyramidal structures, an ultimate owner controls a firm via the vertical layer(s) of public companies, in cross-shareholding structures, an ultimate owner controls a firm by having firms hold each other shares horizontally across the chain of control. Therefore, the voting rights of an ultimate controlling group are dispersed over the whole control chain, rather than concentrated on a single shareholder (Bebchuk et al., 1999). We define cross-shareholdings in the same way as La Porta et al. (1999). That is, *Company Z* is in cross-holding structure if it also holds shares of its controlling shareholder, or of any companies along the control chain.

Calculation of cash-flow rights and control rights

Both pyramidal structures and cross-shareholdings can separate voting rights from cash-flow rights. Consider a simple case of the sequence of two companies, *Y* and *Z*. *Shareholder X* holds 50 percent of shares in *Public Company Y*, which in turn owns 60 percent of *Company Z*'s equity. Suppose that there are neither multiple classes of shares in companies *Y* and *Z*, nor cross-holdings between these two companies. In this case, *Shareholder X* actually holds only 30 percent (the product of two ownership structure along the chain) of *Company Z*'s cash-flow rights. However, he can exercise more control over *Company Z* since he holds 50 percent (the smallest ownership stake along the chain) of *Company Z*'s voting rights. If there exists more than one layer in the control chain, an ultimate owner's cash-flow rights are the products of all ownership stakes along the chain, while his control rights are the smallest ownership stakes in the chain. Unless companies between the sample firm and its ultimate owner are publicly traded, the separation between cash-flow and voting rights is not applicable.

When an ultimate owner controls the company via numerous chains of control, especially in the case of cross-shareholdings, we calculate his cash-flow and control rights for each chain separately, and then sum them up to obtain the ultimate cash-flow and control rights. For example, suppose that *Shareholder X* has, in his hands, 50 percent of shares of *Public Company Y*, which in turn owns 60 percent of *Company Z*'s stocks. That is, along this chain, *Shareholder X* holds 30 percent (the product of two ownership stakes) of cash-flow rights, but 50 percent (the smallest ownership stake) of voting rights of *Company A*. Suppose also that *Shareholder X* holds 30 percent of shares of *Public Company W*, which in turn has 10 percent of *Company Z*'s stocks. Along this chain of control, *Shareholder X* has 3 percent (30 percent*10 percent) of cash-flow rights, but 10 percent (min {30 percent, 10 percent}) of voting rights in *Company Z*. *Shareholder X*, thus, ultimately owns 33 percent (30 percent+3 percent) of cash-flow rights, while he has more control rights of 60 percent (50 percent+10 percent) over *Company Z*. It is easily seen from this example that exercising control-enhancing vehicles can make the huge difference between ultimate ownership and control.

Table 1: Identification of Controlling Shareholders

This table presents the identification of controlling shareholders. Our sample includes non-financial companies listed in the Stock Exchange of Thailand in 1996 and 2000. Firms are classified into each category according to their controlling shareholders. In Panel A and B present the results when the ownership cut-off levels are 25 percent and 20 percent, respectively. Companies without a controlling shareholder are classified as companies with no controlling shareholder. The *'difference'* column in Panel A reports two-tailed t-tests of equal proportion for each variable between the two periods.

Panel A: The 25 percent ownership cut-off

	2000		1996		Difference
Type of controlling shareholder	No. of firms	%	No. of firms	%	t-statistics
1. Firms with controlling shareholders	255	79.19	277	78.69	0.184-
1.1 With one controlling shareholder	209	64.91	236	67.05	0.528
1.1.1 A group of related families	147	45.65	180	51.14	1.431
1.1.2 State	9	2.80	8	2.27	0.206-
1.1.3 Domestic financial institution	4	1.24	2	0.57	1.277-
1.1.4 Foreign investor	47	14.60	46	13.07	0.641-
1.1.5 Foreign institutional investor	2	0.62	0	0.00	1.491-
1.2 With a group of controlling shareholders	46	14.29	41	11.65	0.968-
1.2.1 A group of unrelated families	18	5.59	21	5.97	0.345-
1.2.1 Multiple controlling shareholders	28	8.70	20	5.68	1.567-
2. Firms with no controlling shareholder	67	20.81	75	21.31	0.184
Total	322	100.00	352	100.00	-

Panel B: The 20 percent ownership cut-off

Type of controlling shareholder	2000 No. of firms	2000 %	1996 No. of firms	1996 %
1. Firms with controlling shareholders	289	89.75	311	88.35
1.1 With one controlling shareholder	212	65.84	242	68.75
1.1.1 A group of related families	151	46.89	192	54.55
1.1.2 State	9	2.80	6	1.70
1.1.3 Domestic financial institution	5	1.55	1	0.28
1.1.4 Foreign investor	45	13.98	43	12.22
1.1.5 Foreign institutional investor	2	0.62	0	0.00
1.2 With a group of controlling shareholders	77	23.91	69	19.60
1.2.1 A group of unrelated families	22	6.83	22	6.25
1.2.1 Multiple controlling shareholders	55	17.08	47	13.35
2. Firms with no controlling shareholder	33	10.25	41	11.65
Total	322	100.00	352	100.00

Table 2: Characteristics of Firms with Multiple Controlling Shareholders

This table shows the characteristic of firms that have more than one controlling blocks. A controlling shareholder is a shareholder who directly or indirectly owns more than 25 percent of the firm's voting rights. Figures in the percentage columns are calculated as a fraction of firms with controlling shareholders.

	2000		1996	
Type of controlling shareholder	No. of firms	%	No. of firms	%
1. Two groups of controlling blocks				
1.1 A combination between a group of related families and	18	64.29	18	90.00
1.1.1 A group of other related families	2	7.14	4	20.00
1.1.2 State	1	3.57	0	0.00
1.1.3 Domestic financial institution	3	10.71	0	0.00
1.1.4 Foreign investors	7	25.00	11	55.00
1.1.5 Foreign institutional investors	1	3.57	0	0.00
1.1.6 A group of unrelated families	4	14.29	3	15.00
1.2 Foreign investor with foreign investor	3	10.71	0	0.00
1.3 Foreign investor with foreign institutional investor	1	3.57	0	0.00
1.4 Foreign investor with a group of unrelated families	5	17.86	1	5.00
2. Three groups of controlling blocks	1	3.57	1	5.00
2.1 A group of related families, a group of unrelated families, and foreign investor	1	3.57	1	5.00
Total	28	100.00	20	100.00

Table 3: Control Mechanisms

This table presents how firms are owned or how controlling shareholders exercise their control over the firms. Firms are classified into each category according to their controlling shareholders. A controlling shareholder is a shareholder who directly or indirectly owns more than 25 percent of the firm's voting rights. *Direct ownership* is when a controlling shareholder controls a firm directly under his name, or via his privately owned companies. *Pyramid* is when a firm is controlled via other public firms. *Cross-shareholding* is when there is an incidence of cross-shares between firms that are ultimately controlled by the same controlling shareholders. The percentage column is calculated as the proportion of firms that fall into each category divided by the total number of firms in such category of controlling shareholders.

	Direct (1)				Pyramid (2)				(1) and (2)				(1), (2), and cross-shareholding			
	2000		1996		2000		1996		2000		1996		2000		1996	
Type of controlling shareholder	No. of firms	%	No. of firms	%	No. of firms	%	No. of firms	%	No. of firms	%	No. of firms	%	No. of firms	%	No. of firms	%
One controlling shareholder																
A group of related families	112	78.32	136	76.84	2	1.40	6	3.39	21	14.69	22	12.43	12	8.39	16	9.04
State	8	88.89	8	100.00	0	0.00	0	0.00	1	11.11	0	0.00	0	0.00	0	0.00
Domestic financial institution	2	50.00	1	50.00	0	0.00	0	0.00	0	0.00	1	50.00	2	50.00	0	0.00
Foreign investor	41	89.13	39	90.70	0	0.00	1	2.33	6	13.04	5	11.63	0	0.00	1	2.33
Foreign institutional investor	2	100.00	-	-	0	0.00	-	-	0	0.00	-	-	0	0.00	-	-
Group of controlling shareholders																
A group of unrelated families	13	72.22	16	80.00	0	0.00	1	5.00	3	16.67	1	5.00	2	11.11	3	15.00
Multiple controlling shareholders	21	72.41	12	57.14	0	0.00	0	0.00	7	24.14	8	38.10	0	0.00	0	0.00
Total	199	78.04	212	76.53	2	0.78	8	2.89	38	14.90	37	13.36	16	6.27	20	7.22

Table 4: Ownership and Control Held by Controlling Shareholders

This table presents cash-flow and control rights held by the controlling shareholders, and the separation between these two rights. A controlling shareholder is a shareholder who directly or indirectly owns more than 25 percent of the firm's voting rights. Cash-flow rights represent the ownership stake held by the firm's controlling shareholders. Control rights represent the percentage of voting rights held by the firm's controlling shareholders. The cash-flow and control rights of firms with multiple controlling shareholders are the rights held by the largest controlling shareholder. The *'difference'* columns report two-tailed t-tests of equal means and Wilcoxon z-tests of equal medians for each variable between the two periods.

Panel A: Cash-flow rights (%) held by controlling shareholders

	2000					1996					Difference	
Firms with	No. of firms	Mean	Median	Max	Min	No. of firms	Mean	Median	Max	Min	t-statistics	z-statistics
One controlling shareholder												
A group of related families	147	47.11	47.63	83.83	12.38	180	46.00	47.07	92.53	15.23	-0.589	-0.540
State	9	52.71	49.00	92.85	25.52	8	54.68	46.12	92.86	29.58	0.183	0.000
Domestic financial institution	4	34.20	29.11	58.43	20.13	2	27.36	27.36	33.78	20.93	-0.512	0.000
Foreign investor	47	44.77	44.41	76.47	14.41	46	42.85	42.11	70.14	18.04	-0.636	-0.603
Foreign institutional investor	2	43.03	43.03	56.00	30.06	0	-	-	-	-	-	-
Group of controlling shareholders												
A group of unrelated families	18	47.16	47.98	78.24	26.66	21	43.75	42.52	76.63	21.56	-0.794	-0.866
Multiple controlling shareholders	28	36.63	38.73	50.82	13.38	20	35.41	35.58	50.30	17.09	-0.429	-0.439
Total	255	45.27	44.41	92.85	12.38	277	44.66	44.10	92.86	15.23	-0.574	-0.488

Panel B: Control rights (%) held by controlling shareholders

	2000					1996					Difference	
Firms with	No. of firms	Mean	Median	Max	Min	No. of firms	Mean	Median	Max	Min	t-statistics	z-statistics
One controlling shareholder												
A group of related families	147	50.41	49.54	84.26	25.54	180	49.47	49.65	92.53	25.13	-0.704	-0.576
State	9	52.83	49.00	92.85	25.52	8	54.68	46.12	92.86	29.58	0.172	0.000
Domestic financial institution	4	40.30	38.87	58.43	25.03	2	30.92	30.92	33.78	28.06	-0.781	-0.463
Foreign investor	47	46.05	44.70	76.47	25.51	46	44.76	44.85	70.14	25.50	-0.468	-0.292
Foreign institutional investor	2	43.03	43.03	56.00	30.06	0	-	-	-	-	-	-
Group of controlling shareholders												
A group of unrelated families	18	48.05	49.16	78.24	28.86	21	46.46	46.41	76.63	25.59	-0.346	-0.338
Multiple controlling shareholders	28	40.13	40.34	53.37	28.26	20	40.41	39.80	53.87	29.56	0.143	0.052
Total	255	48.18	46.99	92.85	25.03	277	47.75	47.75	92.86	25.13	-0.350	-0.120

Panel C: Ratio of cash-flow to control rights held by controlling shareholders

	2000					1996					Difference	
Firms with	No. of firms	Mean	Median	Max	Min	No. of firms	Mean	Median	Max	Min	t-statistics	z-statistics
One controlling shareholder												
A group of related families	147	0.926	1.000	1.000	0.385	180	0.927	1.000	1.000	0.438	0.103	0.424
State	9	0.998	1.000	1.000	0.982	8	1.000	1.000	1.000	1.000	0.934	0.943
Domestic financial institution	4	0.843	0.843	1.000	0.684	2	0.873	0.873	1.000	0.746	0.189	0.492
Foreign investor	47	0.967	1.000	1.000	0.408	46	0.955	1.000	1.000	0.472	-0.484	-0.363
Foreign institutional investor	2	1.000	1.000	1.000	1.000	0	-	-	-	-	-	-
Group of controlling shareholders												
A group of unrelated families	18	0.970	1.000	1.000	0.680	21	0.938	1.000	1.000	0.556	-1.394	-0.925
Multiple controlling shareholders	28	0.919	1.000	1.000	0.383	20	0.871	1.000	1.000	0.416	-0.865	-1.363
Total	255	0.939	1.000	1.000	0.383	277	0.931	1.000	1.000	0.416	-0.641	-0.507

Panel D: Control rights minus cash-flow rights (%) held by controlling shareholders

	2000					1996					Difference	
Firms with	No. of firms	Mean	Median	Max	Min	No. of firms	Mean	Median	Max	Min	t-statistics	z-statistics
One controlling shareholder												
A group of related families	147	3.31	0.00	26.05	0.00	180	3.43	0.00	33.16	0.00	-0.118	-0.410
State	9	0.12	0.00	1.07	0.00	8	0.00	0.00	0.00	0.00	-0.934	-0.943
Domestic financial institution	4	6.10	4.54	15.33	0.00	2	3.57	3.57	7.13	0.00	-0.421	-0.492
Foreign investor	47	1.29	0.00	20.87	0.00	46	1.91	0.00	20.15	0.00	0.6148	0.350
Foreign institutional investor	2	0.00	0.00	0.00	0.00	0	-	-	-	-	-	-
Group of controlling shareholders												
A group of unrelated families	18	1.58	0.00	16.39	0.00	21	2.71	0.00	17.24	0.00	1.389	0.925
Multiple controlling shareholders	28	4.04	0.00	32.68	0.00	20	5.00	0.00	23.99	0.00	0.647	1.363
	255										0.585	0.506
Total		2.92	0.00	32.68	0.00	277	3.10	0.00	33.16	0.00		

Table 5: The Separation between Ownership and Management

This table shows the degree of involvement in the management by the controlling shareholders. A controlling shareholder is a shareholder who directly or indirectly owns more than 25 percent of the firm's voting rights. Panel A shows the number of firms where the controlling shareholders are executive and non-executive directors. An executive director is a person who holds one of the following positions: honorary chairman, chairman, chairman of the management committee, executive chairman, vice chairman, deputy chairman, chairman of executive director, president, vice president, chief executive officer, managing director, deputy managing director, assistant managing director. A non-executive director is a person who is not an executive director or an independent director, but is a member of the board of directors. Figures in the percentage columns are calculated as the proportion of firms that fall into each category divided by the total number of firms in such category of controlling shareholders. The *‘difference’* column in Panel A reports two-tailed t-tests of equal proportion for each variable between the two periods. The *‘difference’* columns in Panel B and C report two-tailed t-tests of equal means and Wilcoxon z-tests of equal medians for each variable between the two periods.

Panel A: Controlling shareholders as executive and non-executive directors

	As executive directors					As non-executive directors				
	2000		1996		Difference	2000		1996		Difference
Type of controlling shareholder	No. of firms	%	No. of firms	%	t-statistics	No. of firms	%	No. of firms	%	t-statistics
One controlling shareholder										
A group of related families	126	85.71	152	84.44	0.444-	112	76.19	138	76.67	0.169
State	0	0.00	0	0.00	-	0	0.00	0	0.00	-
Domestic financial institution	0	0.00	0	0.00	-	0	0.00	0	0.00	-
Foreign investor	10	21.28	11	23.91	0.35824	7	14.89	9	19.57	0.371
Foreign institutional investor	0	0.00	-	-	-	0	0.00	-	-	-
Group of controlling shareholders										
A group of unrelated families	16	88.89	14	66.67	1.564-	17	94.44	20	95.24	0.825-
Multiple controlling shareholders	21	75.00	14	70.00	0.376-	19	67.86	15	75.00	0.922
All firms with controlling shareholders	173	67.84	191	68.95	0.367	155	60.78	182	65.70	1.185

Panel B: Board positions held by the controlling shareholders

	As executive directors											
	2000					1996					Difference	
Type of controlling shareholder	No. of firms	Mean	Median	Max	Min	No. of firms	Mean	Median	Max	Min	t-stat.	z-stat.
A group of related families	126	1.68	2.00	5.00	0.00	152	1.62	2.00	5.00	0.00	0.396-	0.368-
State	0	0.00	-	-	-	0	-	-	-	-	-	-
Domestic financial institution	0	0.00	-	-	-	0	-	-	-	-	-	-
Foreign investor	10	0.26	0.00	2.00	0.00	11	0.30	0.00	2.00	0.00	0.618	0.411
Foreign institutional investor	0	0.00	-	-	-	-	-	-	-	-	-	-
A group of unrelated families	16	1.39	1.00	3.00	0.00	14	1.05	1.00	3.00	0.00	0.951-	1.142-
Multiple controlling shareholders	21	1.21	1.00	4.00	0.00	14	1.40	1.00	4.00	0.00	0.300	0.055-
All firms with controlling shareholders	173	1.23	1.00	5.00	0.00	191	1.29	1.00	5.00	0.00	0.554	0.523

	As non-executive directors											
	2000					1996					Difference	
Type of controlling shareholder	No. of firms	Mean	Median	Max	Min	No. of firms	Mean	Median	Max	Min	t-stat.	z-stat.
A group of related families	112	1.75	1.00	8.00	0.00	138	1.87	2.00	9.00	0.00	0.766	0.755
State	0	0.00	-	-	-	0	-	-	-	-	-	-
Domestic financial institution	0	0.00	-	-	-	0	-	-	-	-	-	-
Foreign investor	7	0.28	0.00	2.00	0.00	9	0.35	0.00	2.00	0.00	0.239	0.335
Foreign institutional investor	0	0.00	-	-	-	-	-	-	-	-	-	-
A group of unrelated families	17	2.89	2.00	6.00	0.00	20	2.67	2.00	7.00	0.00	0.885-	0.791-
Multiple controlling shareholders	19	1.10	1.00	3.00	0.00	15	1.55	1.00	5.00	0.00	1.543	1.291
All firms with controlling shareholders	155	1.37	1.00	8.00	0.00	182	1.59	1.00	9.00	0.00	1.448	1.561

Panel C: Ratio of board positions held by the controlling shareholders to total number of board positions

	2000				1996				Difference	
Type of controlling shareholder	No. of firms	%	Mean	Median	No. of firms	%	Mean	Median	t-statistics	z-statistics
A group of related families	136	92.52	0.43	0.40	168	93.33	0.40	0.36	0.101	-0.044
State	0	0.00	-	-	0	0.00	-	-	-	-
Domestic financial institution	0	0.00	-	-	0	0.00	-	-	-	-
Foreign investor	13	27.66	0.09	0.00	15	32.61	0.09	0.00	0.226	0.543
Foreign institutional investor	0	0.00	-	-	-	-	-	-	-	-
A group of unrelated families	18	100.00	0.50	0.48	21	100.00	0.37	0.29	-1.651	-1.630
Multiple controlling shareholders	25	89.29	0.27	0.22	19	95.00	0.32	0.31	0.997	0.764
All firms with controlling shareholders	192	75.29	0.33	0.30	223	80.51	0.33	0.29	0.943	0.932

Table 6: Ownership by Board Members: Non-Controlling Shareholders

This table provides the ownership held by the directors who are not from the firm's controlling shareholders. Ownership here is measured by an aggregate percentage of cash-flow rights held by the board members. A controlling shareholder is a shareholder who directly or indirectly owns more than 25 percent of the firm's voting rights. Firms are classified into each category according to their controlling shareholders. Figures in the percentage columns are calculated as the proportion of firms that fall into each category divided by the total number of firms in such category of controlling shareholders. The *'difference'* columns report two-tailed t-tests of equal means and Wilcoxon z-tests of equal medians for each variable between the two periods.

Panel A: Ownership by the executive directors who are not the controlling shareholders (%)

	2000				1996				Difference	
Type of controlling shareholder	No. of firms	%	Mean	Median	No. of firms	%	Mean	Median	t-statistics	z-statistics
A group of related families	100	68.03	2.40	0.00	128	71.11	2.22	0.00	-0.368	0.332
State	9	100.00	0.00	0.00	8	100.00	0.00	0.00	-	-
Domestic financial institution	4	100.00	4.60	3.72	2	100.00	0.00	0.00	-1.115	-1.095
Foreign investor	42	89.36	3.43	0.00	39	84.78	3.30	0.00	-0.123	0.050
Foreign institutional investor	2	100.00	0.00	0.00	0	0.00	-	-	-	-
A group of unrelated families	13	72.22	4.08	1.99	19	90.48	2.51	0.00	-0.956	-1.542
Multiple controlling shareholders	22	78.57	1.11	0.00	17	85.00	1.60	0.00	0.454	0.211
All firms with controlling shareholders	192	75.29	2.54	0.00	213	76.90	2.26	0.00	-0.484	0.210

Panel B: Ownership by the non-executive directors who are not the controlling shareholders (%)

Type of controlling shareholder	2000 No. of firms	2000 %	2000 Mean	2000 Median	1996 No. of firms	1996 %	1996 Mean	1996 Median	Difference t-statistics	Difference z-statistics
A group of related families	135	91.84	3.52	0.00	167	92.78	3.45	0.00	-0.265	0.524
State	9	100.00	1.44	0.00	8	100.00	2.88	0.00	0.612	0.579
Domestic financial institution	4	100.00	8.39	8.31	2	100.00	11.29	11.29	0.330	0.235
Foreign investor	45	95.74	5.42	0.00	44	95.65	3.80	0.00	-0.852	-0.378
Foreign institutional investor	2	100.00	17.43	17.43	0	0.00	-	-	-	-
A group of unrelated families	16	88.89	4.17	1.40	20	95.24	1.77	0.00	-1.520	-1.542
Multiple controlling shareholders	27	96.43	0.98	0.00	19	95.00	0.46	0.00	-0.730	0.113
All firms with controlling shareholders	238	93.33	3.85	0.00	260	93.86	3.18	0.00	-1.115	0.022

Table 7: Ownership by the Largest Shareholder: Firms with no Controlling Shareholder

This table shows the cash-flow and control rights by the largest shareholder of firms that have no controlling shareholder. The numbers of such firms are 75 in 1996, and 67 in 2000. A controlling shareholder is a shareholder who directly or indirectly owns more than 25 percent of the firm's voting rights. The *'difference'* columns in Panel A report two-tailed t-tests of equal means and Wilcoxon z-tests of equal medians for each variable between the two periods. Figures in the percentage columns in Panel B are calculated as the proportion of firms that fall into each category divided by the total number of firms that have no controlling shareholders.

Panel A: Summary statistics of cash-flow and control rights held by the largest shareholder (%)

	2000				1996				Difference	
	Mean	Median	Max	Min	Mean	Median	Max	Min	t-statistics	z-statistics
Cash-flow rights	16.74	16.49	25.00	5.57	16.38	16.67	25.00	4.16	-0.052	-0.087
Control rights	18.16	19.51	25.00	5.57	18.16	19.89	25.00	5.92	0.339	0.479
Ratio of cash-flow to control rights	0.93	1.00	1.00	0.29	0.91	1.00	1.00	0.25	-0.425	-0.597

Panel B: The distribution of cash-flow and control rights held by the largest shareholder

	Cash-flow rights				Control rights			
	2000		1996		2000		1996	
Ownership level	No. of firms	%	No. of firms	%	No. of firms	%	No. of firms	%
0-5%	0	0.00	1	1.33	0	0.00	0	0.00
5-10%	10	14.93	9	12.00	6	8.96	7	9.33
10-15%	13	19.40	20	26.67	8	11.94	13	17.33
15-20%	19	28.36	21	28.00	24	35.82	21	28.00
20-25%	25	37.31	24	32.00	29	43.28	34	45.33
Total	67	100.00	75	100.00	67	100.00	75	100.00

No, the U.S. Market is not the World Factor

Anya Khanthavit, Ph.D.

Professor of Finance and Banking and TRF Senior Researcher

Department of Finance and Banking

Faculty of Commerce and Accountancy, Thammasat University

Bangkok 10200, THAILAND

Tel: (662) 613-2233, 613-2239 Fax: (662) 225-2109

E-mail: akhantha@.tu.ac.th

Suluck Pattarathammas

Lecturer

Department of Finance and Banking

Faculty of Commerce and Accountancy, Thammasat University

Bangkok 10200, THAILAND

Tel: (662) 503-2661, 503-2643 Fax: (662) 984-0604

E-mail: suluckp@clickta.com

Date: July 3, 2002

The authors would like to thank Aekachai Nittayakasetwat, Pornanong Penpas, Chaiyuth Punyasavatsut, Santi Tirapat, and participants at the 9th Annual Thammasat Finance Conference and 14th Annual Australasian Finance and Banking Conference for comments and suggestion. Supports from Thailand Research Fund are gratefully acknowledged.

Abstract

No, the U.S. Market is not the World Factor

Returns in national stock markets exhibit strong interdependence. Among these markets, the U.S. market has ability to explain and predict the movement of other markets. In this study, we examine the mechanism that constitutes this ability. We propose two competing hypotheses. Under the first hypothesis, the U.S. return is a common or world factor that drives returns in all national markets. Hence, all the national market returns must be explained by the U.S. return by the construction. The predictive ability results from the delayed reaction of markets to the U.S. returns on earlier dates. Under the second hypothesis, the U.S. return and other national market returns are driven by a common factor and by the idiosyncratic factors of their own. The explanatory ability is from the common factor that moves all the returns together; the predictive ability is from the delayed reaction of markets to the common factor, which has already acknowledged by the U.S. market on earlier dates.

We use daily return data on the U.S., Canadian, U.K., German and Japanese markets from January 5, 1987 to December 22, 2000 (2,646 observations) for the tests. Our results support the second hypothesis. The U.S. market is not the world factor.

JEL classifications: G14 G15

Key words: Common factor, Kalman filter, Stock returns, Market efficiency

บทคัดย่อ

การทดสอบถึงอิทธิพลของตลาดหลักทรัพย์สหรัฐอเมริกา

การศึกษาทดสอบในเชิงลึกถึงสาเหตุที่ตลาดหลักทรัพย์สหรัฐอเมริกามีอิทธิพลซึ่งทำให้เกิดการเคลื่อนไหวของราคาหลักทรัพย์ในตลาดอื่นทั่วโลก ว่าจะเกิดจากต้นเหตุที่เป็นข่าวสารข้อมูลในสหรัฐอเมริกา หรือเกิดจากการที่ตลาดหลักทรัพย์สหรัฐอเมริกาเป็นตลาดที่มีประสิทธิภาพสูงมาก จึงรับข่าวสารข้อมูลก่อนแล้วจึงกระจายไปสู่ตลาดอื่น การศึกษาทดสอบโดยใช้ข้อมูลจากตลาดในสหรัฐอเมริกาควบคู่กับคานาดา สหราชอาณาจักร เยอรมันนี และญี่ปุ่น พบว่า ตลาดหลักทรัพย์ในประเทศทั้งห้ามีการเคลื่อนไหวไปพร้อมกันจากข่าวสารข้อมูลที่ใช้ร่วมกัน และตลาดหลักทรัพย์ในสหรัฐอเมริกาไม่ได้เป็นตลาดที่มีอิทธิพลจริงในการทำให้เกิดการเคลื่อนไหวของราคาในตลาดอื่น

No, the U.S. Market is not the World Factor

I. Introduction

Returns in national stock markets exhibit strong interdependence (Ripley (1973), Hillard (1979) and Jaffe and Westerfield (1985)). For these markets, Eun and Shim (1989), Becker *et al.* (1990) and Hamao *et al.* (1990) reported that the U.S. market was the most influential market and the U.S. market return was able to explain and predict other national market returns.

In this study, we examine the mechanism that constitutes this ability. We propose two competing hypotheses. Under our *first* hypothesis, the U.S. return is a common or world factor that drives returns in all national markets. Hence, all the national market returns must be explained by the U.S. return by the construction. The predictive ability results from the delayed reaction of markets to the U.S. return on earlier dates.

Jorion (1990), King *et al.* (1994) and Harvey (1995) found that observed economic variables, such as exchange rate, world market portfolio, U.S. term premia, industrial production index and commodity prices, could not explain movements in national stock market returns very well. But strong interdependence and co-movement of stock returns must result from the returns being driven by common factors. These findings seem to suggest that the U.S. market return is not a common factor, hence leading us to our *second*, competing hypothesis.

Under this hypothesis, the U.S. return and other national market returns are driven by a common factor and by the idiosyncratic factors of their own. The explanatory ability is from the common factor that drives all the returns. And, the predictive ability is from the delayed reaction of markets to the common factor, which has already acknowledged by the U.S. market on earlier dates.

It is important to test these hypotheses for at least three reasons. *First*, the findings will help us to understand the mechanism of information transmission in the world capital markets. That is, if the U.S. market return is a common factor as in our first hypothesis, the information is originated from the U.S.A. That information then disseminates to other national markets. But if all national market returns are driven by a common factor as in our second hypothesis, information transmission cannot explain interdependence of national market returns. Correlation of returns on a market with lagged returns on other markets has to come from different degrees of market efficiency to acknowledge the information.

Second, in tests of the capital asset pricing model used, for example, by Chen, Roll and Ross (1986), the U.S. market return can serve as a predetermined pricing factor. This variable is appropriate and justified only when it is a factor that drives asset returns in common. *Third*, the U.S. market return is widely used in regressions as an explanatory or predictive variable for asset returns. If the U.S. and asset returns are driven by a common factor as in our second hypothesis, all the returns are endogenous. The regressions are mis-specified and cannot give correct results.

In this study, we examine the hypotheses by decomposing national market returns into two parts. One is explained by a common factor and the remainder is explained by their idiosyncratic factors. If the U.S. market return is that common, world factor, it must be proportional to the explanatory common factor and its idiosyncratic factor must be zero.

Even though the common factor and idiosyncratic factors cannot be observed, we can estimate these factors based on a state-space model by the Kalman-filtering technique. The technique is a recursive, predictive updating technique that can determine the parameters of a process with unobserved regressors. We estimate the model and perform hypothesis tests, using daily return data on the U.S., Canadian, U.K., German, and Japanese markets from January 5, 1987 to December 22, 2000 (2,646 observations). Our results show a common factor exists. All the sample returns are driven by this common factor and their idiosyncratic factors. The common factor can explain about 50% of the total return volatilities, except for about 25% for the Japanese return volatility. As for the U.S. market return, the idiosyncratic factor's role to explain the return movement is significant. Hence, the U.S. market return cannot be that common factor. The empirical evidence enables us to conclude that the U.S. market is not the world factor.

The organization of the paper is the following. In Section II, we construct a state-space model to describe the return behavior in our sample markets and propose tests for our competing hypotheses. The data description is in Section III. We report the empirical results in Section IV and conclude our study in Section V.

II. METHODOLOGY

II.1 The State-Space Model

In this study, we explain the movement of national market returns by a common factor and their idiosyncratic factors. We assume that the idiosyncratic factors are independent and serially uncorrelated. The independence assumption is intended to express the role of the common factor as being the only factor to explain the interdependence and co-movement of returns. Because this common factor is the only factor that drives all the returns, we will refer to this factor as the world, common factor. The serial-correlation assumption implies that the markets can absorb local news immediately. Hence, serial correlation of the returns must result from the market inefficiency to respond to the world factor. This assumption is not unrealistic with respect to geographical vicinity of information sources and to better understanding of local information contents.

Let Y_t be an (n×1) column vector of time t's returns on n national stock markets, $\tilde{C}_t$ be time t's world factor, and E_t be an (n×1) column vector of time t's idiosyncratic factors. We assume that the returns Y_t are related linearly with the common factor and their idiosyncratic factors as in equation (1).

$$Y_t = \sum_{j=0}^{p} A_j \tilde{C}_{t-j} + E_t \qquad (1)$$

where A_j is an (n×n) column vector of coefficients a_{ij} for i = 1,…, n and for j = 0, 1, …, p. These coefficients describe the reaction of Y_t to lagged common factor C_{t-j}, where n is the number of sample countries and p is the lag length. We assume that the idiosyncratic factors E_t are distributed multivariate normally with a zero mean vector and an (n×n) diagonal covariance matrix H. h_i--the diagonal element i of matrix H, is the variance of country i's idiosyncratic factor. Moreover, E{E_tE_s}= **0** for t≠s. This assumed structure reflects the independence and serial correlation assumptions for E_t.

We assume that the common factor $\widetilde{C}_t$ is a random walk, distributed normally with a zero mean and variance q. That is,

$$\widetilde{C}_t = \widetilde{\eta}_t \qquad (2)$$

where $\widetilde{\eta}_t \sim N(0,q)$ and $E\{\widetilde{\eta}_t\ \widetilde{\eta}_s\} = 0$ for $t \neq s$. The assumption $E\{\widetilde{\eta}_t\ \widetilde{\eta}_s\} = 0$ guarantees that $\widetilde{C}_t$ is news. The markets cannot predict $\widetilde{C}_t$ using any $\widetilde{\eta}_{s<t}$. Finally, we assume that $\widetilde{C}_t$ and E_t are independent to clearly separate the roles of the common factor and the idiosyncratic factors.

Our model in equations (1) and (2) is very similar to the model used by Gregory *et al.* (1997). In that model, the output, consumption and investment in seven countries are explained by the unobserved world common factor. That world factor is assumed to follow a random walk. But that model differs from ours in that its dependent variables respond to the world factor in the current period. Our model is less restrictive. It allows the dependent returns to respond to the common factor on the current date as well as on previous dates.

The common factor and the idiosyncratic factors in equations (1) and (2) cannot be observed. But we can estimate these factors from the realized return series, using the Kalman-filtering technique.

To proceed, we analyze the model in equations (1) and (2) in a state-space framework by interpreting the common factor $\widetilde{C}_t$ as the state variable. The motion of the stock returns and the common factor can be modeled by the measurement equations (3.1) and (3.2) and the transition equations (4.1) and (4.2), respectively. The measurement equations relate the observed return variables linearly with the state variable by

$$\mathrm{Y}_t = \mathbf{AC}_t + E_t \qquad (3.1)$$

$$\begin{bmatrix} y_{1t} \\ \vdots \\ y_{nt} \end{bmatrix} = \begin{bmatrix} a_{10} & \cdots & a_{1p} \\ \vdots & \ddots & \vdots \\ a_{n0} & \cdots & a_{np} \end{bmatrix} \begin{bmatrix} C_t \\ \vdots \\ C_{t-p} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ \vdots \\ e_{nt} \end{bmatrix}, \qquad (3.2)$$

where $\mathbf{A}_{(n \times p+1)} = \begin{bmatrix} a_{10} & \cdots & a_{1p} \\ \vdots & \ddots & \vdots \\ a_{n0} & \cdots & a_{np} \end{bmatrix}$ $\boldsymbol{C}_t = \begin{bmatrix} C_t \\ \vdots \\ C_{t-p} \end{bmatrix}$ and $E_t = \begin{bmatrix} e_{1t} \\ \vdots \\ e_{nt} \end{bmatrix}$.

The transition equations describe the evolution of the state variable by

$$\mathbf{C_t} = \mathbf{BC_{t-1}} + \mathbf{R}\eta_t \tag{4.1}$$

$$\begin{bmatrix} C_t \\ \vdots \\ \vdots \\ C_{t-p} \end{bmatrix} = \begin{bmatrix} 0 & \cdots & \cdots & 0 \\ 1 & 0 & \cdots & \vdots \\ 0 & \ddots & 0 & \vdots \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} C_{t-1} \\ \vdots \\ \vdots \\ C_{t-p-1} \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \eta_t . \tag{4.2}$$

where $\mathbf{B}_{(p+1 \times p+1)} = \begin{bmatrix} 0 & \cdots & \cdots & 0 \\ 1 & 0 & \cdots & \vdots \\ 0 & \ddots & 0 & \vdots \\ 0 & 0 & 1 & 0 \end{bmatrix}$ and $\mathbf{R}_{(p+1 \times 1)} = \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$.

Harvey (1989) explains that Kalman filtering can estimate the system of equations (3.2) and (4.2) by delivering recursive values that can be fed into the prediction error decomposition of the likelihood function. The estimation problem is then to maximize the likelihood function with respect to the parameter set {**A**, H, q}.

II.2 Identification of Lag Length

In our model, the lag length p is not known and must be estimated. It is important to estimate p correctly. If the estimate $\hat{p}$ is too small, the model will be mis-specified. It should be noted that the model is highly non-linear in parameters and in data. Its complexity grows quickly with p. Hence, if the estimate $\hat{p}$ is too large, it is difficult to reach convergence. The model calibration is inefficient and can be imprecise.

We follow Harvey (1989) to use the Bayes information criterion (BIC) test to identify the lag length p. The BIC statistic is given by

$$\text{BIC} = |F|\, Exp\left(\frac{Ln(\text{T}) \times \text{k}}{\text{T}} \right) \tag{5}$$

where T is the number of observations, |F| is the determinant of prediction error variance[1], and k is the total number of parameters in the system. The BIC test trades off reduction in the prediction error variance with reduction in degrees of freedom as lag length grows in parsimonious models. We will choose the lag length p* that corresponds to the minimum BIC statistic.[2]

II.3 Is the U.S. Market the World Factor?

We will use the model in equations (3.2) and (4.2) to examine the role the U.S. market plays in the world capital markets. Our test is performed in two steps. In step one, we test for existence of the common factor. If that common factor exists, we will proceed in the second step to test for the significant role of idiosyncratic factor to explain the U.S. return. If the idiosyncratic factor is insignificant, the U.S. return and the common factor must be the same factor.

II.3.1 Test for Existence of Common Factor

In equations (1) and (3), if the factor C is a common factor, its current and/or lagged value must move the returns Y_t in all the national markets. This fact implies the response coefficients a_{ij} must be significant for *some lag j* = 0,1,..,p and *for all countries i*. Our null hypothesis for the existence of common factor is

$$H_0: \quad a_{i0} = a_{i1} = \dots = a_{ip} = 0 \qquad (6)$$

for country i = 1, 2,...,n. We will use a Wald test to test the hypothesis in equation (6). If the factor C cannot explain the return movement in country i, the Wald statistic will be distributed as a chi-square variable with p+1 degrees of freedom. If the factor C is common to all the markets, the hypothesis must be rejected for all the sample countries.

---

[1] The prediction error (V_t) equals the actual returns (Y_t) minus the predicted returns ($Y_{t|t-1}$) from the Kalman Filtering technique. The prediction error variance (F) is estimated from $\frac{1}{T}\sum_{t=1}^{T} V_t V_t'$

[2] The Akaike Information Criteria (AIC) test is also a popular test for lag length. But we do not consider the AIC test in this study because, in tests with a large sample size like ours, the AIC test tends to bias toward selecting an over-parameterized model (Enders (1995)).

II.3.2 Test for the U.S. Return Being the World Factor

In the studies of Eun and Shim (1989) and Hamao *et al.* (1990), the U.S. market return is presumed to be the world factor that influences the returns in other national markets. If this presumption is correct, the idiosyncratic factor of the U.S. market must be insignificant. From equations (1) and (3), the U.S. return must be a function of the common factor C alone.

We interpret the insignificance of the idiosyncratic factor as representing by a small variance h_{US} of the U.S.' idiosyncratic factor. A zero h_{US} implies that the idiosyncratic factor does not exist at all. So, we test for the U.S. return being the world factor by

$$H_0: h_{US} = 0. \tag{7}$$

Because the variance h_{US} cannot be negative, a conventional *t*-test of hypothesis (7) is inappropriate. Harvey (1989, p. 236) suggests the hypothesis is tested by a classical likelihood-ratio (LR) test. The LR statistic equals minus two times the difference of log likelihoods of the unrestricted and restricted models.[3]

It should be noted that, under H_0 the LR statistic is not distributed as a chi-square variable with one degree of freedom. Instead it is distributed as a mixture of two chi-square variables.

$$LR \approx \frac{1}{2}\chi_0^2 + \frac{1}{2}\chi_1^2, \tag{8}$$

meaning in a large sample the LR statistic has a 0.5 chance of taking a value χ_0^2 of zero and a 0.5 chance of being drawn from a χ_1^2 distribution. At a 1-α confidence level, the size of the LR test must be set appropriately to a 2α level, not just α.

We are aware of our large sample size of 2,646 observations. The significant LR statistic may be a pure statistical artifact from a large sample. In order to ensure the

[3] The restricted model is estimated under the restriction h_{us} = 0. The estimation is possible because the variance used in the likelihood function is H plus the covariance matrix of the estimation error.

significance (or insignificance) of h_{US}, we analyze the share of the U.S. return, explained by the common factor.

Consider the structure of return i in equations (1) and (3). The total variance σ^2_{yi} of the return must be

$$\sigma^2_{yi} = \sum_{j=0}^{p} a^2_{ij}\sigma^2_C + \sigma^2_{ei} = \sum_{j=0}^{p} a^2_{ij} q + h_i \qquad (9)$$

Let $R_i \leq 1.00$ denote the share of the variance σ^2_{yi} to be explained by the common factor C. From equation (9), R_i is

$$R_i = \frac{\sum_{j=0}^{p} a^2_{ij} q}{\sigma^2_{yi}} . \qquad (10)$$

For the U.S. market, if the variance h_{US} is small and insignificant, the ratio R_{US} must be large of about 1.00.

III. DATA DESCRIPTION

In the empirical tests, we will use daily returns on five national stock markets, consisting of the U.S., Canadian, U.K., German and Japanese markets. These markets are the most important, developed markets in North America, Europe, and Asia. The returns are the logged difference of the countries' closing indexes. We use the Dow Jones Industrial 30 index for the U.S. market, the Toronto SE 300 Composite index for the Canadian market, the FTSE 100 for the U.K. market, the DAX 30 Performance for the German market and the Nikkei 225 for the Japanese market. All the indexes are collected from the Datastream database and run from January 5, 1987 to December 22, 2000.

We construct the time-series returns very carefully. First, we consider only trading days on which all the markets open, in order to recognize national holidays for respective markets. Second, we are aware that the sample markets operate in different time zone. For the same trading day, the U.S. and Canadian stock markets are the last to close. Following Eun and Shim (1980), for trading day t we will use day t's returns for the U.K. German and Japanese markets and day t-1's returns for the U.S. and Canadian markets. This data construction constitutes 2,646 observations for our tests.

Table 1: Descriptive Statistics

The table reports descriptive statistics of the 5 national market returns. The returns are daily starting from January 5, 1987 and ending December 22, 2000 (2,646 observations). P-values appear in parentheses.

Statistics	Sample Countries				
	USA	Canada	UK	Germany	Japan
Mean	0.0006 (0.0031)*	0.0004 (0.0275)***	0.0005 (0.0181)**	0.0006 (0.0312)***	-0.0001 (0.6579)
Standard Deviation	0.0121	0.0105	0.0120	0.0155	0.0162
Serial Correlation Lag1	0.032 (0.0499)***	0.167 (0.000)*	0.093 (0.0000)*	0.013 (0.2518)	-0.014 (0.7643)
Lag2	-0.026 (0.9095)	-0.018 (0.8228)	-0.03 (0.9386)	-0.009 (0.6783)	-0.059 (0.9988)*
Lag3	-0.007 (0.6406)	0.007 (0.3594)	-0.02 (0.8482)	0.019 (0.1642)	-0.02 (0.8482)

* Significance at 99%, ** Significance at 95%, *** Significance at 90%

Table 1 reports the descriptive statistics of the sample returns. Their p-values are on the second lines. The sample means of daily returns are positive and significantly different from zero for all the sample countries except for Japan. Since our model in equations (1) and (3) does not include intercepts, the return series must be de-meaned before it is used in model calibration.

The table also reports serial correlations up to three lags. For the U.S., U.K. and Canadian markets, the correlation is significant at one lag. For the Japanese market, it is significant at two lags. With respect to our description of returns in equations (1) and (3), the significant serial correlation indicates inefficient response of the markets to the common factor C.

IV. EMPIRICAL RESULTS

IV.1 Full Sample

We estimate a system of equations (3.2) and (4.2), using Kalman filtering for 1-, 2- and 3-lag specifications to identify the appropriate lag length p*. The numbers of parameters and the BIC statistics for each specification are reported in Table 2. We find that the BIC statistic of the 1-lag specification is smallest, suggesting the appropriate lag length is 1. So, our analyses and tests to follow will be based on the 1-lag specification.

Table 2: Identification of Lag Length

The table reports the results for BIC test for lag length. The BIC statistic is computed as

$$\text{BIC} = |F|^{Exp\left(\frac{Ln(\text{T}) \times \text{k}}{\text{T}}\right)}$$

where T = numbers of observation, |F| = the determinant of prediction error variance

k = total number of parameters estimated in all equations

Lag	**N**	**BIC (*e -20)**
1	16	3.0111
2	21	3.0450
3	26	3.0711

Table 3: Estimation Results

(Full Sample: January 5, 1987-December 22, 2000)

The national market returns are described by

$$Y_t = A_0\tilde{C}_t + A_1\tilde{C}_{t-1} + E_t$$
$$\tilde{C}_t = \tilde{\eta}_t$$

where Y_t is a (5x1) column vector of daily returns at time *t,* A_0 is a (5x1) column vector of coefficients whose elements a_{i0}, for *i* = 1, 2, 3, 4, 5 describes the reaction of y_{it} to*,* A_1 is a (5x1) column vector of coefficients whose elements a_{i1}, for *i* = 1, 2, 3, 4, 5, describes the reaction of y_{it} to C_{t-1}, $\tilde{C}_{t-j}$ is the world common factor at time *t* and *j* = 0, 1, E_t is a (5x1) column vector of the idiosyncratic factors at time *t,* $\tilde{\eta}_t$ is a series of independent disturbances with mean zero and variance q, and E_t is MVN (0, H) and E (e_{it}, e_{jt}) = 0 for i $\neq$ j.

Wald test:

The Wald test is for testing whether each national market responds to the unobserved world factor. The null hypothesis is

H_0: ai0 = ai1 = 0

Likelihood Ratio test (LR):

LR is for testing whether a national.market represents the unobserved world factor. The null hypothesis is

H_0: $h_i = 0$

R:

R_i denotes the share of the variance of return of market i accounted for by the response to the common factor.

$$R_i = \frac{\left(a_{i0}^2 + a_{i1}^2\right)q}{\sigma_{yi}^2}$$

Parameters Estimates and Test Statistics	Sample Countries				
	U.S.	Canada	U.K.	Germany	Japan
a_{i0}	0.0246 (0.0000)*	0.0176 (0.0000)*	0.0284 (0.0000)*	0.0366 (0.0000)*	0.0252 (0.0000)*
a_{i1}	0.0116 (0.0000)*	0.0145 (0.0000)*	0.0009 (0.0363)***	0.0002 (0.0063)**	0.0043 (0.0000)*
h_i	7.71E-05 (0.0000)*	5.98E-05 (0.0000)*	6.56E-05 (0.0000)*	0.0001 (0.0000)*	0.0002 (0.0000)*
q	0.0959 (0.0000)*				
Wald test	125.0679 (0.0000)*	123.4125 (0.0000)*	67.6347 (0.0000)*	70.2897 (0.0000)*	78.4478 (0.0000)*
LR test	732.9582 (0.0000)*	1292.3581 (0.0000)*	736.3585 (0.0000)*	953.8789 (0.0000)*	2344.5942 (0.0000)*
R	0.4781 (0.0000)*	0.4536 (0.0000)*	0.5413 (0.0000)*	0.5337 (0.0000)*	0.2386 (0.0000)*

* Significance at 99%, ** Significance at 95%, *** Significance at 90%

Table 3 reports the parameter estimates of the state-space model with a 1-lag specification. It is found that all the estimates are significant at a conventional confidence level. Significance of the response coefficients a_{i1} to the lagged common factor C_{t-1} indicates inefficient response of the sample markets to the world news. This result is consistent with significant serial correlation found for all the markets in Table 1.

Next, we test for significance response of the return on market i with the common factor, based on the joint hypothesis $a_{i0} = a_{i1} = 0.00$. If market i does not respond to the common factor, the Wald statistic must be distributed as a chi-square variable with 2 degrees of freedom. From the table, we find that the Wald statistics are very large and significant for all the sample markets. We conclude that the common factor exists and this factor drives all the markets to move together.

This common factor can or cannot be the U.S. market return. If it is the U.S. return, the U.S. idiosyncratic factor must be zero, implying $h_{US} = 0.00$. The LR statistic is reported in the U.S. column of the table. The LR statistic is 732.9582 and is much larger than its 99%-critical value of 5.412. We reject the hypothesis that $h_{US} = 0.00$.

We notice that the variance h_{US} is small of 7.71*e*-5. So, this small h_{US} may be economically insignificant and can be simply a statistical artifact resulting from our large sample size. In order to ensure the significance of h_{US}, we compute the share R_{US} of the U.S. total return volatility being explained by the common factor. If the U.S. return is the world factor, the variance h_{US} has to be small and the share R_{US} will be close to 1.00. The table reports the share R_{US} is 0.4781. This share is significantly different from 1.00. The significant LR statistic and the share R_{US} lead us to conclude that the U.S. market is not the world factor.

If the U.S. market is not the world factor, it is interesting to ask further whether any other markets in our sample can be the world factor. To answer this question, we repeat the LR tests and compute the shares R_i for all the remaining countries. The LR tests indicate that the idiosyncratic factors are highly significant. The shares R_i are about 0.50 for Canada, U.K. and Germany and it is 0.24 for Japan. These shares are significantly different from 1.00. These results are also in Table 3. So, no countries in the sample can be the world factor.

IV.2 Sub-samples

Our sample period is quite long, covering January 5, 1987 to December 22, 2000. There may be significant structural changes during this long period. For example, the studies by Bang and Furstenberg (1990) and Chan *et al.* (1992) reported that the interdependence among markets was much stronger after the Black Monday incident in 1987 and the Asian financial crisis in 1997. Moreover, the importance of the U.S. market in terms of market capitalization is decreasing over time due to higher growth rates of other national markets. Hence, the influence of the U.S. market could be more noticeable during the early sample period than during later sample period. These structural changes may bias our results.

Table 4.1: Estimation Results

(First Sub-Sample: January 5, 1987-December 30, 1993)

Parameters Estimates and Test Statistics	Sample Countries				
	U.S.	Canada	U.K.	Germany	Japan
a_{i0}	0.0261 (0.0000)*	0.0162 (0.0000)*	0.0251 (0.0000)*	0.0290 (0.0000)*	0.0249 (0.0000)*
a_{i1}	0.0133 (0.0000)*	0.0139 (0.0000)*	0.0023 (0.0040)**	-0.0017 (1.0000)*	0.0034 (0.0040)**
h_i	6.28E-05 (0.0000)*	3.14E-05 (0.0000)*	7.80E-05 (0.0000)*	0.0002 (0.0000)*	0.0002 (0.0000)*
q			0.1060 (0.0000)*		
Wald test	219.4660 (0.0000)*	249.4887 (0.0000)*	132.3561 (0.0000)*	174.5305 (0.0000)*	113.9550 (0.0000)*
LR test	206.2500 (0.0000)*	455.9380 (0.0000)*	879.4440 (0.0000)*	474.9845 (0.0000)*	1211.0952 (0.0000)*
R	0.5916 (0.0000)*	0.6064 (0.0000)*	0.4632 (0.0000)*	0.3734 (0.0000)*	0.2453 (0.0000)*

Table 4.2: Estimation Results

(Second Sub-Sample: January 5, 1994-December 22, 2000)

Parameters Estimates and Test Statistics	Sample Countries				
	U.S.	Canada	U.K.	Germany	Japan
a_{i0}	0.0301 (0.0000)*	0.0249 (0.0000)*	0.0408 (0.0000)*	0.0570 (0.0000)*	0.0299 (0.0000)*
a_{i1}	0.0112 (0.0000)*	0.0184 (0.0000)*	-0.0028 (0.9836)**	-0.0001 (0.7229)	0.0055 (0.0007)*
h_i	8.69E-05 (0.0000)*	8.73E-05 (0.0000)*	5.29E-05 (0.0000)*	7.07E-05 (0.0000)*	0.0002 (0.0000)*
q			0.0524 (0.0014)*		
Wald test	58.8104 (0.0000)*	65.8794 (0.0000)*	39.4700 (0.0000)*	36.2879 (0.0000)*	43.1877 (0.0000)*
LR test	594.4972 (0.0000)*	850.3381 (0.0000)*	207.2488 (0.0000)*	324.8390 (0.0000)*	1357.0023 (0.0000)*
R	0.3837 (0.0000)*	0.3653 (0.0000)*	0.6236 (0.0000)*	0.7067 (0.0000)*	0.1927 (0.0000)*

* Significance at 99%, ** Significance at 95%, *** Significance at 90%

We check for robustness of the results by dividing the sample period into two sub-periods. The first sub-period covers January 5, 1987 to December 30, 1993 (1,304 observations) and the second sub-period covers January 5, 1994 to December 22, 2000

(1,342 observations). The 1987 Black Monday incident is in the first sub-sample, while the 1997 Asian financial crisis is in the second sub-sample. The parameter estimates and test statistics for the first and second sub-samples are shown in Tables 4.1 and 4.2, respectively. We find that the sub-sample results are similar to the full-sample results. All the sample returns are driven by the common factor. But this common factor is not the U.S. return in either sub-sample. We also cannot find returns on any other sample markets to be the world factor.

V. CONCLUSION

In this study, we examine the mechanism that enables the U.S. market return to explain and predict other national market returns. We propose two competing hypotheses. Under the first hypothesis, the U.S. return is a common or world factor that drives returns in all national markets. Hence, all the national market returns must be explained by the U.S. return by the construction. The predictive ability results from the delayed reaction of markets to the U.S. returns on earlier dates. Under the second hypothesis, the U.S. return and other national market returns are driven by a common factor and by the idiosyncratic factors of their own. The explanatory ability is from the common factor that drives all the returns; the predictive ability is from the delayed reaction of markets to the common factor, which has already acknowledged by the U.S. market on earlier dates.

We apply the state-space model to describe the sample returns and estimate the common factor and idiosyncratic factors by Kalman filtering. Using daily return data on the U.S., Canadian, U.K., German and Japanese markets from January 5, 1987 to December 22, 2000, we find that the common factor exists. But our results clearly show that the U.S. market is not the world factor. Neither can the returns on other markets be that factor. These findings support our second hypothesis. We leave the identification of the common, world factor for future research.

REFERENCES

Bang, N. J. and G. M. Von Furstenberg, 1990, Growing international co-movement in stock price indexes, **Quarterly Review of Economics and Business** 30, 15-30.

Becker, K. G., J. E. Finnerty, and M. Gupta, 1990, The intertemporal relation between the U.S. and Japanese stock markets, **Journal of Finance** 45, 1297-1306.

Chan, K. C., B. E. Cup and M. S. Pan, 1992, An empirical analysis of stock prices in major Asian markets and the United Sates, **Financial Review** 27, 289-307.

Chen, N.R., R. Roll, and S. Ross, 1986, Economic forces and the stock market, **Journal of Business** 59, 383-403.

Enders, W., 1995, **Applied Econometric Time Series**, New York: John Wiley and Sons, Chapter 5.

Eun, C. S. and S. Shim, 1989, International transmission of stock market movements, **Journal of Financial and Quantitative Analysis** 24, 241-56.

Gregory, A. W., A. C. Head, and J Raynauld, 1997, Measuring World Business Cycles, **International Economic Review** 38, 677-701.

Hamao, Y., R. W. Masulis, and V. Ng, 1990, Correlations in price changes and volatility across international stock markets, **Review of Financial Studies** 3, 281-307.

Harvey, A. C., 1989, **Forecasting, structural time, series models and the Kalman filter**, Cambridge University Press, Cambridge.

Harvey, C. R., 1995, Predictable risk and returns in emerging markets, **Review of Financial Studies** 8, 773-816.

Hillard, J. E., 1979, The relationship between equity indices on world exchanges, **Journal of Finance** 26, 103-14.

Jaffe, J. and R. Westerfield, 1985, The weekend effect in common stock returns: the international evidence, **Journal of Finance** 40, 433-54.

Jorion, P., 1990, The exchange rate exposure of U.S. multinationals, **Journal of Business** 63, 331-45.

King, M., E. Setana, and S. Wadhwani, 1994, Volatility and links between national stock markets, **Econometrica** 62, 901-933.

Ripley, D. M., 1973, Systematic elements in the linkage of national stock market indices, **Review of Economics and Statistics** 55, 356-361.

Appendix A: Estimation Results

2-Lag Specification

The national market returns are described by

$$Y_t = A_0\tilde{C}_t + A_1\tilde{C}_{t-1} + A_2\tilde{C}_{t-2} + E_t$$

$$\tilde{C}_t = \tilde{\eta}_t$$

Parameters Estimates and Test Statistics	Sample Countries				
	U.S.	Canada	U.K.	Germany	Japan
a_{i0}	0.0207 (0.0003)*	0.0148 (0.0003)*	0.0240 (0.0003)*	0.0309 (0.0004)*	0.0212 (0.0005)*
a_{i1}	0.0097 (0.0005)*	0.0122 (0.0003)*	0.0006 (0.1231)	0.0001 (0.0012)*	0.0036 (0.0050)*
a_{i2}	-0.0013 (0.8228)	-0.0004 (0.9852)**	-0.0013 (1.0000)*	-0.0010 (0.8902)	-0.0023 (0.9870)**
h_i	7.71E-05 (0.0000)*	5.96E-05 (0.0000)*	6.55E-05 (0.0000)*	0.0001 (0.0000)*	0.0002 (0.0000)*
q	0.1339 (0.0430)***				
Wald test	23.4197 (0.0000)*	28.1713 (0.0000)*	32.6686 (0.0000)*	21.9653 (0.0000)*	22.6049 (0.0000)*
R	0.4770 (0.0000)*	0.4538 (0.0000)*	0.5419 (0.0000)*	0.5320 (0.0000)*	0.2394 (0.0000)*

* Significance at 99%, ** Significance at 95%, *** Significance at 90%

Wald test:

The Wald test is for testing whether each national market responds to the unobserved world factor. The null hypothesis is

H_0: $a_{i0} = a_{i1} = a_{i2} = 0$

R:

R_i denotes the share of the variance of return of market *i* accounted for by the response to the common factor. $R_i = \frac{\left(a_{i0}^2 + a_{i1}^2 + a_{i2}^2\right)q}{\sigma_{yi}^2}$

Appendix B: Estimation Results

3-Lag Specification

The national market returns are described by

$$Y_t = A_0\tilde{C}_t + A_1\tilde{C}_{t-1} + A_2\tilde{C}_{t-2} + A_3\tilde{C}_{t-3} + E_t$$

$$\tilde{C}_t = \tilde{\eta}_t$$

Parameters Estimates and Test Statistics	Sample Countries				
	U.S.	Canada	U.K.	Germany	Japan
a_{i0}	0.0076 (0.0000)*	0.0054 (0.0000)*	0.0088 (0.0000)*	0.0113 (0.0000)*	0.0077 (0.0000)*
a_{i1}	0.0036 (0.0000)*	0.0045 (0.0000)*	0.0002 (0.0018)*	0.0000 (0.0517)	0.0013 (0.0006)*
a_{i2}	-0.0005 (0.9793)**	-0.0001 (0.9817)**	-0.0005 (0.9802)**	-0.0004 (0.9971)*	-0.0009 (0.9800)**
a_{i3}	-0.0002 (0.9997)*	0.0001 (0.0539)	-0.0001 (0.9996)*	0.0007 (0.0477)***	0.0002 (0.1363)
h_i	7.71E-05 (0.0000)*	5.98E-05 (0.0000)*	6.52E-05 (0.0000)*	0.0001 (0.0000)*	0.0002 (0.0000)*
q	0.9995 (0.0000)*				
Wald test	805.52761 (0.0000)*	846.7541 (0.0000)*	924.3783 (0.0000)*	907.1245 (0.0000)*	409.4230 (0.0000)*
R	0.4761 (0.0000)*	0.4523 (0.0000)*	0.5439 (0.0000)*	0.5337 (0.0000)*	0.2388 (0.0000)*

* Significance at 99%, ** Significance at 95%, *** Significance at 90%

Wald test:

The Wald test is for testing whether each national market responds to the unobserved world factor. The null hypothesis is

H_0: $a_{i0} = a_{i1} = a_{i2} = a_{i3} = 0$

R:

R_i denotes the share of the variance of return of market *i* accounted for by the response to the common factor. $R_i = \frac{\left(a_{i0}^2 + a_{i1}^2 + a_{i2}^2 + a_{i3}^2\right)q}{\sigma_{yi}^2}$

Factors influencing health-related quality of life in chronic liver disease

Abhasnee Sobhonslidsuk*

Chatchawan Silpakit**

Ronnachai Kongsakon**

Patchareeya Satitpornkul*

Chaleaw Sripetch*

And

Anya Khanthavit***

KEYWORDS: Quality of life, chronic hepatitis, cirrhosis, chronic liver diseases.

Date: August 2006

---

*Department of Medicine, Ramathibodi Hospital, Mahidol University and **Department of Psychiatry, Ramathibodi Hospital, Mahidol University, *** Faculty of Commerce and Accountancy, Thammasat University. Correspondent author: Abhasnee Sobhonslidsuk, M.D., Department of Medicine, Ramathibodi Hospital, 270 Rama VI Road, Bangkok 10400, Thailand, Phone: +66 (02) 201 1387; Fax: +66 (02) 965 1769, This reerach is financially supported by Thailand Research Fund.

ABSTRACT

The Quality of Life in Thai Patients with Chronic Liver Diseases

Health-related quality of life (HRQOL) is a concept that incorporates many aspects of life beyond “health”. HRQOL is important for measuring the impact of chronic disease on patients. The research for QOL in chronic liver disease (CLD) has hardly been received attention in Southeast Asian countries. We compare the QOL in Thai patients having CLD with that in normal people and to investigate for factors relating to the QOL. We find that the CLDQ, a western originated questionnaire, is valid and applicable in Thai patients with CLD. Generic and liver disease-specific health measurement reveals that QOL in these patients is lower than that in normal people. QOL is more impaired in advanced stage of CLD. Other factors, such as age, sex, education level, career, financial problem and etiology of liver disease may individually influence HRQOL in Thais with CLD.

บทคัดย่อ

การสำรวจคุณภาพชีวิตของคนไทยซึ่งป่วยเป็นโรคตับชนิดเรื้อรัง

การศึกษาใช้แบบสำรวจเพื่อวัดระดับคุณภาพชีวิตของคนไทยซึ่งป่วยเป็นโรคตับชนิดเรื้อรัง และตรวจสอบปัจจัยที่มีผลกระทบต่อระดับคุณภาพชีวิต ทั้งปัจจัยที่เกี่ยวกับความรุนแรงของโรค ปัจจัยด้านสภาพบุคคล ปัจจัยด้านเศรษฐกิจและสังคม และปัจจัยด้านทัศนคติของผู้ป่วยต่อโรค การศึกษาพบว่าปัจจัยเหล่านี้มีผลกระทบต่อคุณภาพชีวิตอย่างมีนัยสำคัญและยังพบต่อไปว่าทัศนคติของผู้ป่วยต่อโรคมีผลกระทบต่อตัวชี้ค่าคุณภาพชีวิตทุกตัว การศึกษาสรุปว่าการปรับเปลี่ยนทัศนคติของผู้ป่วย เช่น การจัดกลุ่มแลกเปลี่ยนประสบการณ์ของผู้ป่วยและการให้กำลังใจไปพร้อมกับการรักษาทางกายภาพจะทำให้คุณภาพชีวิตของผู้ป่วยดีขึ้นมาก

PO Box 2345, Beijing 100023, China
www.wjgnet.com
wjg@wjgnet.com

World J Gastroenterol 2006 December 28; 12(48): 7786-7791
World Journal of Gastroenterology ISSN 1007-9327

CLINICAL RESEARCH

Factors influencing health-related quality of life in chronic liver disease

Abhasnee Sobhonslidsuk, Chatchawan Silpakit, Ronnachai Kongsakon, Patchareeya Satitpornkul, Chaleaw Sripetch, Anya Khanthavit

Abhasnee Sobhonslidsuk, Patchareeya Satitpornkul, Chaleaw Sripetch, Department of Medicine, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand
Chatchawan Silpakit, Ronnachai Kongsakon, Department of Psychiatry, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand
Anya Khanthavit, Faculty of Commerce and Accountancy, Thammasat University, Bangkok, Thailand
Supported by Thailand Research Fund
Correspondence to: Abhasnee Sobhonslidsuk, MD, Department of Medicine, Ramathibodi Hospital, 270 Praram 6 road, Rajathevee, Bangkok 10400, Thailand. teasb@mahidol.ac.th
Telephone: +66-2-2011304 Fax: +66-2-2011387
Received: 2006-10-21 Accepted: 2006-11-23

Abstract

AIM: To investigate the factors contributing to health-related quality of life (HRQL) in chronic liver disease (CLD).

METHODS: Patients with CLD and age- and sex-matched normal subjects performed the validated Thai versions of the short-form 36 (SF-36) by health survey and chronic liver disease questionnaire (CLDQ). Stepwise multiple regression analysis was used to assess the impact of disease severity, demography, causes of CLD, socioeconomic factors, and self-rating health perception on HRQL.

RESULTS: Two-hundred and fifty patients with CLD and fifty normal subjects were enrolled into the study. Mean age and the numbers of low educated, unemployed, blue-collar career and poor health perception increased significantly from chronic hepatitis to Child's Classes A to B to C. Advanced stage of CLD was related to deterioration of HRQL. Increasing age and female reduced physical health area. Low socioeconomic factors and financial burden affected multiple areas of HRQL. In overall, the positive impact of self-rating health perception on HRQL was consistently showed.

CONCLUSION: Advanced stages of chronic liver disease, old age, female sex, low socioeconomic status and financial burden are important factors reducing HRQL. Good health perception improves HRQL regardless of stages of liver disease.

Key words: Health-related quality of life; Cirrhosis; Chronic hepatitis; Short-form 36; Chronic liver disease questionnaire

Sobhonslidsuk A, Silpakit C, Kongsakon R, Satitpornkul P, Sripetch C, Khanthavit A. Factors influencing health-related quality of life in chronic liver disease. *World J Gastroenterol* 2006; 12(48): 7786-7791

http://www.wjgnet.com/1007-9327/12/7786.asp

INTRODUCTION

In 1947, the World Health Organization expanded the definition of health to include in addition to the absence of disease, a complete state of physical, mental and social well-being[1]. Health-related quality of life (HRQL) emerges as a tool for measuring outcome from the patient's viewpoint, incorporating social, psychological, physiological and physical functioning[1,2]. Combined using generic and disease-specific instruments can provide more accurate assessment of both the global aspects and the specific features of HRQL of a specific condition[1]. The assessment of HRQL has been done in gastrointestinal diseases and chronic liver disease (CLD)[3-7]. It has been reported that the presence of CLD reduce HRQL and the deterioration of HRQL is apparent while the severity of disease increases[8-13]. Furthermore, demographic factors such as age and gender, alcohol, co-morbid illness, disease awareness and psychological status can affect HRQL in CLD[8-15]. However, a recent study showed that active psychiatric illness and medical co-morbidities, but not severity of liver disease, were determinants of HRQL reduction[16]. Previous researches of HRQL in normal and chronic medical conditions showed that socioeconomic and demographic factors can influence HRQL[17-20]. The contribution of socioeconomic factors and health perception to HRQL was not known in CLD. Self-rating patient health perception is one of the strongest predictors of mortality[21]. HRQL in CLD may be improved by changing patient health perception if there is a relationship between health perception and HRQL. The impact of marital status on HRQL is our interest because its significance had never been studied in CLD[8-13]. Our assumption was that married couple would have more psychosocial and emotional support than single, unmarried or divorced people. An earlier study revealed that HRQL in Thai patients with CLD was lower than that of normal subjects similar to the reports from Western countries[22]. We aimed to investigate variables that truly affected HRQL, such as disease severity, etiology of liver disease, demographic and socioeconomic factors, and patient health perception in Thai patients with CLD.

MATERIALS AND METHODS

Study design and population

A cross-sectional study was carried out at the Gastroenterological Clinic between 1st January 2004 and 30th June 2004. Eligible patients with CLD, age 15-80 years, both men and women, were enrolled consecutively into the study. Exclusion criteria were the concomitant presence of hepatic encephalopathy, active medical co-morbidity, malignancy, current or previous treatment of antiviral agents and those who refused to participate with the study. CLD were classified into chronic hepatitis and cirrhosis. Chronic hepatitis was defined by the elevation of serum transaminase higher than 1.5 times of upper normal limit for 6 mo. The diagnosis of cirrhosis was confirmed from clinical finding, biochemical test, ultrasound or liver histology[23]. The staging of cirrhosis was graded according to Child-Pugh classification: Child's classes A, B and C[24]. Causes of CLD were divided into viral hepatitis, alcohol, viral hepatitis combining with alcohol, non-alcoholic fatty liver disease and miscellaneous causes. Alcohol was the etiology of CLD if daily alcohol drinking was greater than 40 g for at least 10 years. The cause of CLD was viral hepatitis B if hepatitis B surface antigen (Abbott Laboratories, North Chicago, IL) was positive, or viral hepatitis C if antibody to hepatitis C virus (anti-HCV) (Abbott Laboratories, North Chicago, IL) was positive. Data were collected from patient inquiry and medical records. Normal subjects who did not have medical illness were invited into the study. The study protocol was approved by the Hospital Ethical Committee and it was carried out according to the Helsinki Declaration Guidelines[25]. Written informed consent was obtained prior to the study.

Data collection

HRQL instruments (dependent variables): The study patients were asked to self-administer the short-form 36 (SF-36) heath survey and chronic liver disease questionnaire (CLDQ), and the answered questionnaires were checked for completeness by a research assistant who also helped interviewing illiterate patients for the questionnaires. The SF-36 consists of 36 items which are categorized into 8 domains of physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional and mental health ranging from 0 to 100 with higher scores reflecting better perception of health. Physical functioning, role-physical, bodily pain and general health represent physical health scale, whereas vitality, social functioning, role-emotional and mental health define mental health scale. The domain scores were calculated according to the standard reference[26].

There are 29 items in the CLDQ summarized into 6 domains of abdominal symptoms, fatigue, systemic symptoms, activity, emotional function and worry. Each item consists of 7 linkert scales. Domain score is calculated from the average score of all items of that domain[7]. Both questionnaires were formally translated from the original versions and the validation of the questionnaires was reported elsewhere[22,27].

Definition of study variables (independent variables): Clinical, demographic and socioeconomic data were collected from each subject. Marital status was dichotomized into single and paired. Single was extended to include unmarried person, divorced or deceased couple. Socioeconomic status was assessed by using the level of education: lower than bachelor's degree and equal to or higher than bachelor's degree; presence and types of career: unemployed, blue-collar and white-collar; presence or absence of financial burden. Subjects were asked to rate their health as "very good", "good", "fair", "poor" or "very poor". Good health perception included "very good", "good" and "fair". Poor health perception consisted of "poor" and "very poor".

Statistical analysis

Data were entered into Excel spreadsheet (Microsoft Corporation) and analyzed using SPSS (version 11.5; SPSS, Inc., Chicago, IL) Categorical data are described as number and percentage [*n* (%)]. Continuous data were presented as mean ± SD and median (range). Statistical analysis of continuous data was performed with One-way Anova or non-parametric methods as appropriate. χ^2 test was used for analysis of discrete data, which give us the preliminary understanding of the association of the HRQL and studied variables. Stepwise multiple regression analysis was used to study the influence of independent variables on the CLDQ and SF-36 domains while controlling the effect of other variables. *P* value less than 0.05 was considered statistically significant

RESULTS

Characteristics of the study population

A total of 364 patients with CLD attended the Gastroenterology Clinic during the 6-mo period. Of these, 114 patients were ineligible for the study: 80 patients were either currently receiving or had received antiviral therapy; 17 patients had hepatocellular carcinoma; 13 patients had active co-morbid illness; two patients were having hepatic encephalopathy and two patients refused to participate in the study. Two-hundred and fifty subjects with CLD, and 50 normal subjects were enrolled into the study. Mean age (range) of the whole group was 48.1 (18-77) years. The number (%) of male to female ratio was 188:112 (62.7%:37.3%). The details of clinical, demographic and socioeconomic data are shown in Table 1. The majority of patients in both groups was male and had education lower than bachelor's degree. Although both groups reported financial problems in equal proportion, the socioeconomic status of CLD group was inferior to that of normal group, which was shown from the higher number of unemployed subjects and blue-collar typed career in the former group ($P < 0.01$). It is not surprising that poor health perception

Table 1 Baseline data of chronic liver disease and normal groups

Variable	Chronic liver disease	Normal group	*P*
n	250	50	
Age (Mean ± SD, yr)	49.1 ± 8.5	47.9 ± 12.0	0.65
Sex			
Male	160 (64.0%)	28 (56.0%)	0.33
Marital status[1]			
Single	71/238 (29.8%)	9/49 (18.4%)	0.07
Educational level[1]			
< Bachelor degree	165/237 (69.6%)	30/50 (60.0%)	0.12
Career[1]			
Unemployed	61/231 (26.4%)	3/46 (6.5%)	< 0.01
Blue-collar	37/231 (16.0%)	1/46 (2.2%)	
White-collar	133/231 (57.6%)	42/46 (91.3%)	
Financial burden[1]			
Present	87/238 (36.6%)	22/50 (44.0%)	0.20
Self-rating health perception[1]			
Poor health perception	61/238 (25.6%)	4/50 (8.0%)	< 0.01
Disease severity			
Chronic hepatitis	135/250 (54.0%)		
Child's class A cirrhosis	59/250 (23.6%)		
Child's class B cirrhosis	40/250 (16.0%)		
Child's class C cirrhosis	16/250 (6.4%)		
Causes of chronic liver disease			
Viral hepatitis B	99 (39.6%)		
Viral hepatitis C	48 (19.2%)		
Alcohol	43 (17.2%)		
Non-alcoholic fatty liver disease	27 (10.8%)		
Others	33 (13.2%)		

[1]Incomplete data.

Table 2 Variables by severity of the liver diseases

Variable	Normal	Chronic hepatitis	Child's class A	Child's class B	Child's class C	*P*
n	50	135	59	40	16	
Age (Mean ± SD, yr)	49.1 ± 8.5	43.5 ±12.2	51.7 ± 9.1	54.1 ± 10.2	54.6 + 8.0	< 0.01
Male	28 (56%)	88 (65.2%)	39 (66.1%)	22 (55%)	10 (62.5%)	0.73
Single[1]	9/49 (18.4%)	55/133 (41.4%)	7/53 (13.2%)	7/37 (18.9%)	3/15 (20.0%)	< 0.01
Low education[1]	30/50 (60%)	79/133 (59.4%)	39/53 (73.6%)	33/36 (91.7%)	14/15 (93.3%)	< 0.01
Unemployment[1]	2/50 (4.0%)	16/133 (12.0%)	11/53 (20.8%)	14/37 (37.8%)	3/15 (20.0%)	< 0.01
Blue-collar career[1]	1/46 (2.2%)	16/129 (12.4%)	8/51 (15.7%)	6/37 (16.2%)	7/15 (46.7%)	< 0.01
Financial burden[1]	22/50 (44.0%)	46/133 (34.6%)	22/53 (41.5%)	14/37 (37.8%)	5/15 (33.3%)	0.77
Good health perception[1]	46/50 (92.0%)	106/133 (79.7%)	38/53 (71.7%)	24/37 (64.9%)	9/15 (60.0%)	< 0.01

[1]Incomplete data.

was more frequent in the CLD than the normal group. In this study, there were only 16 (6.4%) patients with Child's class C cirrhosis, and viral hepatitis was the most common cause of CLD (58.8%), followed by chronic alcoholic (17.2%) and non-alcoholic fatty liver disease (10.8%).

Association of variables and disease severity

Similar to previous reports of any chronic liver diseases, male predominated in this study. The greatest number of single was found in chronic hepatitis group (P < 0.01). Mean age of this group was the lowest and age increased in advanced stages of CLD (P < 0.01). Low socioeconomic status, which was represented by lower education, unemployment and blue-collar typed career, increased in advanced stages of CLD. The reason of this finding is not known. Low socioeconomic status may keep the patients from appropriate treatment; hence the deterioration of liver disease is likely to happen. The proportion of good health perception decreased while the severity of CLD went up (Table 2).

The effect of disease severity on HRQL by univariate analysis

By univariate analysis, higher stages of CLD decreased HRQL in some domains of the SF-36, such as physical function, role-physical, general health and role-emotion (P < 0.001), and in all area of the CLDQ (P < 0.03). However, we could not make a conclusion that advanced

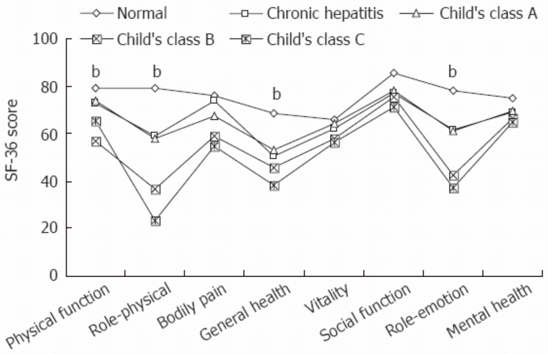

Figure 1 The domain scores of short-form 36 (SF-36) by disease severity. [b]P < 0.001 *vs* normal group.

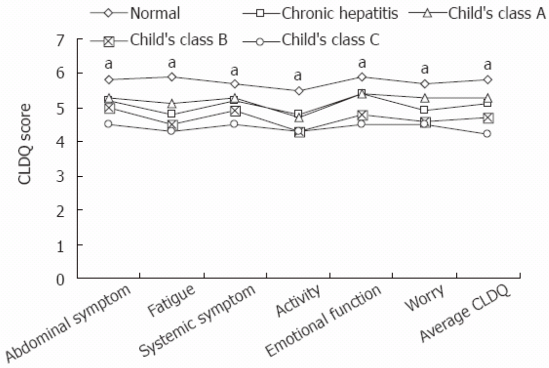

Figure 2 The domain scores of chronic liver disease questionnaire (CLDQ) by disease severity. [a]P < 0.03 *vs* normal group.

Table 3 Variables affecting SF-36 domains[1]

Variable	Physical function	Role-physical	Bodily pain	General health	Vitality	Social function	Role-emotion	Mental health
Good health perception	13.7 (2.6)	36.4 (5.4)	21.6 (5.3)	26.2 (2.9)	17.2 (2.1)	15.8 (2.8)	23.1 (5.9)	18.0 (2.2)
Advanced stage	-3.1 (1.0)	-7.5 (2.2)		-4.0 (1.1)			-6.1 (2.4)	
Age (yr)	-0.4 (0.1)	-0.6 (0.2)	-0.8 (0.2)					
Female	-6.3 (2.2)							
Financial burden	-6.9 (2.2)	-15.8 (4.6)			-4.4 (1.8)		-17.0 (5.0)	-6.9 (1.9)
Low education					-4.7 (1.8)			
High level career							7.7 (3.0)	
F-statistic	18.5	26.2	18	55.6	32.2	31.7	13.3	42.8
R^2	0.26	0.28	0.12	0.29	0.26	0.1	0.17	0.24

[1]Only data with $P < 0.05$ are expressed as β-coefficient (SEM).

Table 4 Variables affecting CLDQ domains[1]

Variable	Abdominal symptoms	Fatigue	Systemic symptoms	Activity	Emotional function	Worry	Average CLDQ
Good health perception	1.1 (0.2)	0.9 (0.2)	0.9 (0.2)	0.7 (0.2)	0.9 (0.2)	1.0 (0.2)	1.0 (0.2)
Advanced stage	-0.2 (0.1)	-0.3 (0.1)	-0.2 (0.1)	-0.2 (0.1)	-0.3 (0.1)	-0.2 (0.1)	-0.3 (0.1)
Financial burden		-0.4 (0.1)		-0.3 (0.1)		-0.3 (0.2)	
F-statistic	29	22.2	24.5	19.2	36.3	16.1	25.2
R^2	0.18	0.2	0.15	0.18	0.21	0.15	0.22

[1]Only data with $P < 0.05$ are expressed as β-coefficient (SEM).

stages of CLD reduced the HRQL due to the presence of several confounding factors in advanced stages of CLD, such as old age, low socioeconomic status and poor health perception (Figures 1 and 2).

Influence of disease stage and variables on HRQL while controlling other variables

Multiple regression analysis of the association of HRQL domains and multiple variables such as stages of CLD, self-rating health perception, age, sex, financial burden, type of career, education level and viral hepatitis infection as a cause of CLD was performed. The advanced stages of CLD reduced all of the CLDQ domains, the majority of physical health scales of the SF-36 (physical functioning, role-physical and general health) and role-emotional domains. A one-year increase in age was associated with the reduction of 3 domains of physical heath scales of the SF-36 (physical functioning, role-physical and bodily pain), similar to the negative effect of female on physical functioning. While the presence of financial burden decreased multiple domains of the SF-36 and CLDQ, lower levels of education and career reduced predominantly the domains of mental health scales (vitality and role-emotion, respectively). Good health perception increased the SF-36 and CLDQ scores across the board. Viral hepatitis infection was not shown to affect any domains of HRQL (Tables 3 and 4).

DISCUSSION

Patients with CLD usually have HRQL lower than normal population, and the deterioration of HRQL appears while the severity of CLD increases[8-13]. This study focus not only on liver disease factors but also on other variables, such as age, sex, family support, socioeconomic status (education level, employment and career type), financial burden and self-rating health perception. Multiple regression analysis was performed to confirm the effect of variables on HRQL while controlling the influence of other variables. Advanced stages of CLD reduced all domains of the CLDQ, and the physical function, role-physical, general health and role-emotion domains of the SF-36. The effect of viral hepatitis infection as causes of CLD on HRQL reported from several studies is still inconclusive[15,28]. Recent systematic review revealed that the patients with HCV infection scored lower than the controls across all domains of the SF-36[27]. In our study, we could not find the impact of viral hepatitis infection, especially viral hepatitis C, on HRQL. However, the total cases of HCV infection in the study were quite low. There were only 48 (19.2%) patients with HCV infection distributing in three stages of cirrhosis and chronic hepatitis. In general, the elderly is associated with less favorable appraisal of personal health due to their health concerns, pessimistic health appraisals, social isolation and unemployment[29]. A previous study in CLD revealed that old age had a negative impact on HRQL[11]. Nevertheless, another study reported that cirrhotic patients with younger age had a more impairment in HRQL than the elder[9]. While important factors were controlled, a one-year increase in age reduced the scores of physical function, role-physical, and bodily pain from 0.4 to 0.8. In general, females have more health concerns and are more treatment-seeker than male. One study in CLD reported the minor effect of gender on HRQL in CLD[11]. We found that female gender yielded negative influence on physical functioning. Surprisingly, the marital status did not affect HRQL. This finding may be explained by the close-knit type of Thai society, so CLD patients could get psychosocial support from other family members even when they are single or divorced. Low socioeconomic status was shown to be important factor affecting HRQL in normal population and in patients with medical illnesses, such as prostate cancer, end-stage renal diseases and lung cancer[18-20,30]. Education level and career type were used as markers of socioeconomic status in this study because there is no standard categorization of socioeconomic status in Thailand. In general, education can help people cope their own problems. Low educated people are prone to have psychological problems and have false beliefs. People with lower socioeconomic status have more stress, more depression and interfamilial relationship problems in their life. As far as we know, there is only one study in chronic hepatitis C that reported the effect of education on HRQL[15]. We found that lower education level and type of career reduced vitality and role-emotion. The presence of financial burden can lower HRQL in several areas of the SF-36 and CLDQ. The impact of low socioeconomic status on HRQL supports the proposed conceptual model of HRQL by Wilson IB and Cleary PD in 1995, which states that socioeconomic factors influence multiple domains of functional status[21]. The most important contribution showed from our study is that self-rating patient health perception can affect HRQL in CLD. In the conceptual model, health perception is included in the model together with other factors, such as biological and physiological variables, symptom status, functional status, characteristics of individual and environment[21]. We found that the proportion of good health perception declined while the severity of CLD increased. Good health perception was the only factor shown to be positively associated with the SF-36 and CLDQ domains unanimously. This finding supports the HRQL model that health perception is related to functional status, symptom status, biological and physiological variables. It is possible that HRQL in CLD can be improved by searching strategy to increase patient's health perception. There is some evidence showing that psychological and emotional support can improve patient health perception[31].

In this study, we showed that the important factors that reduced HRQL in CLD included not only advanced stages of CLD but also old age, female sex, low socioeconomic status, financial burden, as well as poor health perception in accordance with the conceptual model of HRQL. We conclude that while medical treatment is a key to improve patient condition and HRQL, additional treatment with psychosocial support to raise patient health perception may improve HRQL, perhaps even better.

REFERENCES

1 **Martin LM**, Sheridan MJ, Younossi ZM. The impact of liver disease on health-related quality of life: a review of the literature. *Curr Gastroenterol Rep* 2002; **4**: 79-83

2 **Sousa KH**. Description of a health-related quality of life conceptual model. *Outcomes Manag Nurs Pract* 1999; **3**: 78-82

3 **Talley NJ**, Weaver AL, Zinsmeister AR. Impact of functional dyspepsia on quality of life. *Dig Dis Sci* 1995; **40**: 584-589

4 **Irvine EJ**, Feagan B, Rochon J, Archambault A, Fedorak RN, Groll A, Kinnear D, Saibil F, McDonald JW. Quality of life: a valid and reliable measure of therapeutic efficacy in the treatment of inflammatory bowel disease. Canadian Crohn's Relapse Prevention Trial Study Group. *Gastroenterology* 1994; **106**: 287-296

5 **Younossi ZM**, Guyatt G. Quality-of-life assessments and chronic liver disease. *Am J Gastroenterol* 1998; **93**: 1037-1041

6 **Borgaonkar MR**, Irvine EJ. Quality of life measurement in gastrointestinal and liver disorders. *Gut* 2000; **47**: 444-454

7 **Younossi ZM**, Guyatt G, Kiwi M, Boparai N, King D. Development of a disease specific questionnaire to measure health related quality of life in patients with chronic liver disease. *Gut* 1999; **45**: 295-300

8 **Younossi ZM**, Boparai N, McCormick M, Price LL, Guyatt G. Assessment of utilities and health-related quality of life in patients with chronic liver disease. *Am J Gastroenterol* 2001; **96**: 579-583

9 **Marchesini G**, Bianchi G, Amodio P, Salerno F, Merli M, Panella C, Loguercio C, Apolone G, Niero M, Abbiati R. Factors associated with poor health-related quality of life of patients with cirrhosis. *Gastroenterology* 2001; **120**: 170-178

10 **Chong CA**, Gulamhussein A, Heathcote EJ, Lilly L, Sherman M, Naglie G, Krahn M. Health-state utilities and quality of life in hepatitis C patients. *Am J Gastroenterol* 2003; **98**: 630-638

11 **Younossi ZM**, Boparai N, Price LL, Kiwi ML, McCormick M, Guyatt G. Health-related quality of life in chronic liver disease:

the impact of type and severity of disease. *Am J Gastroenterol* 2001; **96**: 2199-2205
12 **Arguedas MR**, DeLawrence TG, McGuire BM. Influence of hepatic encephalopathy on health-related quality of life in patients with cirrhosis. *Dig Dis Sci* 2003; **48**: 1622-1626
13 **Cordoba J**, Flavia M, Jacas C, Sauleda S, Esteban JI, Vargas V, Esteban R, Guardia J. Quality of life and cognitive function in hepatitis C at different stages of liver disease. *J Hepatol* 2003; **39**: 231-238
14 **Hussain KB**, Fontana RJ, Moyer CA, Su GL, Sneed-Pee N, Lok AS. Comorbid illness is an important determinant of health-related quality of life in patients with chronic hepatitis C. *Am J Gastroenterol* 2001; **96**: 2737-2744
15 **Schwarzinger M**, Dewedar S, Rekacewicz C, Abd Elaziz KM, Fontanet A, Carrat F, Mohamed MK. Chronic hepatitis C virus infection: does it really impact health-related quality of life? A study in rural Egypt. *Hepatology* 2004; **40**: 1434-1441
16 **Hauser W**, Holtmann G, Grandt D. Determinants of health-related quality of life in patients with chronic liver diseases. *Clin Gastroenterol Hepatol* 2004; **2**: 157-163
17 **Djibuti M**, Shakarishvili R. Influence of clinical, demographic, and socioeconomic variables on quality of life in patients with epilepsy: findings from Georgian study. *J Neurol Neurosurg Psychiatry* 2003; **74**: 570-573
18 **Thumboo J**, Fong KY, Machin D, Chan SP, Soh CH, Leong KH, Feng PH, Thio S, Boey ML. Quality of life in an urban Asian population: the impact of ethnicity and socio-economic status. *Soc Sci Med* 2003; **56**: 1761-1772
19 **Penson DF**, Stoddard ML, Pasta DJ, Lubeck DP, Flanders SC, Litwin MS. The association between socioeconomic status, health insurance coverage, and quality of life in men with prostate cancer. *J Clin Epidemiol* 2001; **54**: 350-358
20 **Sesso R**, Rodrigues-Neto JF, Ferraz MB. Impact of socioeconomic status on the quality of life of ESRD patients. *Am J Kidney Dis* 2003; **41**: 186-195
21 **Wilson IB**, Cleary PD. Linking clinical variables with health-related quality of life. A conceptual model of patient outcomes. *JAMA* 1995; **273**: 59-65
22 **Sobhonslidsuk A**, Silpakit C, Kongsakon R, Satitpornkul P, Sripetch C. Chronic liver disease questionnaire: translation and validation in Thais. *World J Gastroenterol* 2004; **10**: 1954-1957
23 **Leevy CM**, Sherlock S, Tygstrup N, Zetterman R. Cirrhosis. In: Disease of the liver and biliary tract. Standardization of nomenclature, diagnostic criteria and prognosis. New York, Raven Press, 1994: 61-68
24 **Sherlock S**, Dooley J. Disease of the liver and biliary system. 10th ed. Oxford: Blackwell Science, 1997: 135-180
25 **World Medical Association.** Declaration of Helsinki: ethical principals for research involving human subjects. As amended in Tokyo, 2004. Ferney-Voltaire, French: The Association: 2004. Available from: www.wma.net/e/ethicsunit/helsinki.htm
26 **Ware JE**, Snow KK, Kosinski MK, Gadnek B. Scoring the SF-36. In: SF-36 Health Survey: Manual and interpretation Guide. Boston, MA: Nimrod Press, 1992
27 **Kongsakon R**, Silpakit C. Thai version of the medical outcome study in 36 items short form health survey: an instrument for measuring clinical results in mental disorder patients. *Rama Med J* 2000; **23**: 8-19
28 **Spiegel BM**, Younossi ZM, Hays RD, Revicki D, Robbins S, Kanwal F. Impact of hepatitis C on health related quality of life: a systematic review and quantitative assessment. *Hepatology* 2005; **41**: 790-800
29 **Garrity TF**, Somes GW, Marx MB. Factors influencing self-assessment of health. *Soc Sci Med* 1978; **12**: 77-81
30 **Montazeri A**, Hole DJ, Milroy R, McEwen J, Gillis CR. Quality of life in lung cancer patients: does socioeconomic status matter? *Health Qual Life Outcomes* 2003; **1**: 19
31 **Cheng C**, Hui WM, Lam SK. Psychosocial factors and perceived severity of functional dyspeptic symptoms: a psychosocial interactionist model. *Psychosom Med* 2004; **66**: 85-91

COMMENTS

Background

Health-related quality of life (HRQL) in chronic liver disease patients is lower than normal population. Factors relating to the reduction of HRQL are inconsistently reported. The study of factors affecting HRQL in chronic liver disease in Asians has never been carried out.

Research frontiers

The data of several variables, e.g. disease severity, etiologic factor, demographic and socioeconomic, and patient self-rating health perception were collected. Then, multiple regression analysis was used to identify the factors that independently affect HRQL in chronic liver disease.

Innovations and breakthroughs

The study demonstrated that advanced stages of chronic liver disease, old age and female sex reduced HRQL in Thai patients. Furthermore, socioeconomic factors which hardly receive attention in previous studies of HRQL in chronic liver disease can affect HRQL. Importantly, this is the first time that patient health perception is shown to be strongly associated with HRQL in chronic liver disease.

Applications

While the medical treatment is a key to improve patient condition and HRQL, complementary treatment with psychosocial support aimed to raise patient health perception may improve HRQL. This conclusion needs further study to confirm.

Terminology

HRQL is a concept which reflects the physical, social, and emotional attitudes and behaviors of an individual as they relate to their prior and current health state. HRQL assessment describes health status from patients' perspective and serves as a powerful tool to assess and explain disease outcomes.

Peer review

This study concerns over the understanding of readers for the demonstration of results from multiple regression analysis. The key point of the analysis is to show if the presence of individual relating factor affects HRQL in chronic liver disease. Overall the paper requires grammatical work.

S- Editor Wang GP **L- Editor** Kumar M **E- Editor** Ma WH

Empirical Evidence on Equity Valuation of Thai Firms[*]

Somchai Supattarakul

and

Anya Khanthavit

[*] Somchai Supattarakul is with the Department of Accounting, Thammasat Business School, Thammasat University, Bangkok 10200, THAILAND. (e-mail: ssomchai@tu.ac.th). Somchai Supattarakul is grateful to Professor Sangvian Indaravijaya Foundation and the Thailand Research Fund (TRF) for financial supports. Anya Khanthavit is with the Department of Finance, Thammasat Business School, Thammasat University, Bangkok 10200, THAILAND. (e-mail: akhantha@gmail.com).

ABSTRACT

Empirical Evidence on Equity Valuation of Thai Firms

This study aims at providing empirical evidence on a comparison of two equity valuation models: (1) the dividend discount model (DDM) and (2) the residual income model (RIM), in estimating equity values of Thai firms during 1995-2004. Results suggest that DDM and RIM underestimate equity values of Thai firms and that RIM outperforms DDM in predicting cross-sectional stock prices. Results on regression of cross-sectional stock prices on the decomposed DDM and RIM equity values indicate that book value of equity provides the greatest incremental explanatory power, relative to other components in DDM and RIM terminal values, suggesting that book value distortions resulting from accounting procedures and choices are less severe than forecast and measurement errors in discount rates and growth rates.

We also document that the incremental explanatory power of book value of equity during 1998-2004, representing the information environment under Thai Accounting Standards reformed after the 1997 economic crisis to conform to International Accounting Standards, is significantly greater than that during 1995-1996, representing the information environment under the pre-reformed Thai Accounting Standards. This implies that the book value distortions are less severe under the 1997 Reformed Thai Accounting Standards than the pre-reformed Thai Accounting Standards.

บทคัดย่อ

หลักฐานเชิงประจักษ์ด้านการกำหนดมูลค่าของบริษัทจดทะเบียน ในตลาดหลักทรัพย์แห่งประเทศไทย

การศึกษาเปรียบเทียบตัวแบบจำลองเพื่อกำหนดมูลค่าของบริษัทจำนวน 2 ตัวแบบ คือ (1) ตัวแบบ Dividend Discount Model (DDM) และ (2) ตัวแบบ Residual Income Model (RIM) โดยใช้ตัวอย่างจากบริษัทจดทะเบียนในตลาดหลักทรัพย์แห่งประเทศไทยช่วงปี 2538 ถึงปี 2547 การศึกษาพบว่า ทั้งตัวแบบ DDM และ RIM ให้มูลค่าที่ต่ำกว่าระดับที่ควรจะเป็นจริง แต่เมื่อเปรียบเทียบตัวแบบทั้งสองระหว่างกันแล้ว การศึกษาพบว่า ตัวแบบ RIM ให้ค่าที่กำหนดได้ที่คลาดเคลื่อนน้อยกว่าที่ตัวแบบ DDM ให้ การศึกษาโดยใช้สมการถดถอยสำหรับบริษัทที่ใช้เป็นตัวอย่าง พบว่า ตัวแปรราคาตามบัญชีของส่วนของทุนสามารถอธิบายมูลค่าที่พบโดยตัวแบบ DDM และ RIM ได้ดี ผลการศึกษานี้ชี้โดยนัยว่าความคลาดเคลื่อนของมูลค่าที่รายงานผ่านมูลค่าทางบัญชีมีระดับที่ไม่มากนักและต่ำกว่าที่หลายฝ่ายเข้าใจไปเองแต่แรก

Empirical Evidence on Equity Valuation of Thai Firms

Somchai Supattarakul and Anya Khanthavit

***Abstract*—**This study aims at providing empirical evidence on a comparison of two equity valuation models: (1) the dividend discount model (DDM) and (2) the residual income model (RIM), in estimating equity values of Thai firms during 1995-2004. Results suggest that DDM and RIM underestimate equity values of Thai firms and that RIM outperforms DDM in predicting cross-sectional stock prices. Results on regression of cross-sectional stock prices on the decomposed DDM and RIM equity values indicate that book value of equity provides the greatest incremental explanatory power, relative to other components in DDM and RIM terminal values, suggesting that book value distortions resulting from accounting procedures and choices are less severe than forecast and measurement errors in discount rates and growth rates.

We also document that the incremental explanatory power of book value of equity during 1998-2004, representing the information environment under Thai Accounting Standards reformed after the 1997 economic crisis to conform to International Accounting Standards, is significantly greater than that during 1995-1996, representing the information environment under the pre-reformed Thai Accounting Standards. This implies that the book value distortions are less severe under the 1997 Reformed Thai Accounting Standards than the pre-reformed Thai Accounting Standards.

***Keywords*—**Dividend Discount Model, Equity Valuation Model, Residual Income Model, Thai Stock Market

I. Introduction

FINANCIAL analysts and investors typically use the dividend discount model (DDM) in valuing a firm's equity value. An alternative valuation model is the residual income model (RIM) re-introduced by [6]. RIM puts an emphasis on accounting numbers (i.e., book value and earnings). Even though both models are theoretically equivalent, empirical evidence says otherwise. Reference [2] and [7] compare equity values of U.S. companies estimated by DDM and RIM. Their results suggest that RIM, over a range of conditions, outperforms DDM in predicting US companies' stock prices. Moreover, [2] suggest that the superiority of RIM over DDM can be explained by the fact that book values distortions resulting from accounting procedures and accounting choices of U.S. companies are less severe than forecast and measurement errors in discount rates and growth rates. Accounting data of Thai firms are prepared in conformity with the Thai Accounting Standards (Thai GAAP) which is not identical to the U.S. Accounting Standards (US GAAP). Whether RIM will outperform DDM in explaining stock prices of Thai firms is therefore an empirical question. This study aims at providing empirical evidence on relative performance of RIM and DDM in explaining contemporaneous stock prices of Thai firms.

This study compares equity values of Thai firms estimated by DDM and RIM during 1995-2004. In order to examine whether RIM generates more accurate equity values than does DDM, we first calculate the bias index ($BIAS^{DDM}$ and $BIAS^{RIM}$) defined as a difference between estimated equity value and stock price, scaled by the stock price and the accuracy index (ACC^{DDM} and ACC^{RIM}) defined as the absolute value of a difference between estimated equity value and stock price, deflated by the stock price.

We find that medians of $BIAS^{DDM}$ over a specific range of conditions are significantly less than zero, suggesting that DDM equity values are downwardly biased, relative to contemporaneous stock prices. We also document that medians of $BIAS^{RIM}$ over a specific range of conditions generally are significantly less than zero and less negative than medians of $BIAS^{DDM}$. This suggests that both DDM and RIM underestimate cross-sectional stock prices, but RIM equity values are less biased than DDM equity values. Our empirical evidence also shows that DDM and RIM equity values with a component of the corresponding terminal values are less biased than those without the terminal values. The effect of DDM terminal values in reducing the bias, however, is more pronounced than is the effect of RIM terminal values.

Empirical evidence on the accuracy index of DDM equity values (ACC^{DDM}) and RIM equity values (ACC^{RIM}) shows that as forecast horizons increase, DDM equity values are more accurate in predicting the stock prices, suggesting that forecast horizons positively affect performance of DDM in estimating equity values while forecast horizons have no effect on RIM performance. Furthermore, consistent with [7], we find that DDM equity values with a component of DDM terminal values are more accurate than those without a component of DDM terminal values while RIM terminal values have no effect on the accuracy of RIM equity values.

More importantly, our empirical results reveal that RIM equity values are more accurate in predicting contemporaneous stock prices than are DDM equity values. In other words, RIM outperforms DDM in predicting cross-sectional stock prices of Thai firms, consistent with empirical evidence on U.S. companies in [2] and [7].

Alternatively, in order to evaluate the relative explainability of DDM and RIM equity values on cross-sectional stock prices, we regress cross-sectional stock prices on either DDM or RIM equity values and compare the resulting adjusted R^2. Our empirical evidence indicates that adjusted R^2 of both

Somchai Supattarakul is with the Department of Accounting, Thammasat Business School, Thammasat University, Bangkok 10200, THAILAND. (e-mail: ssomchai@tu.ac.th). Somchai Supattarakul is grateful to Professor Sangvian Indaravijaya Foundation and the Thailand Research Fund (TRF) for financial support.

Anya Khanthavit is with the Department of Finance, Thammasat Business School, Thammasat University, Bangkok 10200, THAILAND. (e-mail: akhantha@gmail.com).

DDM and RIM equity values increases as forecast horizons increase but the adjusted R^2 of the model with the corresponding terminal value is similar to that of the model without the terminal value. This suggests that forecast horizons improve the explainability of DDM and RIM equity values on cross-sectional stock prices, but DDM and RIM terminal values seem to have no effect on the explainability of DDM and RIM equity values. More importantly, a comparison of adjusted R^2 of DDM and RIM equity values reveals inconclusive evidence on the relative performance of DDM and RIM in explaining contemporaneous stock prices. Specifically, for a one-year forecast horizon, DDM outperforms RIM; for a two-year forecast horizon, RIM outperforms DDM; for a three-year forecast horizon, DDM and RIM perform equally well.

Additionally, in order to further evaluate the relative performance of DDM and RIM in explaining cross-sectional stock prices and to further examine whether for Thai firms, book value distortions in book values resulting from accounting procedures and accounting choices are less severe than forecast and measurement errors in discount rates and growth rates used to estimated future dividends and earnings as for the US firms, we regress cross-sectional stock prices on decomposed DDM and RIM equity values. Specifically, DDM equity values are decomposed into two components: (i) the sum of the present values of future dividends over a specified finite forecast horizon and (ii) the present value of DDM terminal value whereas RIM equity values are decomposed into three components: (i) book value of equity, (ii) the sum of the present values of future residual income or abnormal earnings over a specified finite forecast horizon, and (iii) the present value of RIM terminal value.

We find that RIM's adjusted R^2 is higher than DDM's adjusted R^2 for both two-year and three-year forecast horizons, suggesting that RIM outperforms DDM in explaining cross-sectional stock prices, consistent with Francis, Olsson, and Oswald [2000]. We also document that DDM terminal value provides greater incremental explanatory power than does the sum of the present values of future dividends, consistent with our results on the accuracy of DDM equity values in predicting cross-sectional stock prices. Our empirical evidence on the incremental explanatory power for models with decomposed RIM equity values indicates that book value of equity provides the highest incremental explanatory power over the other two components in decomposed RIM equity values and both components in decomposed DDM equity values. In other words, book value of equity explains a significant portion of the variation in cross-sectional stock prices. Overall, our empirical evidence implies that book value distortions resulting from accounting procedures and choices are less severe than forecast and measurement errors in discount rates and growth rates.

In addition, Thai Accounting Standards have been reformed to conform to International Accounting Standards (IAS) after the 1997 economic crisis because the society perceived that the former Thai Accounting Standards did not generate high quality of accounting numbers. Thus, this provides a unique setting to examine the relative distortions in accounting numbers generated from the former and current Thai Accounting Standards. We compare the relative explainability of book value for sub-sample firms prior to 1997 (i.e., a sample period of 1995-1996) and book value of sub-sample firms after 1997 (i.e., a sample period of 1998-2004) to contemporaneous stock prices.

Our empirical results on the incremental explanatory power of each component in decomposed DDM and RIM equity values for sub-sample firms during 1995-1996 and 1998-2004 are consistent with those for full-sample firms discussed earlier. More importantly, the incremental explanatory power of book value of equity for sub-sample firms during 1998-2004, representing information environment under the current Thai Accounting Standards reformed after the 1997 economic crisis, is significantly greater than that for sub-sample firms during 1995-1996, representing information environment under the former Thai Accounting Standards. This implies that the book value distortions are less severe under the current Thai Accounting Standards which is inconformity with International Accounting Standards than under the former Thai Accounting Standards.

The remainder of the paper is organized as follows. Section 2 reviews two valuation models: DDM and RIM. Section 3 discusses DDM and RIM model specifications. Section 4 describes our sample and data collection. Section 5 reports empirical results.

II. Two Equity Valuation Models

A. Review Stage

In this study, we consider two equity valuation models: the dividend discount model (DDM) and the residual income model (RIM). Both DDM and RIM define an equity value as the sum of the present values of expected future payoffs to shareholders. However, they differ in terms of their defined payoffs.

DDM equity value equals the sum of the present values of all expected future dividends. The following equation depicts the definition. Firm subscripts and expectation operators are suppressed for ease of notation.

$$V_S^{DDM} = \sum_{t=1}^{\infty} \frac{DIV_{S+t}}{(1+r_e)^t} \qquad (1)$$

where:

V_S^{DDM} = intrinsic value of equity at valuation date S,

DIV_{S+t} = expected dividends for year $S+t$, and

r_e = cost of equity capital.

RIM is developed based on the DDM concept with an additional accounting assumption typically called the *clean surplus* relation. The following equation depicts the clean surplus relation.

$$BV_t = BV_{t-1} + NI_t - DIV_t \qquad (2)$$

where:

BV_t = equity capital invested or book value at time t,

NI_t = net income or earnings for year t, and

DIV_t = dividends for year *t*.

Equation (2) can be rewritten as follows:

$$DIV_t = BV_{t-1} - BV_t + NI_t \quad (3)$$

RIM also defines residual income or abnormal earnings as net income minus charges of equity capital invested. The following equation depicts the definition.

$$AE_t = NI_t - (BV_{t-1} \times r_e) \quad (4)$$

where:

AE_t = residual income or abnormal earnings for year *t*.

Equation (3) can we rewritten as follows:

$$NI_t = AE_t + (BV_{t-1} \times r_e) \quad (5)$$

Substitute *NI* from equation (5) in equation (3) gives the following equation:

$$\begin{aligned} DIV_t &= BV_{t-1} - BV_t + AE_t + (BV_{t-1} \times r_e) \\ &= AE_t + (1+r_e)BV_{t-1} - BV_t \end{aligned} \quad (6)$$

Substitute *DIV* from equation (6) in equation (1) gives RIM equity value (V_S^{RIM}) as follows:

$$\begin{aligned} V_S^{RIM} &= \sum_{t=1}^{\infty} \frac{AE_{S+t} + (1+r_e)BV_{S+t-1} - BV_t}{(1+r_e)^t} \\ &= \left(\frac{AE_{S+1}}{(1+r_e)} + BV_S - \frac{BV_{S+1}}{(1+r_e)} \right) + \left(\frac{AE_{S+2}}{(1+r_e)^2} + \frac{BV_{S+1}}{(1+r_e)} - \frac{BV_{S+2}}{(1+r_e)^2} \right) + \ldots \\ &= BV_S + \frac{AE_{S+1}}{(1+r_e)} + \frac{AE_{S+2}}{(1+r_e)^2} + \ldots \\ &= BV_S + \sum_{t=}^{\infty} \frac{AE_{S+t}}{(1+r_e)^t} \end{aligned} \quad (7)$$

Therefore, RIM equity value equals a combination of equity capital invested (or book value of equity) and the sum of all expected future residual income or abnormal earnings where residual income equals net income minus charges of equity capital invested at the beginning of the period. Above set of equations shows that RIM is an algebraic transformation of DDM. In other words, RIM is theoretically equivalent to DDM.

III. Model Specification

From equation (1), DDM is implemented as follows:

$$\begin{aligned} V_S^{DDM} &= \sum_{t=1}^{T} \frac{DIV_{S+t}}{(1+r_e)^t} + \frac{DIV_{S+T}(1+g_{DIV})}{(1+r_e)^T (r_e - g_{DIV})} \\ &= \sum_{t=1}^{T} \frac{DIV_{S+t}}{(1+r_e)^t} + \frac{TV_{S+T}^{DDM}}{(1+r_e)^T} \end{aligned} \quad (8)$$

where TV_{S+T}^{DDM} is DDM terminal value under certain assumptions of growth rates of future dividends (g_{DIV}) and forecast horizons (*T*). From equation (8), it can be concluded that an accuracy of V_S^{DDM} depends primarily on measurement errors in discount rates (i.e., cost of equity capital, r_e) and forecast errors in future dividends which depends heavily on growth rates.

From equation (7), RIM is implemented as follows:

$$\begin{aligned} V_S^{RIM} &= BV_S + \sum_{t=1}^{T} \frac{AE_{S+t}}{(1+r_e)^t} + \frac{AE_{S+T}(1+g_{AE})}{(1+r_e)^T (r_e - g_{AE})} \\ &= BV_S + \sum_{t=1}^{T} \frac{AE_{S+t}}{(1+r_e)^t} + \frac{TV_{S+T}^{RIM}}{(1+r_e)^T} \end{aligned} \quad (9)$$

where TV_{S+T}^{RIM} is RIM terminal value under certain assumptions of growth rates of future abnormal earnings (g_{RIM}) and forecast horizons (*T*).

As discussed in Section 2, RIM is an algebraic transformation of DDM; thus, RIM is theoretically equivalent to DDM. As a result, V_S^{RIM} is subject to the same theoretical limitations as V_S^{DDM}, mentioned earlier. Specifically, both DDM and RIM face measurement errors in discount rates and forecast errors in growth rates. Measurement errors in discount rates and forecast errors in growth rates, however, should have a smaller effect on an accuracy of V_S^{RIM} than they do on an accuracy of V_S^{DDM} since V_S^{RIM} is also based partly on the amount of current equity capital invested or current book value of equity, which is not subject to the forecast and measurement errors. The fact that book value of equity is one component in V_S^{RIM} causes an accuracy of V_S^{RIM} to depend upon a degree of distortions in book value of equation resulting from accounting procedures and accounting choices while the book value distortions have no effect on an accuracy of V_S^{DDM}.

Reference [2] uses analyst forecast data of future dividends and earnings to proxy for future dividends (*DIV*) and earnings (*NI*) in both DDM and RIM while [7] uses realizations (ex post data) instead of analyst forecast data. References [1], [3], [4], and [5] also use analysts' forecasts of future earnings and dividends as a basis for estimating future book value of equity and abnormal earnings in RIM. Consistent with prior studies, this study uses analysts' forecasts of future dividends as a proxy for future dividends (*DIV*) in DDM and uses analysts' forecasts of both future dividends and earnings as a basis for estimating future book value of equity (*BV*) and future residual income or abnormal earnings in RIM. Specifically, future book value is calculated using the clean surplus relation stated in equation (2) as $BV_t = BV_{t-1} + NI_t - DIV_t$, and future abnormal earnings (*AE*) are calculated using equation (4) as $AE_t = NI_t - (BV_{t-1} \times r_e)$.

Subject to data availability of analysts' forecasts of future dividends and earnings, we use four different forecast horizons (*T*) for both DDM and RIM: one-year, two-year, three-year, and four-year forecast horizons. Three different growth rates are arbitrarily chosen for both future dividends and abnormal earnings (g_{DIV} and g_{RIM}): 0 percent, 3 percent, and 5 percent and three different levels of cost of equity capital (r_e) are arbitrarily employed: 10 percent, 12 percent, and 15 percent.

IV. Sample and Data Collection

Thai firms included in our sample must have (1) actual annual earnings per share (EPS), (2) year-end book value per share (BPS), (3) annual dividend per share (DPS), and (4) year-end stock price (PRICE), available on Thomson Datastream database, and (5) analysts' forecasts of future earnings and (6) analysts' forecasts of future dividends, available on I/B/E/S database. Subject to data availability of analysts' forecasts of future earnings and dividends on I/B/E/S database, our sample period is limited to 1995 to 2004.

V. Empirical Tests and Results

A. Bias and Accuracy of DDM and RIM Equity Values

In order to examine which model between DDM and RIM generates more accurate value, relative to stock price, the bias index and accuracy index are calculated as follows:

Bias Index of DDM Equity Values

$$BIAS^{DDM} = \frac{V_S^{DDM} - P_s}{P_S} \tag{10}$$

Bias Index of RIM Equity Values

$$BIAS^{RIM} = \frac{V_S^{RIM} - P_s}{P_S} \tag{11}$$

Accuracy Index of DDM Equity Values

$$ACC^{DDM} = \frac{\left|V_S^{DDM} - P_S\right|}{P_S} \tag{12}$$

Accuracy Index of RIM Equity Values

$$ACC^{RIM} = \frac{\left|V_S^{RIM} - P_S\right|}{P_S} \tag{13}$$

$BIAS^{DDM}$ and $BIAS^{RIM}$ are the bias index of DDM and RIM, respectively, ACC^{DDM} and ACC^{RIM} are the accuracy index of DDM and RIM, respectively, and P_S is the stock price at the valuation date *S*. A comparison of $BIAS^{DDM}$ and $BIAS^{RIM}$ provides empirical evidence on a relative bias of DDM and RIM equity values, relative to cross-sectional stock prices; a comparison of ACC^{DDM} and ACC^{RIM} provides empirical evidence on a relative accuracy of DDM and RIM equity values, relative to cross-sectional stock prices.

Panel A of table 1 presents medians of $BIAS^{DDM}$ and $BIAS^{RIM}$, the bias index or signed prediction errors while panel B of table 1 shows medians of ACC^{DDM} and ACC^{RIM}, the accuracy index or absolute prediction errors. $BIAS^{DDM}$, $BIAS^{RIM}$, ACC^{DDM} and ACC^{RIM} are calculated over a range of conditions: three levels of cost of equity capital (10%, 12%, and 15%), three different growth rates (1%, 3%, and 5%), four forecast horizons (one year to four years), and equity values with and without a component of terminal value.

We arbitrarily choose to report results on three pairs of cost of equity capital (r_e) and growth rates (g): (10%, 1%), (12%, 3%) and (15%, 5%). For DDM under the assumed cost of equity capital of 10% and the assumed growth rate of 1%, and four forecast horizons (T) of one to four years, medians of $BIAS^{DDM}$ for DDM equity values without terminal value (with terminal value) range from -0.9746 to -0.8923 (from -0.6901 to -0.5554). All medians are significantly less than zero. For the same forecast horizon, median of $BIAS^{DDM}$ for DDM equity values with terminal value is significantly less negative than median of $BIAS^{DDM}$ for DDM equity values without terminal value, as expected. This suggests that DDM equity values are downwardly biased, relative to contemporaneous stock prices and the downward bias is reduced when DDM terminal values are taken into account in estimating DDM equity values. Evidence on the other two pairs of cost of equity capital and growth rates is qualitatively identical.

For RIM under the assumed cost of equity capital of 10% and the assumed growth rate of 1%, and four forecast horizons (T) of one to four years, medians of $BIAS^{RIM}$ for RIM equity values without terminal value (with terminal value) range from -0.2724 to -0.1701 (from 0.0222 to 0.1465). For the same forecast horizon, median of $BIAS^{RIM}$ for RIM equity values with terminal value is significantly greater than median of $BIAS^{RIM}$ for RIM equity values without terminal value, as predicted. Empirical results on the other two pairs of cost of equity capital and growth rates are consistent with discussed results. This suggests that in general RIM equity values are downwardly biased, relative to cross-sectional stock prices and the downward bias is reduced when RIM terminal values are included, consistent with results on DDM equity values. Overall, DDM and RIM implementing as discussed in this paper generally underestimate equity values, relatively to contemporaneous stock prices.

A comparison of the accuracy index of DDM and RIM (ACC^{DDM} and ACC^{RIM}) helps address how accurate DDM and RIM estimate contemporaneous stock prices. Since our empirical results for all three pairs of cost of equity capital and growth rates are qualitatively identical, we discuss in this paper only results for the first pair: cost of equity capital of 10% and growth rate of 1%. Medians of ACC^{DDM} for DDM equity values without terminal value (with terminal value) range from 0.8251 to 0.9455 (from 0.4023 to 0.4653). Results show that as forecast horizons increase, DDM equity values are more accurate in predicting the stock prices, suggesting that forecast horizons affect performance of DDM in estimating equity values. This is consistent with empirical evidence of US firms in [7]. Moreover, for the same forecast horizon, medians of ACC^{DDM} for DDM equity values with terminal value is significantly less than that without terminal value, suggesting that DDM equity values are more accurate when DDM terminal values are included in the estimation of equity value. Specifically, median of ACC^{DDM} is doubled when DDM terminal value is taken into account. This indicates that DDM terminal value is an important componentof DDM equity values. This is consistent with results on US firms documented by [7].

For RIM, medians of ACC^{RIM} for RIM equity values without terminal value (with terminal value) range from 0.2485 to 0.2709 (from 0.2113 to 0.2547). Medians of ACC^{RIM} under eight reported conditions are not significantly different. Our results indicate that forecast horizons and RIM terminal values do not have a significant effect on performance of RIM in estimating equity value. This is consistent with empirical evidence on US firms documented in [7].

More importantly, medians of ACC^{RIM} are significantly lower than medians of ACC^{DDM} in all reported conditions, suggesting that RIM equity values are more accurate than are DDM equity values, relative to cross-sectional stock prices. In other words, RIM outperforms DDM in predicting contemporaneous stock prices of Thai firms. This is consistent with empirical evidence on US companies reported in [2] and [7]. In addition, median of ACC^{RIM} for book value of equity (BV) is 0.2931, which is lower than that of DDM equity values. This suggests that book value of equity also outperforms DDM in predicting cross-sectional stock prices of Thai firms.

B. The Explainability of DDM and RIM Equity Values

In order to examine relative performance of DDM and RIM equity values in explaining cross-sectional stock prices, the following regression models are estimated.

Stock Prices and DDM Equity Values

$$P_S = \alpha^{DDM} + \beta^{DDM} V_S^{DDM} + \varepsilon^{DDM} \quad (14)$$

Stock Prices and RIM Equity Values

$$P_S = \alpha^{RIM} + \beta^{RIM} V_S^{RIM} + \varepsilon^{RIM} \quad (15)$$

A comparison of adjusted R^2s of these models provides evidence on the relative explainability of DDM and RIM equity values on cross-sectional stock prices. Table 2 reports estimated slope coefficients, β^{DDM} and β^{RIM}, standard errors, adjusted R^2, and number of observations (n) for the DDM and RIM regression models over a range of conditions: three levels of cost of equity capital (10%, 12%, and 15%), three different growth rates (1%, 3%, and 5%), three forecast horizons (one year to three years), and models with equity values with and without terminal values.

TABLE 1

The Bias and Accuracy Index of the DDM and RIM Equity Values

Panel A: Bias or Signed Prediction Errors

Model	r_e	g	BV	Without Terminal Value				With Terminal Value			
				T=1	T=2	T=3	T=4	T=1	T=2	T=3	T=4
DDM	10.00%	1.00%		-0.9746	-0.9464	-0.9154	-0.8923	-0.6901	-0.6407	-0.5680	-0.5554
				1482	1414	945	290	1482	1414	945	290
RIM	10.00%	1.00%	-0.1223	-0.1701	-0.1975	-0.2618	-0.2724	0.0662	0.0222	0.0819	0.1465
			2741	1452	1300	923	315	1259	1201	918	320
DDM	12.00%	3.00%		-0.9751	-0.9477	-0.9184	-0.8985	-0.6901	-0.6471	-0.5826	-0.5775
				1482	1414	945	290	1482	1414	945	290
RIM	12.00%	3.00%	-0.1223	-0.1849	-0.2252	-0.2989	-0.3220	-0.0183	-0.0958	-0.0362	-0.0089
			2741	1452	1300	923	315	1163	1120	875	310
DDM	15.00%	5.00%		-0.9757	-0.9500	-0.9227	-0.9060	-0.7211	-0.6877	-0.6388	-0.6405
				1482	1414	945	290	1482	1414	945	290
RIM	15.00%	5.00%	-0.1223	-0.2062	-0.2641	-0.3499	-0.3870	-0.2204	-0.2872	-0.2493	-0.2560
			2741	1452	1300	924	315	1096	1052	845	301

Panel B: Accuracy or Absolute Prediction Errors

Model	r_e	g	BV	Without Terminal Value				With Terminal Value			
				T=1	T=2	T=3	T=4	T=1	T=2	T=3	T=4
DDM	10.00%	1.00%		0.9455	0.8908	0.8291	0.8251	0.4653	0.4381	0.4105	0.4023
				1482	1414	945	290	1482	1414	945	290
RIM	10.00%	1.00%	0.2931	0.2659	0.2690	0.2709	0.2485	0.2547	0.2461	0.2392	0.2113
			2741	1452	1300	923	315	1259	1201	918	320
DDM	12.00%	3.00%		0.9465	0.8937	0.8354	0.8321	0.4653	0.4418	0.4280	0.4169
				1482	1414	945	290	1482	1414	945	290
RIM	12.00%	3.00%	0.2931	0.2665	0.2665	0.2806	0.2397	0.2479	0.2452	0.2461	0.1950
			2741	1452	1300	923	315	1163	1120	875	310
DDM	15.00%	5.00%		0.9479	0.8978	0.8419	0.8437	0.5000	0.4807	0.4710	0.4590
				1482	1414	945	290	1482	1414	945	290
RIM	15.00%	5.00%	0.2931	0.2622	0.2678	0.2828	0.2756	0.2809	0.2997	0.2950	0.2430
			2741	1452	1300	924	315	1096	1052	845	301

TABLE 2

The Relative Explainability of the DDM and RIM Equity Values

Model	r_e	g		BV	Without Terminal Value			With Terminal Value		
					T=1	T=2	T=3	T=1	T=2	T=3
DDM	10.00%	1.00%	b		0.3278 ***	0.1723 ***	0.1366 ***	0.0268 ***	0.0259 ***	0.0468 ***
			SE		0.0064	0.0026	0.0014	0.0005	0.0003	0.0005
			$Adj\ R^2$		0.6394	0.7588	0.9136	0.6394	0.8031	0.9149
			n		1482	1414	945	1482	1414	945
RIM	10.00%	1.00%	b	3.3199 ***	0.2303 ***	0.1588 ***	0.0976 ***	0.0170 ***	0.0134 ***	0.0163 ***
			SE	0.0861	0.0082	0.0018	0.0010	0.0009	0.0002	0.0002
			$Adj\ R^2$	0.3518	0.3501	0.8549	0.9191	0.3338	0.8599	0.9134
			n	2741	1452	1300	923	1259	1201	918
DDM	12.00%	3.00%	b		0.3338 ***	0.1770 ***	0.1410 ***	0.0268 ***	0.0264 ***	0.0484 ***
			SE		0.0065	0.0027	0.0014	0.0005	0.0003	0.0005
			$Adj\ R^2$		0.6394	0.7581	0.9136	0.6394	0.8031	0.9149
			n		1482	1414	945	1482	1414	945
RIM	12.00%	3.00%	b	3.3199 ***	0.2345 ***	0.1633 ***	0.1014 ***	0.0169 ***	0.0135 ***	0.0163 ***
			SE	0.0861	0.0084	0.0019	0.0010	0.0009	0.0002	0.0002
			$Adj\ R^2$	0.3518	0.3501	0.8551	0.9190	0.3322	0.8598	0.9022
			n	2741	1452	1300	923	1163	1120	875
DDM	15.00%	5.00%	b		0.3427 ***	0.1841 ***	0.1476 ***	0.0298 ***	0.0299 ***	0.0547 ***
			SE		0.0067	0.0028	0.0015	0.0006	0.0004	0.0005
			$Adj\ R^2$		0.6394	0.7572	0.9136	0.6394	0.8026	0.9149
			n		1482	1414	945	1482	1414	945
RIM	15.00%	5.00%	b	3.3199 ***	0.2408 ***	0.1702 ***	0.1071 ***	0.0186 ***	0.0152 ***	0.0182 ***
			SE	0.0861	0.0086	0.0019	0.0010	0.0010	0.0002	0.0002
			$Adj\ R^2$	0.3518	0.3501	0.8554	0.9188	0.3323	0.8587	0.8888
			n	2741	1452	1300	924	1096	1052	845

Since our results for all three pairs of cost of equity capital and growth rates are qualitatively identical, we discuss in this paper only results for the first pair: cost of equity capital of 10% and growth rate of 1%. β^{DDM} and β^{RIM} under all conditions are significantly positive. A comparison of adjusted R^2 of DDM models without terminal value indicates that adjusted R^2 increases as forecast horizons increase. Specifically, adjusted R^2 increases from 63.94% in the one-year forecast horizon (T=1) to 75.88% in the two-year forecast horizon and 91.36% in the three-year forecast horizon. Results for DDM models with terminal value are consistent with the previously discussed results. That is, adjusted R^2 increases from 63.94% in the one-year forecast horizon (T=1) to 80.31% in the two-year forecast horizon and 91.49% in the three-year forecast horizon. This suggests that the explainability of DDM equity values on cross-sectional stock prices is increasing with forecast horizons, consistent with our empirical results on the accuracy of DDM equity values in predicting stock prices discussed earlier. Moreover, for the same forecast horizon, adjusted R^2 of DDM models with terminal value is similar to that without terminal value. This suggests that DDM terminal value has no significant effect on the explainability of DDM equity values on cross-sectional stock prices while our results on the accuracy of DDM equity values indicate that DDM terminal value improves performance of DDM equity value in estimating contemporaneous stock prices.

For RIM performance in explaining cross-sectional stock prices, we find that adjusted R^2 increases as forecast horizons increase but is not affected by RIM terminal value, consistent with results DDM results. Specifically, for RIM models without terminal value, adjusted R^2 increases from 35.01% in the one-year forecast horizon (T=1) to 85.49% in the two-year forecast horizon and 91.91% in the three-year forecast horizon, and for RIM models with terminal value, adjusted R^2 increases from 33.38% in the one-year forecast horizon (T=1) to 85.99% in the two-year forecast horizon and 91.34% in the three-year forecast horizon. Moreover, for the same forecast horizon, adjusted R^2 of RIM models with terminal value is similar to that without terminal value. Note also that the explainability on cross-sectional stock prices of book value of equity (adjusted R^2 of 35.01%) and RIM equity values in the one-year forecast horizon are at a similar level.

A comparison of adjusted R^2 of DDM and RIM models reveals mixed results on the relative explainability of DDM and RIM equity values on cross-sectional stock prices. Specifically, for the one-year forecast horizon, adjusted R^2 of DDM model (63.94%) is greater than those of RIM model (35.01%) and book value of equity (35.18%); for the two-year forecast horizon, adjusted R^2 of DDM model (75.88%) is lower than that of RIM model (85.49%); for the three-year forecast horizon, adjusted R^2 of DDM model (91.36%) and RIM (91.91%) model are not significantly different. Reference [2] find empirical evidence that for five-year

TABLE 3

Regression of Stock Prices on the Decomposed DDM and RIM Equity Values

Model	r_e	g		Book Value		Sum of PV of *DIV* or *AE*		PV of *TV*	
				T=2	T=3	T=2	T=3	T=2	T=3
DDM	10.00%	1.00%	*b*			-0.1188 ***	-5.1618 ***	0.0504 ***	2.7568 ***
			SE			0.0139	0.1873	0.0024	0.0974
			Adj R^2			0.8171	0.9532		
			Inc R^2			0.0096	0.0375	0.0583	0.0395
			n			1414	945		
RIM	10.00%	1.00%	*b*	1.5063 ***	1.57 ***	-0.0865 ***	2.7049 ***	0.0196 ***	-0.557 ***
			SE	0.0316	0.043	0.0063	0.2925	0.0005	0.0622
			Adj R^2			0.9536	0.9697		
			Inc R^2	0.0931	0.0476	0.0076	0.0030	0.0525	0.0029
			n			1134	853		
DDM	12.00%	3.00%	*b*			-0.1209 ***	-5.3028 ***	0.0511 ***	2.8406 ***
			SE			0.0141	0.1924	0.0024	0.1004
			Adj R^2			0.8171	0.9532		
			Inc R^2			0.0094	0.0375	0.0590	0.0395
			n			1414	945		
RIM	12.00%	3.00%	*b*	1.5618 ***	1.6334 ***	-0.0904 ***	2.5856 ***	0.0198 ***	-0.529 ***
			SE	0.0323	0.0442	0.0065	0.3065	0.0005	0.0649
			Adj R^2			0.9572	0.9706		
			Inc R^2	0.0957	0.05	0.0078	0.0026	0.0533	0.0024
			n			1048	807		
DDM	15.00%	5.00%	*b*			-0.1242	-5.5159	0.0584	3.3301
			SE			0.0145	0.2002	0.0027	0.1177
			Adj R^2			0.8171	0.9532		
			Inc R^2			0.0094	0.0375	0.0599	0.0395
			n			1414	945		
RIM	15.00%	5.00%	*b*	1.6038	1.6905	-0.0925 ***	2.6470 ***	0.0222 ***	-0.604 ***
			SE	0.0332	0.0447	0.0067	0.3161	0.0006	0.0746
			Adj R^2			0.9594	0.9715		
			Inc R^2	0.0968	0.0531	0.0078	0.0026	0.0535	0.0024
			n			978	771		

forecast horizon, adjusted R^2 of DDM model (51%) is lower than that of RIM model (71%), suggesting that RIM outperforms DDM in explaining cross-sectional stock prices while our empirical evidence shows inconclusive evidence on the relative explainability of DDM and RIM equity value on cross-sectional stock prices.

C. The Book Value Distortions and Forecast and Measurement Errors

In order to further examine relative performance of DDM and RIM in explaining cross-sectional stock prices and examine whether book value distortions resulting from accounting procedures and choices are less severe than forecast and measurement errors in discount rates and growth rates, we regress cross-sectional stock prices on decomposed DDM and RIM equity values. DDM equity values with terminal value are decomposed into two components: (1) the sum of the present values of future dividends over specified finite forecast horizons $\left(\sum_{t=1}^{T}\frac{DIV_{S+t}}{(1+r_e)^t}\right)$, and (2) the present value of the corresponding DDM terminal value $\left(\frac{TV_{S+T}^{DDM}}{(1+r_e)^T}\right)$. Similarly, RIM equity values with terminal value are decomposed into three components: (1) the corresponding book values of equity (BV_S), (2) the sum of the present values of future residual income or abnormal earnings over specified finite forecast horizons $\left(\sum_{t=1}^{T}\frac{AE_{S+t}}{(1+r_e)^t}\right)$, and (3) the present value of the corresponding RIM terminal value $\left(\frac{TV_{S+T}^{RIM}}{(1+r_e)^T}\right)$.

Therefore, the following regression models are estimated.

Stock Prices and Decomposed DDM Equity Values:

$$P_S = \alpha^{DDM'} + \beta_1^{DDM'}\sum_{t=1}^{T}\frac{DIV_{S+t}}{(1+r_e)^t} + \beta_2^{DDM'}\frac{TV_{S+T}^{DDM}}{(1+r_e)^T} + \varepsilon^{DDM'} \quad (16)$$

Stock Prices and Decomposed RIM Equity Values:

$$P_S = \alpha^{RIM'} + \beta_1^{RIM'}BV_S + \beta_2^{RIM'}\sum_{t=1}^{T}\frac{AE_{S+t}}{(1+r_e)^t} + \beta_3^{RIM'}\frac{TV_{S+T}^{RIM}}{(1+r_e)^T} + \varepsilon^{RIM'} \quad (17)$$

Table 3 presents estimated slope coefficients for models with decomposed DDM equity values ($\beta_1^{DDM'}$ and $\beta_2^{DDM'}$) and models with decomposed RIM equity values ($\beta_1^{RIM'}$, $\beta_2^{RIM'}$, and $\beta_3^{RIM'}$), the corresponding standard errors (*SE*), adjusted R^2, incremental R^2, and number of observations (*n*).

TABLE 4

Regression of Stock Prices on the Decomposed DDM and RIM Equity Values

Model	re	g		Book Value		Sum of PV of DIV or AE		PV of TV	
				T=2	T=3	T=2	T=3	T=2	T=3
DDM	10.00%	1.00%	*b*			-0.1174 ***	-5.3204 ***	0.0499 ***	2.8390 ***
			SE			0.0244	0.4865	0.0042	0.2532
			Adj R^2			0.8599	0.9758		
			Inc R^2			0.0100	0.0192	0.0615	0.0202
			n			326	151		
RIM	10.00%	1.00%	*b*	1.7225 ***	1.9872 ***	-0.1112 ***	4.7038 ***	0.0214 ***	-0.9830 ***
			SE	0.0569	0.1004	0.0089	0.8844	0.0008	0.1879
			Adj R^2			0.9772	0.9919		
			Inc R^2	0.0698	0.0205	0.0119	0.0015	0.0611	0.0014
			n			299	154		
DDM	12.00%	3.00%	*b*			-0.1196 ***	-5.4659 ***	0.0506 ***	2.9254 ***
			SE			0.0249	0.4998	0.0042	0.2608
			Adj R^2			0.8599	0.9758		
			Inc R^2			0.0100	0.0192	0.0620	0.0202
			n			326	151		
RIM	12.00%	3.00%	*b*	1.7869 ***	2.0394 ***	-0.1162 ***	4.7298 ***	0.0216 ***	-0.9839 ***
			SE	0.0562	0.0994	0.0089	0.9300	0.0007	0.1968
			Adj R^2			0.9804	0.9920		
			Inc R^2	0.0727	0.0227	0.0123	0.0014	0.0621	0.0014
			n			272	148		
DDM	15.00%	5.00%	*b*			-0.1228 ***	-5.6857 ***	0.0578 ***	3.4296 ***
			SE			0.0255	0.5198	0.0048	0.3057
			Adj R^2			0.8599	0.9758		
			Inc R^2			0.0100	0.0192	0.0632	0.0202
			n			326	151		
RIM	15.00%	5.00%	*b*	1.8193 ***	2.1417 ***	-0.1182 ***	4.3343 ***	0.0241 ***	-1.0031 ***
			SE	0.0585	0.0950	0.0094	0.9660	0.0008	0.228
			Adj R^2			0.9812	0.9923		
			Inc R^2	0.0728	0.0274	0.0120	0.0011	0.0619	0.0010
			n			250	143		

Since our empirical results for all three pairs of cost of equity capital and growth rates are qualitatively identical, we discuss in this paper only results for the first pair: cost of equity capital of 10% and growth rate of 1%. Note that adjusted R^2 of decomposed RIM model is higher than that of decomposed DDM model for both two-year and three-year forecast horizons. This evidence indicates that RIM outperforms DDM in explaining cross-sectional stock prices, consistent with [2].

For decomposed DDM model, the incremental explanatory power measured by the incremental R^2 is higher for $\left(\frac{TV_{S+T}^{DDM}}{(1+r_e)^T}\right)$ (5.83%) than for $\left(\sum_{t=1}^{T}\frac{DIV_{S+t}}{(1+r_e)^t}\right)$ (0.96%) for three-year forecast horizon while for the two-year horizon, the incremental R^2 of $\left(\sum_{t=1}^{T}\frac{DIV_{S+t}}{(1+r_e)^t}\right)$ is similar to that of $\left(\frac{TV_{S+T}^{DDM}}{(1+r_e)^T}\right)$. This suggests that DDM terminal value is an important component of DDM equity values in explaining cross-sectional stock prices, consistent with our results on the accuracy of DDM equity values in predicting contemporaneous stock prices.

For decomposed RIM model, the incremental R^2 of book value of equity is the highest, relative to those of $\left(\sum_{t=1}^{T}\frac{AE_{S+t}}{(1+r_e)^t}\right)$ and $\left(\frac{TV_{S+T}^{RIM}}{(1+r_e)^T}\right)$. For example, for the two-year forecast horizon, the incremental R^2 is 9.31% for book value of equity, 0.76% for $\left(\sum_{t=1}^{T}\frac{AE_{S+t}}{(1+r_e)^t}\right)$,and 5.25% for $\left(\frac{TV_{S+T}^{RIM}}{(1+r_e)^T}\right)$. This indicates that book value of equity provides the highest incremental explanatory power over the other two components in RIM equity values. In other words, book value of equity explains a significant portion of the variation in

TABLE 5

Regression of Stock Prices on the Decomposed DDM and RIM Equity Values

Model	r_e	g		*Book Value*		Sum of PV of *DIV* or *AE*		Present Value of *TV*	
				T=2	T=3	T=2	T=3	T=2	T=3
DDM	10.00%	1.00%	*b*			4.0025***	1.3249 *	0.5154 *	0.9922 ***
			SE			1.5098	0.7117	0.2707	0.1855
			Adj R^2			0.4828	0.5139		
			Inc R^2			0.0040	0.0024	0.0020	0.0194
			n			909	717		
RIM	10.00%	1.00%	*b*	0.9329 ***	1.0196 ***	1.5054***	0.6374 ***	0.1518 *	0.4302 ***
			SE	0.041	0.0445	0.4161	0.2302	0.0775	0.0717
			Adj R^2			0.6347	0.6035		
			Inc R^2	0.2715	0.3420	0.0069	0.0050	0.0020	0.0234
			n			697	610		
DDM	12.00%	3.00%	*b*			4.0753 ***	1.3571 *	0.5304 *	1.0313 ***
			SE			1.5373	0.7306	0.2727	0.1902
			Adj R^2			0.4828	0.5139		
			Inc R^2			0.0040	0.0024	0.0021	0.0200
			n			909	717		
RIM	12.00%	3.00%	*b*	0.9886 ***	1.0930***	1.6276 ***	0.7662 ***	0.1748 **	0.4873 ***
			SE	0.0413	0.0469	0.4231	0.2362	0.0786	0.0755
			Adj R^2			0.6440	0.6077		
			Inc R^2	0.3117	0.3674	0.0081	0.0071	0.0027	0.0282
			n			654	579		
DDM	15.00%	5.00%	*b*			4.1844***	1.4054 *	0.6202 *	1.2240 ***
			SE			1.5784	0.7592	0.3094	0.2213
			Adj R^2			0.4828	0.5139		
			Inc R^2			0.0040	0.0024	0.0022	0.0208
			n			909	717		
RIM	15.00%	5.00%	*b*	1.1294 ***	1.2923***	1.9111***	0.9569 ***	0.1595	0.5750
			SE	0.0402	0.0468	0.4780	0.2383	0.0976	0.08762
			Adj R^2			0.6444	0.6198		
			Inc R^2	0.4552	0.5247	0.0092	0.0111	0.0015	
			n			654	553		

contemporaneous stock prices. Additionally, the incremental explanatory power of book value of equity is greater than those of $\left(\sum_{t=1}^{T}\frac{DIV_{S+t}}{(1+r_e)^t}\right)$ and $\left(\frac{TV_{S+T}^{DDM}}{(1+r_e)^T}\right)$. This is consistent with empirical evidence on US firms documented in [2]. Overall, this suggests that book value distortions resulting from accounting procedures and choices (influencing only RIM equity values) are less severe than forecast and measurement errors in discount rates and growth rates (influencing both DDM and RIM equity values).

In addition, we also regress cross-sectional stock prices on decomposed DDM and RIM equity values for a sample period of 1995-1996, representing the time period prior to the 1997 economic crisis and a sample period of 1998-2004, representing the time period after the 1997 economic crisis. This allows us to evaluate whether the current Thai Accounting Standards reformed as after the 1997 economic crisis to conform to International Accounting Standards generates higher-quality accounting data than does the former Thai Accounting Standards. Tables 4 and 5 present estimated slope coefficients for decomposed DDM equity values ($\beta_1^{DDM'}$ and $\beta_2^{DDM'}$) and decomposed RIM equity values ($\beta_1^{RIM'}$, $\beta_2^{RIM'}$, and $\beta_3^{RIM'}$), the corresponding standard errors (*SE*), adjusted R^2, incremental R^2, and number of observations (*n*) for sample periods of 1995-1996 and 1998-2004, respectively.

Results on relative performance of DDM and RIM in explaining cross-sectional stock prices evaluated by adjusted R^2 suggest that RIM outperforms DDM over a range of conditions and for both sample periods which is consistent with our empirical results discussed earlier and also prior empirical evidence on US firms documented in [2].

Furthermore, results on the incremental explanatory power of each component in decomposed DDM and RIM equity values for the sample periods of 1995-1996 and 1998-2004 are consistent with those for a full sample discussed earlier. That is, DDM terminal value provides greater incremental explanatory power than the sum of the present values of finite future dividends. For RIM model, book value of equity provides the greatest incremental explanatory power and RIM terminal value comes in second and the sum of the present values comes in last. Moreover, book value of equity provides greater incremental explanatory than DDM terminal value. Overall, our results reveal that book value distortions resulting from accounting procedures and choices are less severe than forecast and measurement errors in discount rates and growth rates, consistent with our findings discussed earlier.

More importantly, the incremental explanatory power of book value of equity for the sample period of 1998-2004, representing the information environment under the current Thai Accounting Standards reformed after the 1997 economic crisis, is significantly greater than that for the sample period of 1995-1996, representing the information environment under the former Thai Accounting Standards. Specifically, the incremental R^2 of book value of equity for the sample period of 1998-2004 (1995-1996) is 27.15% (5.69%) and 34.20% (2.05%) for the two-year and three-year forecast horizons, respectively. This implies that book value distortions resulting from accounting procedures and choices are less severe under the current Thai Accounting Standards which is inconformity with International Accounting Standards than are those under the former Thai Accounting Standards. In other words, the current Thai Accounting Standards seem to generate higher-quality accounting numbers than do the former Thai Accounting Standards.

REFERENCES

[1] Dechow, P. M., A. M. Hutton, and R. G. Sloan. 1999. "An Empirical Assessment of the Residual Income Valuation Model," *Journal of Accounting and Economics* 26: 1-34.

[2] Francis, J., P. Olsson, and D. R. Oswald. 2000. "Comparing the Accuracy and Explainability of Dividend, Free Cash Flow, and Abnormal Earnings Equity Value Estimates," *Journal of Accounting Research* 38 (Spring): 45-70.

[3] Frankel, R. and C. M.C. Lee. 1998. "Accounting Valuation, Market Expectation, and Cross-sectional stock returns," *Journal of Accounting and Economics* 25: 283-319.

[4] Lee, M.C. C., J. Myers, and B. Swaminathan. 1999. "What is the Intrinsic Value of the Dow?," *The Journal of Finance* LIV (October): 1693-1741.

[5] Tse, S. and R. Yaansah. 1999. "An Analysis of Historical and Future-Oriented Information in Accounting-Based Security Valuation Models," *Contemporary Accounting Research* (Summer), 347-380.

[6] Ohlson, J. 1995. "Earnings, Book Value and Dividends in Security Valuation," *Contemporary Accounting Research* (Spring): 661-687.

[7] Penman, S. H. and T. Sougiannis. 1998. "A Comparison of Dividend, Cash Flow, and Earnings Approaches to Equity Valuation," *Contemporary Accounting Research* 15 (Fall): 343-383.

World and Regional Factors in Stock Market Returns

Suluck Pattarathammas

and

Anya Khanthavit

Department of Finance

Faculty of Commerce and Accountancy,

Thammasat University, Bangkok, Thailand

Support from the Faculty of Commerce and Accountancy, Thammasat University, and the Professor Sangvian Indaravijaya Foundation is gratefully acknowledged. Anya Khanthavit also thanks the Thailand Research Fund for supports.

ABSTRACT

World and Regional Factors in Stock Market Returns

This paper aims to test the hypothesis that the national stock market returns are driven by a world factor, regional factors and idiosyncratic factors, and to measure the importance of each factor. The state-space model is applied to describe the sample returns and estimate a world factor, regional factors and idiosyncratic factors by Kalman filtering. Weekly and daily returns calculated from MSCI country indexes from January 1988 to December 2004 of 11 national stock markets in four regions, i.e. North America (the USA and Canada), South America (Brazil, Mexico and Chile), Europe (the UK, Germany and France), and Asia (Japan, Hong Kong, and Singapore) are used. The results support the hypothesis that national market returns are driven by a world factor, regional factors and idiosyncratic factors. National markets do not always respond mainly to the world factor; regional factors and idiosyncratic factors play important roles as well. They also respond to world news at a slower rate than regional news.

บทคัดย่อ

ปัจจัยโลกและปัจจัยภูมิภาคซึ่งผลักดันพฤติกรรมของอัตราผลตอบแทนในตลาดหลักทรัพย์

การศึกษาทดสอบสมมติฐานว่า การเคลื่อนไหวของอัตราผลตอบแทนในตลาดหลักทรัพย์ในประเทศต่างๆ ทั่วโลกจะได้รับผลกระทบหรือไม่และเป็นจำนวนมากหรือน้อยเพียงใดจากปัจจัยโลก (World Factor) และปัจจัยภูมิภาค (Regional Factor) การศึกษาใช้ตัวแบบจำลอง State-Space Model ร่วมกับเทคนิค Kalman Filter ซึ่งสามารถระบุปัจจัยคู่นี้ได้จากข้อมูลอัตราผลตอบแทนในประเทศต่างๆ ซึ่งการศึกษาใช้เป็นตัวอย่าง ข้อมูลที่ใช้เป็นข้อมูลอัตราผลตอบแทนรายวันและรายสัปดาห์ในช่วงเดือนมกราคม 2531 ถึงเดือน ธันวาคม 2547 ของประเทศต่างๆ จำนวน 11 ประเทศ ใน 4 ทวีป การทดสอบพบว่า อัตราผลตอบแทนของประเทศในกลุ่มตัวอย่างสามารถอธิบายได้โดยปัจจัยโลกและปัจจัยภูมิภาค ในขณะที่ส่วนที่เหลือเป็นปัจจัยเฉพาะตัวของประเทศนั้น การศึกษาพบต่อไปว่า ปัจจัยโลกมีบทบาทค่อนข้างน้อยในการอธิบายพฤติกรรมการเคลื่อนไหวของอัตราผลตอบแทน ส่วนปัจจัยภูมิภาคและปัจจัยเฉพาะตัวเป็นปัจจัยที่มีความสำคัญมากกว่า นอกจากนั้น การตอบสนองของอัตราผลตอบแทนของแต่ละประเทศยังรวดเร็วกว่าสำหรับปัจจัยภูมิภาค เมื่อเปรียบเทียบกับปัจจัยโลก

World and regional factors in stock market returns

Suluck Pattarathammas and Anya Khanthavit
Department of Finance, Faculty of Commerce and Accountancy, Thammasat University, Bangkok, Thailand

Abstract

Purpose – This paper aims to test the hypothesis that the national stock market returns are driven by a world factor, regional factors and idiosyncratic factors, and to measure the importance of each factor.

Design/methodology/approach – The state-space model is applied to describe the sample returns and estimate a world factor, regional factors and idiosyncratic factors by Kalman filtering. Weekly and daily returns calculated from MSCI country indexes from January 1988 to December 2004 of 11 national stock markets in four regions, i.e. North America (the USA and Canada), South America (Brazil, Mexico and Chile), Europe (the UK, Germany and France), and Asia (Japan, Hong Kong, and Singapore) are used.

Findings – The results support the hypothesis that national market returns are driven by a world factor, regional factors and idiosyncratic factors. National markets do not always respond mainly to the world factor; regional factors and idiosyncratic factors play important roles as well. They also respond to world news at a slower rate than regional news.

Research limitations/implications – This paper does not identify the source or origins of news directly but the factors are assumed as random variables and are estimated under certain strict assumptions.

Originality/value – This paper applies Kalman filtering to estimate a world factor and regional factors and test the importance of each factor directly, an extension of previous studies that mostly showed strong independence among markets.

Keywords Stock markets, Stock returns, World economy, National economy, Factor analysis

Paper type Research paper

1. Introduction

Returns in national stock markets exhibit strong interdependence (Jaffe and Westerfield, 1985 and Becker *et al.*, 1992). Investors follow news closely on how major markets react and apply this knowledge as part of their investment strategies in their interested stock markets. Researchers like Eun and Shim (1989), Becker *et al.* (1990) and Hamao *et al.* (1990) reported that the US market was the most influential market, and that the US market return was able to explain and predict other national market returns (e.g. Japan, the UK, Germany and Canada). However, the US market itself must react to some fundamental factors or news but they could react to these factors at a faster rate. This belief led researchers to further study economic variables or world news that might be able to explain the movements in national stock markets. Jorion (1990), King *et al.* (1994), Harvey (1995), Harvey *et al.* (2002), Shackman (2006),

International Journal of Managerial Finance
Vol. 5 No. 2, 2009
pp. 222-241

1743-9132
DOI 10.1108/17439130910947912

Support from the Faculty of Commerce and Accountancy, Thammasat University, and the Professor Sangvian Indaravijaya Foundation is gratefully acknowledged. Anya Khanthavit also thanks the Thailand Research Fund for support.

and Nandha and Hammoudeh (2007) found that observed economic variables, such as exchange rates, world market portfolio, dividend yields, interest rates, industrial production index and commodity prices, could explain only small parts of the movements in national stock market returns. For example, Harvey *et al.* (2002) found that the amount of returns variance explained by the economic variables was about 5.7 percent on average (as shown by the adjusted R^2 values) for 18 countries. The study by Connolly and Wang (2003) found that macroeconomic news announcements made in the USA, the UK and Japan accounted for a very small part in explaining the return co-movement among national markets. Thus, strong interdependence and co-movement of stock returns must result from the returns being driven by common world factors, which are difficult to quantify or measure. Moreover, Engle and Susmel (1993), Bilson *et al.* (2001), Rangvid (2001), Chan-Lau and Ivaschenko (2003), Leong and Felmingham (2003), Climent and Meneu (2003), and Phengpis and Apilado (2004) found some evidence that regional factors in Europe and Asia could contribute to the interdependence of national markets in the same regions but they did not specify what the factors are and did not compare the importance between the world and regional factors directly.

This study tries to shed some light about how world factors, regional factors and idiosyncratic factors contribute to the stock price dynamics in national markets. We propose the hypothesis that the national market returns are driven by a common world factor, regional factors and idiosyncratic factors. A common world factor is defined as news (items) or innovations that impact all national markets. The examples of such factor would be the Asian crisis in July 1997 or the fear of the credit markets in the USA in August 2007, which caused all national markets to decline substantially. Regional factors are defined as news (items) or innovations that impact only the national markets in the same region but do not have any impacts on the rest of the markets. Idiosyncratic factors or country-specific factors are defined as news (items) or innovations that impact only one national market. Thus, the explanatory ability of the leading markets is from the common world and regional factors that drive all the returns.

It is important to test the hypothesis for at least three reasons. First, the findings will help us to understand the mechanism of information transmission in the world capital markets. That is, if all national market returns are driven by a common world factor and regional factors as in our hypothesis, correlation of returns on a market with lagged returns on other markets has to come from different degrees of market efficiency to acknowledge the information. These would contradict the findings that found information transmission from major markets (e.g. the USA and Japan) to other national markets, as the source of information might not necessarily originate from these leading markets.

Second, certain national market returns (e.g. the USA and Japan) are widely used as explanatory variables in regressions of other national market returns. If the common and regional factors drive the asset returns, as in our hypothesis, all the returns are endogenous. The regressions are mis-specified and generate biased and inconsistent estimators.

Third, we can investigate whether world or regional factors play a major role that drives national market returns. Previous studies did not investigate this issue directly.

This information should also be of interest for investors to learn what factors that they should put focus on.

In this study, we examine the hypotheses by decomposing national market returns into three parts. The first part is explained by a common world factor. Because this factor drives all the national market returns, we can consider this factor as being a world factor regardless of the origin of this factor. The second part is explained by a regional factor, which only drives returns of all the national markets within the same region without affecting those markets outside the region. The last part is explained by an idiosyncratic factor or a country-specific factor. Even though most of the world factor, regional factors and idiosyncratic factors cannot be directly observed by researchers as their data are unavailable, the investors must be able to observe them as the national markets tend to move together. We try to estimate these factors based on a state-space model by the Kalman filtering technique. The technique is a recursive, predictive updating technique that can determine the parameters of a process with unobserved regressors. We estimate the model and perform hypothesis tests, using weekly and daily return data from January 1988 to December 2004 on 11 national markets in four regions:

(1) North America (the USA and Canada);

(2) South America (Brazil, Mexico and Chile);

(3) Europe (the UK, Germany, and France); and

(4) Asia (Japan, Hong Kong and Singapore).

Our results support the hypothesis that the national market returns are driven by a world factor, regional factors and idiosyncratic factors.

The remainder of this paper is organized as follows. In Section 2, we explain previous frameworks and construct a state-space model to describe the return behavior in our sample markets and propose the tests for our hypothesis. The data description is in Section 3. We report the empirical results in Section 4 and conclude our study in Section 5.

2. Framework and methodology

2.1 Previous frameworks and methodologies

Generally, the studies of international stock returns could be divided into three groups. For the first group, researchers followed the international capital asset pricing models and related factor models by applying a regression approach, such as in Harvey (1995) and Harvey *et al.* (2002). They used a world market portfolio and other economic variables as fundamental factors to explain returns. The central intuition of these models was that only the pervasive sources of common variation should be priced. However, as pointed out earlier, these variables were only able to explain returns marginally. They could also face the problem of multicollinearlity as several variables are highly correlated such as interest rates and exchange rates. For the second group, researchers focused on the co-movements among international stock returns by applying a correlation test (Grubel, 1968; Solnik, 1974; Becker *et al.*, 1992) and cointegration test (Cheung, 1993; Chan *et al.*, 1992). They found that the co-movements among developed markets are stronger than the developing ones and there existed a long-term relationship among stock markets. However, the studies used bivariate tests, not multivariate tests, and could not specify what the fundamental factors that led to such relationships are. The last group focused on the information transmission among international stock markets by applying vector autoregressive (VAR) (e.g. Eun and Shim, 1989; Phylaktis, 1999), and generalized autoregressive conditionally heteroscedastic (GARCH) (e.g. Hamao *et al.*, 1990; Koutmos, 1996). Their models assumed that stock returns and volatilities were driven by present and past stock returns and volatilities from other markets. They generally found strong information transmission in both stock returns and volatilities. However, similar to the second group, they did not identify what the fundamental factors, which drove market returns, are. One exception was a research by King *et al.* (1994), which first estimated the VAR model like other papers in this group. They then used the residuals from the estimation and decomposed them into three parts:

(1) the common observable factor;

(2) the common unobservable factor; and

(3) specific risks.

They found that only a small portion of the covariance between national stock markets could be accounted for by observable economic variables, i.e. interest rates, exchange rates, industrial production, inflation, trade account, money supply, oil prices and commodity prices. Most of the portions were driven primarily by movements in unobservable variables, which they interpreted as unobservable fundamental variables that investors had ignored. The limitation was that the VAR model could fit the data rather well, which means that the residuals of their focus were actually a small portion of returns. Our study can be considered the extension of the last group by investigating directly whether there are fundamental factors originating information transmission among national stock markets. This is very similar to the concepts used by Gregory *et al.* (1997) and Bams *et al.* (2004) with other variables. In Gregory *et al.* (1997), the output, consumption and investment in seven countries were explained by the unobserved world common factor. In Bams *et al.* (2004), the exchange rates of four currencies were explained by the unobserved world common factor. These two papers were motivated by the fact that the variables – output, consumption, investment and exchange rates – tended to move together but the observed economic variables as indicated by theories could not explain the movements of these variables very well. Thus, the unobserved factor could be estimated by a state-space model and Kalman filtering.

2.2 The state-space model

In this study, we explain the movement of national market returns by a common world factor, regional factors and idiosyncratic factors. We assume that the idiosyncratic factors are independent and serially uncorrelated. The independence assumption is intended to express the role of the common factor and the regional factors as being the only factors to explain the interdependence and co-movement of returns at the world and regional levels. The serial-correlation assumption implies that the markets can absorb local news immediately. Our model, however, allows serial correlation of the world and regional factors. Hence, serial correlation of the returns must result from the market inefficiency to respond to the world factor or regional factors. This assumption is not unrealistic with respect to the geographical vicinity of information sources and to better understanding of local information content.

Let Y_t be an $(n \times 1)$ column vector of time t's returns on n national stock markets, let $\tilde{C}_{Wt}$ be time t's world factor, let $\tilde{C}_{Rt}$ be an $(m \times 1)$ column vector of time t's m regional factors and let E_t be an $(n \times 1)$ column vector of time t's idiosyncratic factors. We assume that the returns Y_t are related linearly[1] with a common factor, regional factors and their idiosyncratic factors as in equation (1):

$$Y_t = \sum_{j=0}^{p} A_j \tilde{C}_{Wt-j} + \sum_{j=0}^{q} \sum_{R=1}^{m} B_{Rj} \tilde{C}_{Rt-j} + E_t, \quad (1)$$

where A_j is an $(n \times p + 1)$ matrix of coefficients a_{ij} for $i = 1, \ldots, n$ and for $j = 0, 1, \ldots, p$. These coefficients describe the reaction of Y_t to the lagged world factor C_{Wt-j}, where n is the number of sample countries and p is the lag length. B_j is an $[n \times m(q+1)]$ matrix of coefficients b_{ij} for $i = 1, \ldots, n$ and for $j = 0, 1, \ldots, mp - 1$. These coefficients describe the reaction of Y_t to the lagged regional factor C_{Rt-j}, where n is the number of sample countries, m is the number of regional factors and q is the lag length. We assume that the idiosyncratic factors E_t are distributed multivariate normally with a zero mean vector and an $(n \times n)$ diagonal covariance matrix. H. h_i, the diagonal element i of matrix H, is the variance of country i's idiosyncratic factor. Moreover, $E\{E_t E_s\} = 0$ for $t \neq s$. This assumed structure reflects the independence and serial correlation assumptions for E_t.

We assume that the common factor $\tilde{C}_{Wt}$ and the regional factor $\tilde{C}_{Rt}$ are random walk, distributed normally with a zero mean and variance V. That is:

$$\tilde{C}_{Wt} = \tilde{\psi}_{Wt}, \quad (2)$$

$$\tilde{C}_{Rt} = \tilde{\psi}_{Rt}, \quad (3)$$

where $\tilde{\psi}_t \sim N(0, V)$ and $E\{\tilde{\psi}_t \tilde{\psi}_s\} = 0$ for $t \neq s$. The assumption $E\{\tilde{\psi}_t \tilde{\psi}_s\} = 0$ guarantees that $\tilde{C}_{Wt}$ and $\tilde{C}_{Rt}$ are news. The markets cannot predict $\tilde{C}_{Wt}$ and $\tilde{C}_{Rt}$ using any $\tilde{\psi}_{s<t}$. Finally, we assume that $\tilde{C}_{Wt}$, $\tilde{C}_{Rt}$ and E_t are independent to clearly separate the roles of a common world factor, regional factors and idiosyncratic factors.

Our model in equations (1) and (2) is very similar to the models used by Gregory *et al.* (1997) and Bams *et al.* (2004). In Gregory *et al.* (1997), the output, consumption and investment in seven countries were explained by the unobserved world common factor. That world factor was assumed to follow a random walk. In Bams *et al.* (2004), the exchange rates of four currencies were explained by the unobserved world common factor, which was also assumed to follow a random walk. However, both models differ from ours in that its dependent variables responded to the world factor in the current period only and regional factors were not taken into consideration. Our model is less restrictive since it allows the dependent returns to respond to the common factor and the regional factors on the current date as well as on previous dates.

The world factor, regional factors and idiosyncratic factors in equations (1) to (3) cannot be observed. In other words, we cannot use any available economic variables or news announcements like previous studies. However, we can estimate these factors from the realized return series, using the Kalman filtering technique. Since both factors and coefficients will be estimated, the problem of identification could arise. To tackle such a problem, Bams *et al.* (2004) imposed a normalization restriction of coefficient equals 1 on the British pound, which implied that the time variation of the risk premium associated with other currency i was scaled relative to the time variation of the British pound through the coefficient. Thus, we impose that the coefficient a_{US}, describing the reaction of Y_{US} to the world factor C_{W}, equals 1. We also impose that the coefficients b_{US}, b_{Brazil}, b_{UK} and b_{Japan}, describing the reaction of Y_t to the regional factor $C_{\mathrm{North\,America}}$, $C_{\mathrm{South\,America}}$, C_{Europe} and C_{Asia}, respectively, equal 1.

To proceed, we analyze the model in equations (1)-(3) in a state-space framework by interpreting the common factor $\tilde{C}_{\mathrm{W}t}$ and $\tilde{C}_{\mathrm{R}t}$as the state variables. The motion of the stock returns and the common factor can be modeled by the measurement equations (4.1) and (4.2) and the transition equations (5.1) and (5.2), respectively. The measurement equations relate the observed return variables linearly with the state variable by:

$$Y_t = \boldsymbol{AC}_t + E_t, \tag{4.1}$$

$$\begin{bmatrix} y_{1t} \\ \vdots \\ y_{nt} \end{bmatrix} = \begin{bmatrix} a_{10} & \cdots & a_{1p} & a_{1p+1} & \cdots & a_{1p+q+1} & 0 & 0 & 0 \\ \vdots & \ddots & \vdots & 0 & 0 & 0 & \cdots & 0 & 0 \\ a_{n0} & \cdots & a_{np} & 0 & 0 & 0 & 0 & \cdots & a_{np+m(q+1)} \end{bmatrix} \times \begin{bmatrix} C_t \\ \vdots \\ C_{\mathrm{W}t-p} \\ C_{\mathrm{R}1t} \\ \vdots \\ C_{\mathrm{R}1t-q} \\ \vdots \\ \vdots \\ C_{\mathrm{R}mt-q} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ \vdots \\ e_{nt} \end{bmatrix}, \tag{4.2}$$

where:

$$A_{[n\times p+m(q+1)+1]} = \begin{bmatrix} a_{10} & \cdots & a_{1p} & a_{1p+1} & \cdots & a_{1p+q+1} & 0 & 0 & 0 \\ \vdots & \ddots & \vdots & 0 & 0 & 0 & \cdots & 0 & 0 \\ a_{n0} & \cdots & a_{np} & 0 & 0 & 0 & 0 & \cdots & a_{np+m(q+1)} \end{bmatrix},$$

$$C_{t[p+m(q+1)+1\times 1]} = \begin{bmatrix} C_{Wt} \\ \vdots \\ C_{Wt-p} \\ C_{R1t} \\ \vdots \\ C_{R1t-q} \\ \vdots \\ \vdots \\ C_{Rmt-q} \end{bmatrix},$$

and:

$$E_{t(n\times 1)} = \begin{bmatrix} e_{1t} \\ \vdots \\ e_{nt} \end{bmatrix}.$$

The transition equations describe the evolution of the state variable by:

$$C_t = BC_{t-1} + R\psi_t, \tag{5.1}$$

$$\begin{bmatrix} C_{Wt} \\ \vdots \\ C_{Wt-p} \\ C_{R1t} \\ \vdots \\ C_{R1t-q} \\ \vdots \\ \vdots \\ C_{Rmt-q} \end{bmatrix} = \begin{bmatrix} 0 & \cdots & \cdots & 0 \\ 1 & 0 & \cdots & \vdots \\ 0 & \ddots & 0 & \vdots \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} C_{Wt-1} \\ \vdots \\ C_{Wt-p-1} \\ C_{R1t-1} \\ \vdots \\ C_{R1t-q-1} \\ \vdots \\ \vdots \\ C_{Rmt-q-1} \end{bmatrix} + \begin{bmatrix} 1 & \cdots & \cdots & 0 \\ 0 & 0 & \cdots & \vdots \\ \vdots & \ddots & 0 & \vdots \\ 0 & 1 & 0 & 0 \\ \vdots & 0 & 0 & 0 \\ \vdots & \ddots & \vdots & \vdots \\ \vdots & \ddots & 1 & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & \ldots & 0 \end{bmatrix} \begin{bmatrix} \psi_{Wt} \\ \psi_{R1t} \\ \vdots \\ \psi_{Rmt} \end{bmatrix}, \quad (5.2)$$

where:

$$\boldsymbol{B}_{[p+m(q+1)+1\times p+m(q+1)+1]} = \begin{bmatrix} 0 & \cdots & \cdots & 0 \\ 1 & 0 & \cdots & \vdots \\ 0 & \ddots & 0 & \vdots \\ 0 & 0 & 1 & 0 \end{bmatrix},$$

and:

$$R[p+m(q+1)+1\times 1+m] = \begin{bmatrix} 1 & \cdots & \cdots & 0 \\ 0 & 0 & \cdots & \vdots \\ \vdots & \ddots & 0 & \vdots \\ 0 & 1 & 0 & 0 \\ \vdots & 0 & 0 & 0 \\ \vdots & \ddots & \vdots & \vdots \\ \vdots & \ddots & 1 & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & \ldots & 0 \end{bmatrix}.$$

Harvey (1989)[2] explained that Kalman filtering could estimate the system of equations (4.2) and (5.2) by delivering recursive values that could be fed into the prediction error decomposition of the likelihood function. The estimation problem was then to maximize the likelihood function with respect to the parameter set $\{A,H,V\}$.

Some researchers (e.g. Hamao *et al.*, 1990; Lin *et al.*, 1994) applied the generalized autoregressive conditionally heteroscedastic (GARCH) model when financial data exhibited volatility clustering or changing volatility through time. We are aware of its advantage but we cannot incorporate the GARCH model or other models allowing changes in volatility with our proposed system of equations. This is because it will be impossible to estimate all variables. However, the assumption of constant volatility is still comparable and consistent with those papers applying multiple regression models.

2.3 Identification of lag length

In our model, the lag lengths p and q are not known and must be estimated. It is important to estimate p and q correctly. If the estimated $\hat{p}$ and $\hat{q}$ are too small, the model will be mis-specified. It should be noted that the model is highly non-linear in parameters and in data. Its complexity grows quickly with lag lengths p and q. Hence, if the specified p and q are too large, it is difficult for the parameter estimation to reach convergence. The model calibration is inefficient and can be imprecise.

We follow Harvey (1989) and use the Bayes information criterion (BIC) test to identify the lag lengths p and q. The BIC statistic is given by:

$$\mathrm{BIC} = |F|\exp\left(\frac{\ln(\mathrm{T})\times k}{T}\right), \tag{6}$$

where T is the number of observations, $|F|$ is the determinant of prediction error variance[3], and k is the total number of parameters in the system. The BIC test trades off reduction in the prediction error variance with reduction in degrees of freedom as lag length grows in parsimonious models. We will choose the lag length p^* and q^* that correspond to the minimum BIC statistic[4].

2.4 Existence of world factor and regional factors

We will use the model in equations (4.2) and (5.2) to examine how the world factor and the regional factors contribute to the return dynamics in our sample national markets. Our test is performed in two steps. In the first step, we test for existence of the world factor and the regional factors. If that common world factor and regional factors exist, we will proceed to the second step and test the level of importance that these factors play in the national markets.

2.4.1 Test for existence of world factor and regional factors. In equations (1) and (4), if the factor C_W is a common world factor, its current and/or lagged value must move the returns Y_t in all the national markets. This fact implies that the response coefficients a_{ij} must be significant for some lag $j = 0, 1, \ldots, p$ and for all countries i. Our null hypothesis for the existence of common world factor is:

$$H_0: a_{i0} = a_{i1} = \ldots = a_{ip} = 0, \tag{7}$$

for country $i = 1, 2, \ldots, n$. We will use a Wald test to test the hypothesis in equation (7). If the factor C_W cannot explain the return movement in country i, the Wald statistic will be distributed as an χ^2 variable with $p+1$ degrees of freedom. If the factor C_W is common to all the markets, the hypothesis must be rejected for all the sample countries.

Moreover, if the factor C_R is the regional factors, their current and/or lagged value must move the returns Y_t in all the national markets within the same region. This fact implies that the response coefficients b_{ij} must be significant for some lag $j = 0, 1, \ldots, q$ and for all countries i in the same region R. Our null hypothesis for the existence of a regional factor is:

$$H_0 : b_{Ri0} = b_{Ri1} = \ldots = b_{Riq} = 0, \tag{8}$$

for country $i = 1, 2, \ldots, k$, which are in the same region R. We will use a Wald test to test the hypothesis in equation (8). If the factor C_R cannot explain the return movement in country i, the Wald statistic will be distributed as a chi-square variable with $q+1$ degrees of freedom. If the factor C_R is the regional factor, the hypothesis must be rejected for all the sample countries in that particular region R.

2.4.2 Test for the importance of world factor and regional factor. We are aware of our large sample size of weekly and daily returns and the period span over 17 years. We analyze the share of the national market returns, explained by the world factor and regional factors.

Consider the structure of return i of region R in equations (1) and (4). The total variance σ_{yi}^2 of the return must be:

$$\sigma_{yi}^2 = \sum_{j=0}^{p} a_{ij}^2 \sigma_{C_W}^2 + \sum_{j=0}^{q} b_{Rij}^2 \sigma_{C_R}^2 + \sigma_{ei}^2 = \sum_{j=0}^{p} a_{ij}^2 v_W + \sum_{j=0}^{q} b_{Rij}^2 v_R + h_i. \tag{9}$$

Let $RW_i \leq 1.00$ denote the share of the variance σ_{yi}^2 to be explained by the world factor C_W. From equation (9), RW_i is:

$$RW_i = \frac{\sum_{j=0}^{p} a_{ij}^2 v_W}{\sigma_{yi}^2}. \tag{10}$$

Let $RR \leq 1.00$ denote the share of the variance σ_{yi}^2 to be explained by the regional factor C_R. From equation (9), RR_i is:

$$RR_i = \frac{\sum_{j=0}^{q} b_{Rij}^2 v_R}{\sigma_{yi}^2}. \tag{11}$$

3. Data description

In the empirical tests, we will use weekly and daily returns on 11 national stock markets in four regions:

(1) North America (the USA and Canada);

(2) South America (Brazil, Mexico and Chile);

(3) Europe (the UK, Germany and France); and

(4) Asia (Japan, Hong Kong, and Singapore).

These markets are the most important in terms of market capitalization in North America, South America, Europe, and Asia. The regional grouping was commonly done as can be seen from recent works such as Climent and Meneu (2003), Fujii (2005), and Verma and Ozuna (2005). Countries in the same region usually have similar industries, natural resources and economic linkages. Studies such as Engle and Susmel (1993), Rangvid (2001), and Climent and Meneu (2003) found some evidence that the co-movements among national markets was caused by regional factors. The returns are the logged difference of the countries' closing indexes. We use Morgan Stanley Capital International (MSCI) country indexes for all sample countries. Due to the availability of data, all the indexes are collected from the Datastream database from January 1988 to December 2004 covering the 1997 Asian crisis.

We construct the time-series returns very carefully. First, we consider only trading days on which all the markets open, in order to recognize national holidays for respective markets. Second, we are aware that the sample markets operate in different time zones. For the same trading day, the US, Canadian, Brazilian, Mexican and Chilean stock markets are the last to close. Following Eun and Shim (1989), for trading day t we will use day t's returns for the UK, German, French, Japanese, Hong Kong and Singapore markets and day $t-1$'s returns for the US, Canadian, Brazilian, Mexican and Chilean markets. Last, we use Wednesday's closing indexes to calculate weekly returns.

Table I reports the descriptive statistics of the sample daily and weekly returns. Their p-values are shown in parentheses. The test statistics of whether the means of daily returns are significantly different from zero show a similar pattern to those of weekly returns. The sample means of daily and weekly returns are positive and significantly different from zero for the sample returns in the USA, Canada, Brazil, Mexico, Chile, and France, while the sample mean returns in the UK, Germany, Hong Kong, and Singapore are positive but insignificantly different from zero. Only the returns in Japan are negative but insignificantly different from zero. Since our model in equations (1) and (4) does not include intercepts, the return series must be de-meaned before it is used in model calibration.

Table II reports correlations of sample weekly and daily returns. The sample returns seem to move together at the different degrees. The regional factor seems to be very strong for the case of North America and Europe with the correlations higher than 0.6 for all pairs of returns within the same region. On the other hand, the regional factor seems to play a very small role in South America as the correlations were lower than 0.3 for all cases. However, the correlations results measured the co-movement on a pair-wise basis and the results cannot indicate whether the strong co-movements came from the response to the world or regional factors.

4. Empirical results

We estimate a system of equations (4.2) and (5.2), using Kalman filtering for 0 and 1 lag specifications to identify the appropriate lag length p^*. The numbers of parameters and the BIC statistics for each specification are reported in Table III. We find that the BIC statistics of the 0-lag and 1-lag specifications are the smallest for the weekly and daily data, respectively. Thus, our analyses and tests to follow will be based on the 0-lag and 1-lag specifications for weekly and daily data, respectively. Since most of the 11 stock markets are developed markets, the national markets should be able to absorb

Table I. Descriptive statistics of the 11 national market returns

Statistics	Sample countries USA	Canada	Brazil	Mexico	Chile	UK	Germany	France	Japan	Hong Kong	Singapore
Mean	0.0004	0.0003	0.0047	0.0011	0.0007	0.0002	0.0003	0.0003	−0.0001	0.0003	0.0002
Daily returns	(0.0169)**	(0.0535)***	(0.000)*	(0.0000)*	(0.0000)*	(0.1166)	(0.1915)	(0.0762)***	(0.6460)	(0.1591)	(0.2804)
Standard deviation	0.0101	0.0092	0.0259	0.0157	0.0113	0.0099	0.0138	0.0125	0.0124	0.0164	0.0123
Mean	0.0018	0.0013	0.0234	0.0056	0.0035	0.0011	0.0014	0.0016	−0.0005	0.0017	0.0009
Weekly returns	(0.0191)**	(0.0699)***	(0.0000)*	(0.0000)*	(0.0009)*	(0.1298)	(0.1817)	(0.0911)***	(0.5862)	(0.1596)	(0.3671)
Standard deviation	0.0223	0.0214	0.0700	0.0395	0.0312	0.0220	0.0303	0.0286	0.0275	0.0352	0.0292

Notes: The returns are daily and weekly starting from January 1988 and ending December 2004 (4,435 observations for daily returns and 886 observations for weekly returns); *p*-values appear in parentheses; *Statistically significant at 99 percent; **statistically significant at 95 percent; ***statistically significant at 90 percent

Table II.
Correlation matrix among the 11 national market returns

	USA	Canada	Brazil	Mexico	Chile	UK	Germany	France	Japan	Hong Kong	Singapore
Weekly returns[a]											
USA	1.0000										
Canada	0.7097	1.0000									
Brazil	0.2070	0.2002	1.0000								
Mexico	0.4484	0.4127	0.2608	1.0000							
Chile	0.2705	0.2594	0.2654	0.2774	1.0000						
UK	0.6523	0.5021	0.1173	0.3280	0.1887	1.0000					
Germany	0.6308	0.5291	0.1785	0.3782	0.1909	0.6708	1.0000				
France	0.6335	0.5143	0.1726	0.3669	0.1862	0.7298	0.7992	1.0000			
Japan	0.3750	0.3500	0.1179	0.2532	0.1566	0.3583	0.3771	0.3687	1.0000		
Hong Kong	0.3935	0.4180	0.1595	0.3137	0.2235	0.4174	0.4096	0.3945	0.3065	1.0000	
Singapore	0.4259	0.3816	0.1425	0.2827	0.2041	0.3983	0.4076	0.3799	0.3574	0.5824	1.0000
Daily returns[b]											
USA	1.0000										
Canada	0.6569	1.0000									
Brazil	0.2458	0.2261	1.0000								
Mexico	0.4164	0.3583	0.2960	1.0000							
Chile	0.2256	0.2113	0.2654	0.2586	1.0000						
UK	0.2894	0.1652	0.0554	0.1203	0.0599	1.0000					
Germany	0.2889	0.1664	0.0781	0.1226	0.0591	0.6133	1.0000				
France	0.2895	0.1790	0.0784	0.1306	0.0463	0.7300	0.7187	1.0000			
Japan	0.2966	0.2322	0.1022	0.1700	0.1036	0.2383	0.2307	0.2380	1.0000		
Hong Kong	0.3211	0.2628	0.1269	0.2025	0.1074	0.2773	0.2973	0.2628	0.3193	1.0000	
Singapore	0.3449	0.2716	0.1215	0.1941	0.1169	0.2760	0.3040	0.2784	0.3484	0.5424	1.0000

Notes: [a]Returns are weekly starting from January 1988 and ending December 2004 (886 observations); [b]returns are daily starting from January 1988 and ending December 2004 (4,435 observations)

	Region	Lag			
World factor	North America	0	0	1	1
	South America	0	1	1	1
	Europe	0	0	1	1
	Asia	0	0	1	1
Regional factor	North America	0	0	0	1
	South America	0	0	0	1
	Europe	0	0	0	1
	Asia	0	0	0	1
k (number of parameters)		33	36	44	55
BIC					
Weekly data	($^*e$ − 36)	5.133[a]	5.2000	5.1537	5.2257
Daily data	($^*e$ − 43)	1.7670	1.7153	1.5647	1.4356[a]

Notes: Results for BIC test for lag length; the BIC statistic is computed as: $\text{BIC} = |F| \exp[\ln(T) \times k]/T$, where T is the numbers of observation, $|F|$ is the determinant of prediction error variance, and k is the total number of parameters estimated in all equations; [a]lowest BIC statistic

Table III. Identification of lag length

all the news within a week. However, for daily data, the markets could not absorb the news immediately and still responded to the news of the previous day. This is also consistent with most studies (Hamao *et al.*, 1990; Koutmos, 1996) that applied the GARCH (1,1) model.

Tables IV and V report the parameter estimates of the state-space model from a system of equations (4.2) and (5.2), using Kalman filtering from weekly and daily returns, respectively.

From Table IV, we find that all the estimates of coefficients are significant at a conventional confidence level with one exception for b_{Canada}. We test for significant response of the return on market i with the world factor, based on the hypothesis $a_i = 0$ using the t-test. From Table IV, we find that the estimated coefficients a_i are statistically significant at 99 percent for all the sample markets. The results support that the world factor exists and this factor drives all the markets to move together. Next, we test for significant response of the return on market i with the regional factors, based on the hypothesis $b_i = 0$ using the t-test. With the exception of the North America region, we also find that the estimated coefficients b_i are statistically significant at 95 percent for all the sample markets. The results support that the regional factors of South America, Europe and Asia exist and these factors also drive all the markets to move together within the same region. However, for the North American region, it seems that the US and Canadian stock markets do not have a regional factor affecting only these two markets. In other words, even though there is news originating from this North American region, they would drive all the national markets and would be included in the world factor under our definition. This is consistent with previous findings like Eun and Shim (1989) that found the US market to be the most influential.

We analyze the share of the national market returns, explained by the world factor and regional factors by using the ratios of RW and RR. Consistent with the earlier explanation, RW_{US} and RW_{Canada} are highest at 0.79 and 0.61, respectively, but their RR ratios are very small and not significantly different from zero. The European and

Table IV.
Estimation results of weekly returns

Parameters estimates and test statistics	North America		South America			Sample countries Europe			Asia		
	USA	Canada	Brazil	Mexico	Chile	UK	Germany	France	Japan	Hong Kong	Singapore
a_i	1.0000	0.8401	0.8408	1.0262	0.4872	0.7888	1.0909	1.0173	0.6288	0.8934	0.7419
		(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*
b_i	1.0000	−50.0341	1.0000	0.3471	0.3799	1.0000	1.7931	2.3581	1.0000	3.2586	4.4176
		(0.20)		(0.00)*	(0.00)*		(0.00)*	(0.00)*		(0.00)*	(0.01)**
q_W						0.00039					
						(0.00)*					
q_R	0.00000			0.00110			0.00006			0.00002	
	(0.4932)			(0.00)*			(0.00)*			(0.06)***	
RW_i	0.79	0.61	0.06	0.27	0.10	0.51	0.51	0.50	0.21	0.25	0.25
	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*
RR_i	0.00	0.00	0.22	0.08	0.16	0.13	0.21	0.41	0.03	0.20	0.54
	(0.49)	(0.49)	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.00)*	(0.06)***	(0.00)*	(0.00)*
$RW_i + RR_i$	0.79	0.61	0.28	0.35	0.26	0.63	0.72	0.91	0.24	0.45	0.79

Notes: The national market returns are described by: $Y_t = A\tilde{C}_{Wt} + \sum_{R=1}^{m} B_R \tilde{C}_{Rt} + E_t$, $\tilde{C}_{Wt} = \tilde{\psi}_{Wt}$, $\tilde{C}_{Rt} = \tilde{\psi}_{Rt}$ where Y_t is a (11×1) column vector of weekly returns at time t, A is a (11×1) column vector of coefficients whose elements a_i, for $i = 1, \ldots, 11$, describes the reaction of y_{it} to C_{Wt}, B_R is a (11×4) matrix of coefficients whose elements b_{Ri}, for $R = 1, 2, 3, 4$, and $i = 1, \ldots 11$ describes the reaction of y_{it} to C_{Rt}, $\tilde{C}_{Wt}$ is the world factor at time t, $\tilde{C}_{Rt}$ is a (4×1) column vector of the regional factors for $R = 1, 2, 3, 4$ at time t, E_t is a (11×1) column vector of the idiosyncratic factors at time t, $\tilde{\psi}_{Wt}$ is a series of independent disturbances with mean zero and variance q_W, $\tilde{\psi}_{Rt}$ is a series of independent disturbances with mean zero and variance q_R, E_t is $MVN(0,H)$, and $E(e_{it}, e_{jt}) = 0$ for $i \neq j$; RW_i denotes the share of the variance of return of market i accounted for by the response to the world factor; $RW_i = (a_i^2 v_W)/\sigma_{yi}^2$. RR_i denotes the share of the variance of return of market i accounted for by the response to the regional factor; $RR_i = (b_{Ri}^2 v_R)/\sigma_{yi}^2$; *statistically significant at 99 percent; **statistically significant at 95 percent; ***statistically significant at 90 percent

Table V.
Estimation results of daily returns

Parameters estimates and test statistics	North America USA	Canada	South America Brazil	Mexico	Chile	Sample countries Europe UK	Germany	France	Japan	Asia Hong Kong	Singapore
a_{1i}	1.0000	0.4028 (0.00)*	−0.3349 (0.00)*	0.2322 (0.00)*	−0.2006 (0.00)*	4.4353 (0.00)*	6.1445 (0.00)*	5.657 (0.00)*	2.0912 (0.00)*	3.1743 (0.00)*	2.3597 (0.00)*
a_{2i}	7.555 (0.00)*	5.9636 (0.00)*	8.5335 (0.00)*	8.3747 (0.00)*	3.3798 (0.00)*	2.9872 (0.00)*	4.049 (0.00)*	3.75 (0.00)*	4.9212 (0.00)*	6.6799 (0.00)*	5.1675 (0.00)*
b_{1i}	1.0000	0.3994 (0.00)*	1.0000	0.4241 (0.00)*	0.8904 (0.00)*	1.0000	1.3654 (0.00)*	1.6819 (0.00)*	1.0000	2.9192 (0.00)*	2.3132 (0.00)*
b_{2i}	−0.2042 (0.00)*	−0.0578 (0.00)*	0.3185 (0.00)*	0.0587 (0.00)*	0.5166 (0.00)*	−0.2685 (0.00)*	−0.2832 (0.00)*	−0.3045 (0.00)*	0.0050 (0.00)*	0.0359 (0.00)*	0.2839 (0.00)*
q_W						0.000001 (0.00)*					
q_R	0.00004 (0.00)*			0.00005 (0.00)*			0.00003 (0.00)*			0.00001 (0.00)*	
RW_i	0.58 (0.00)*	0.44 (0.00)*	0.11 (0.00)*	0.29 (0.00)*	0.09 (0.00)*	0.31 (0.00)*	0.30 (0.00)*	0.31 (0.00)*	0.18 (0.00)*	0.19 (0.00)*	0.21 (0.00)*
RR_i	0.39 (0.01)*	0.08 (0.00)*	0.08 (0.00)*	0.04 (0.00)*	0.42 (0.00)*	0.33 (0.00)*	0.31 (0.00)*	0.57 (0.00)*	0.07 (0.00)*	0.34 (0.00)*	0.39 (0.00)*
$RW_i + RR_i$	0.97	0.52	0.19	0.32	0.51	0.64	0.60	0.88	0.25	0.53	0.60

Notes: The national market returns are described by: $Y_t = \sum_{j=0}^{1} A_j \tilde{C}_{Wt-j} + \sum_{j=0}^{1}\sum_{R=1}^{m} B_{Rj}\tilde{C}_{Rt-j} + E_t$, $\tilde{C}_{Wt} = \tilde{\psi}_{Wt}$, $\tilde{C}_{Rt} = \tilde{\psi}_{Rt}$, where Y_t is a (11×1) column vector of daily returns at time t, A_j is a (11×2) column vector of coefficients whose elements a_i, for i = 1, …, 11, describes the reaction of y_{it} to C_{Wt}, B_{Rj} is a (11×8) matrix of coefficients whose elements b_{Ri} for R = 1, 2, 3, 4 and i = 1, …., 11 describes the reaction of y_t to C_{Rt}, $\tilde{C}_{Wt-j}$ is a (2×1) column vector of the world factor at time $t-j$, $\tilde{C}_{Rt-j}$ is a (8×1) column vector of the regional factors for $R = 1, 2, 3, 4$ at time $t-j$, and E_t is a (11x1) column vector of the idiosyncratic factors at time t; $\tilde{\psi}_{Wt}$ is a series of independent disturbances with mean zero and variance q_W, $\tilde{\psi}_{Rt}$ is a series of independent disturbances with mean zero and variance q_R, E_t is $MVN(0,H)$ and $E(e_{it}, e_{jt}) = 0$ for $i \neq j$. RW_i denotes the share of the variance of return of market i accounted for by the response to the world factor. $RW_i = (a_i^2 v_W)/\sigma_{yi}^2$; RR_i denotes the share of the variance of return of market i accounted for by the response to the regional factor. $RR_i = (b_{Ri}^2 v_R)/\sigma_{yi}^2$; *statistically significant at 99 percent

Asian markets are driven by both world and regional factors but the world factor is more important for the European markets. RW is about 0.5 and 0.2 for European and Asian markets, respectively. It is also interesting to find that among the Asian markets, the Japanese market has the lowest RW and very low RR of 0.03. This indicates that the Japanese market is driven mainly by its country-specific factor. For the South American region, RW_{Mexico} is 0.27 (this could be due to the AFTA), which is somewhat higher than the RW for the Asian markets, but its RR is very low at 0.08. The RW_{Brazil} and RW_{Chile} ratios are very low at 0.06 and 0.10, respectively, indicating that, like the Japanese market, they are driven mainly by their country-specific factors. If we look at the combined values of RW and RR for each market, the values are ranging from 0.24 for the Japanese market to 0.91 for the French market. The average value of RW and RR is 0.55, which has a higher explanatory power than those studies that followed factor models like Harvey (1995) and Harvey *et al.* (2002).

From Table V with daily data, we test for significant response of the return on market i with the world factor, based on the hypothesis $a_{ip} = 0$ using the t-test. From Table V, we find that the estimated coefficients a_{ip} are statistically significant at 99 percent for all the sample markets. The results support that the world factor exists and this factor drives all the markets to move together similar to what we find in Table IV with weekly data. Next, we test for significant response of the return on market i with the regional factors, based on the hypothesis $b_{iq} = 0$ using the t-test. We also find that the estimated coefficients b_{iq} are statistically significant at 99 percent for all the sample markets, which are somewhat different from what we find in Table IV with weekly data. These support that the regional factors of North America, South America, Europe and Asia exist and these factors also drive all the markets to move together within the same region. The different results between weekly and daily are mainly related to the existence of the North American regional factor. This could be due to the fact that we model the world and regional factor as news. Higher frequency data like daily data can capture how the stock markets respond to the news better. Moreover, with the exception of the European markets, estimated coefficients a_{2i} are larger than those a_{1i}, which means that most national markets do not absorb world news efficiently in the first day but respond more to the news of previous day. On the other hand, estimated coefficients b_{2i} are smaller than those b_{1i} for all markets, which means that all national markets absorb regional news more efficiently than the world news on the first day. This could be viewed as consistent to our assumption that all national markets could respond to local or country specific news immediately.

We then analyze the share of the national market returns, explained by the world factor and regional factors by using the ratios of RW and RR. The results for the South American and Asian regions are somewhat similar to those found in Table III for weekly data. However, for the North American region, the shares of RR_{US} and RR_{Canada} increase from near zero using weekly data to 0.39 and 0.08, respectively, using daily data. The shares of RW_{US} and RW_{Canada} decrease to 0.58 and 0.44, respectively, using daily data. The European region also shows a similar pattern. The share of RW decreases about 0.2 compared to the results from weekly data. The results also coincide with the 0.2 increase in RR for these markets. Similar to weekly data, the results indicate that the North American and the European markets are more responsive to the world factor than the Asian and the South American markets are. The European markets seem to respond to world and regional factors equally, while the rest of the markets respond to the factors at different magnitude. The US, Canadian, Brazilian Mexican and Japanese markets respond more to world news, while Chilean, Hong Kong and Singaporean markets respond more to regional news. For the combined values of *RW* and *RR* for each market, the values are ranging from 0.19 for the Brazilian market to 0.97 for the US market. The average value of RW and RR is 0.55, which is very close to that of weekly data. The results are consistent with those shown in Table II, but the results here provide much more information about how the returns are related. For the North American region, both the US and Canadian markets respond strongly to the world factor and this leads to the high correlations found between the two markets. For the European region, the UK, German and French markets respond equally to both the world and regional factors, and this also leads to the high correlations found between the three markets. For the Asian region, although the Japanese, Hong Kong and Singaporean markets respond equally (*RW* is about 0.2) to the world factor, the Japanese market responds only slightly to the regional factor. This leads to the low correlations found between the Japanese market and the other two Asian markets. On the other hand, the Hong Kong and Singaporean markets respond more to the regional factor (*RR* is about 0.3). Thus, the high correlation found between the two markets is originated more from the regional factor. For the South American region, the Brazilian, Mexican, and Chilean markets only slightly respond to both the world and regional factors, and this leads to low correlations among the three markets. Thus, the South American markets seem to be least affected by the world and regional news. Our results support the hypothesis that the national market returns are driven by a world factor, regional factors and idiosyncratic factors.

5. Conclusion

In this study, we develop a model to examine the stock price dynamics in national markets and propose the hypothesis that the national market returns are driven by a world factor, regional factors and idiosyncratic factors. We apply a state-space model to describe the sample returns and estimate a world factor, regional factors and idiosyncratic factors by Kalman filtering. Using weekly and daily return data on the eleven stock markets from four regions – North America (USA and Canada), South America (Brazil, Mexico and Chile), Europe (U.K., Germany and France) and Asia (Japan, Hong Kong and Singapore) – from January 1988 to December 2004, we find that the world factor and regional factor exist. The only exception is that the North American factor, affecting only the US and Canadian markets, cannot be found from a weekly data. The world factor can mostly explain returns of the North American markets, while the European markets respond equally to both world news and regional news on the daily basis. The Brazilian and Chilean markets are the least affected by the world factor, while the Mexican market shows slightly more responsiveness to the world factor than the Asian markets do. The markets respond to the world news at a slower rate than the regional news. National markets do not always respond mainly to the world factor but regional factors and idiosyncratic factors play important roles as well. Thus, following news in the North America and Europe is highly beneficial for investment in those two particular regions but it is less beneficial for investments in the Asian and South American markets. However, it could imply that to diversify risk, investors could still invest internationally as some markets are driven less by world and regional news.

Notes

1. The assumption of linearity is commonly used when researchers study any factors explaining the national market returns using regressions.
2. The derivation of Kalman Filter can be seen in Harvey (1993, pp. 89-90), which shows that the conditional mean estimator is the minimum mean square estimator (MMSE).
3. The prediction error (V_t) equals the actual returns (Y_t) minus the predicted returns ($Y_{t|t-1}$) from the Kalman Filtering technique. The prediction error variance (F) is estimated from $1/T\sum_{t=1}^{T} V_t V_t'$.
4. The Akaike Information Criteria (AIC) test is also a popular test for lag length. But we do not consider the AIC test in this study because, in tests with a large sample size like ours, the AIC test tends to bias toward selecting an over-parameterized model (Enders, 1995).

References

Bams, D., Walkowiak, K. and Wolff, C.C.P. (2004), "More evidence on the dollar risk premium in the foreign exchange market", *Journal of International Money and Finance*, Vol. 23, pp. 271-82.

Becker, K.G., Finnerty, J.E. and Gupta, M. (1990), "The intertemporal relation between the US and Japanese stock markets", *Journal of Finance*, Vol. 45, pp. 1297-306.

Becker, K.G., Finnerty, J.E. and Tucker, A.L. (1992), "The intraday interdependence structure between US and Japanese equity markets", *Journal of Financial Research*, Vol. 15, pp. 27-37.

Bilson, C.M., Brailsford, T.J. and Hooper, V.J. (2001), "Selecting macroeconomic variables as explanatory factors of emerging stock market returns", *Pacific-Basin Finance Journal*, Vol. 9, pp. 401-26.

Chan, K.C., Cup, B.E. and Pan, M.S. (1992), "An empirical analysis of stock prices in major Asian markets and the United Sates", *The Financial Review*, Vol. 27, pp. 289-307.

Chan-Lau, J.A. and Ivaschenko, I. (2003), "Asian flu or Wall Street virus? Tech and non-tech spillovers in the United States and Asia", *Journal of Multinational Financial Management*, Vol. 13, pp. 303-22.

Cheung, Y.L. (1993), "A note on the stability of the intertemporal relationships between the Asian-pacific equity markets and the developed markets-a non-parametic approach", *Journal of Business, Finance and Accounting*, Vol. 20, pp. 229-36.

Climent, F. and Meneu, V. (2003), "Has 1997 Asian crisis increased information flows between international markets", *International Review of Economics and Finance*, Vol. 12, pp. 111-43.

Connolly, R. and Wang, F. (2003), "International equity market comovements: economic fundamentals or contagion?", *Pacific-Basin Finance Journal*, Vol. 11, pp. 23-43.

Enders, W. (1995), *Applied Econometric Time Series*, Wiley, New York, NY.

Engle, R.F. and Susmel, R. (1993), "Common volatility in international equity markets", *Journal of Business and Economic Statistics*, Vol. 11, pp. 167-76.

Eun, C.S. and Shim, S. (1989), "International transmission of stock market movements", *Journal of Financial and Quantitative Analysis*, Vol. 24, pp. 241-56.

Fujii, E. (2005), "Intra and inter-regional causal linkages of emerging stock markets: evidence from Asia and Latin America in and out of crises", *International Financial Markets, Institutions, and Money*, Vol. 15, pp. 315-42.

Gregory, A.W., Head, A.C. and Raynauld, J. (1997), "Measuring world business cycles", *International Economic Review*, Vol. 38, pp. 677-701.

Grubel, H.G. (1968), "Internationally diversified portfolios: welfare gains and capital flows", *American Economics Review*, Vol. 58, pp. 1299-314.

Hamao, Y., Masulis, R.W. and Ng, V. (1990), "Correlations in price changes and volatility across international stock markets", *Review of Financial Studies*, Vol. 3, pp. 281-307.

Harvey, A. (1993), *Time Series Models*, Harvester-Wheatsheaf, Hemel Hempstead.

Harvey, A.C. (1989), *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge University Press, Cambridge.

Harvey, C.R. (1995), "Predictable risk and returns in emerging markets", *Review of Financial Studies*, Vol. 8, pp. 773-816.

Harvey, C.R., Solnik, B. and Zhou, G. (2002), "What determines expected international asset returns?", *Annals of Economics and Finance*, Vol. 3, pp. 249-98.

Jaffe, J. and Westerfield, R. (1985), "The weekend effect in common stock returns: the international evidence", *Journal of Finance*, Vol. 40, pp. 433-54.

Jorion, P. (1990), "The exchange rate exposure of US multinationals", *Journal of Business*, Vol. 63, pp. 331-45.

King, M., Setana, E. and Wadhwani, S. (1994), "Volatility and links between national stock markets", *Econometrica*, Vol. 62, pp. 901-33.

Koutmos, G. (1996), "Modeling the dynamic interdependence of major European stock markets", *Journal of Business Finance & Accounting*, Vol. 23, pp. 975-88.

Leong, S.C. and Felmingham, B. (2003), "The interdependence of share markets in the developed economies of East Asia", *Pacific-Basin Finance Journal*, Vol. 11, pp. 219-317.

Lin, W.L., Engle, R.F. and Ito, T. (1994), "Do bulls and bears move across borders? International transmission of stock returns and volatility", *Review of Financial Studies*, Vol. 7, pp. 507-38.

Nandha, M. and Hammoudeh, S. (2007), "Systematic risk, and oil price and exchange rate sensitivities in Asia-Pacific stock markets", *Research in International Business and Finance*, Vol. 21, pp. 326-41.

Phengpis, C. and Apilado, V.P. (2004), "Economic interdependence and common stochastic trends: a comparative analysis between EMU and non-EMU stock markets", *International Review of Financial Analysis*, Vol. 13 No. 3, pp. 245-63.

Phylaktis, K. (1999), "Capital market integration in the Pacific Basin Region: an impulse response analysis", *Journal of Financial Services Research*, Vol. 3, pp. 211-46.

Rangvid, J. (2001), "Increasing convergence among European stock markets? A recursive common stochastic trends analysis", *Economics Letters*, Vol. 7, pp. 383-9.

Shackman, J.D. (2006), "The equity premium and market integration: evidence from international data", *International Financial Markets, Institutions and Money*, Vol. 16, pp. 155-79.

Solnik, B. (1974), "Why not diversify internationally rather than domestically?", *Financial Analyst Journal*, Vol. 30, pp. 48-54.

Verma, R. and Ozuna, T. (2005), "Are emerging equity markets responsive to cross-country macroeconomic movements? Evidence from Latin America", *International Financial Markets, Institutions, and Money*, Vol. 15, pp. 73-87.

Corresponding author
Suluck Pattarathammas can be contacted at: suluckp@tu.ac.th

The Influence of Viral Hepatitis C Infection on Quality of Life

Abhasnee Sobhonslidsuk[1], Chatchawan Silpakit[2], Patchareeya Satitpornkul[1], Chaleaw Sripetch[1], and Anya Khanthavit[3]

---

[1]Department of Medicine, Faculty of Medicine, Ramathibodi hospital, Mahidol University, [2]Department of Psychiatry, Faculty of Medicine, Ramathibodi hospital, Mahidol University, [3]Faculty of Commerce and Accountancy, Thammasat University, Bangkok, Thailand. CORRESPONDENCE: Abhasnee Sobhonslidsuk, M.D., Department of Medicine, Ramathibodi hospital, 270 Praram 6 road, Rajathevi, Bangkok 10400 Thailand. Telephone: +66 (02) 201 1304; Fax: +66 (02) 201 1387; E-mail: teasb@mahidol.ac.th. The authors would like to thank Thailand Research fund (TRF) for providing a research grant.

TITLE PAGE

TITLE

The influence of viral hepatitis C infection on quality of life

RUNNING TITLE

Influence of viral hepatitis C on quality of life

AUTHORS

Abhasnee Sobhonslidsuk[1], Chatchawan Silpakit[2], Patchareeya Satitpornkul[1], Chaleaw Sripetch[1], Anya Khanthavit[3].

AFFILIATIONS

[1]Department of Medicine, Faculty of Medicine, Ramathibodi hospital, Mahidol University, [2]Department of Psychiatry, Faculty of Medicine, Ramathibodi hospital, Mahidol University, [3]Faculty of Commerce and Accountancy, Thammasat University, Bangkok, Thailand.

CORRESPONDENCE

Abhasnee Sobhonslidsuk, M.D.

Department of Medicine, Ramathibodi hospital

270 Praram 6 road, Rajathevi

Bangkok 10400 Thailand

Telephone: +66 (02) 201 1304; Fax: +66 (02) 201 1387; E-mail: teasb@mahidol.ac.th

ACKNOWLEDGEMENTS

The authors would like to thank Thailand Research fund (TRF) for providing a research grant.

ABBREVIATIONS:

Health-related quality of life (HRQL), hepatitis C virus (HCV), hepatitis B virus (HBV), Chronic Liver Disease Questionnaire (CLDQ), Short-Form 36 (SF-36)

ABSTRACT

The Influence of Viral Hepatitis C Infection

on Quality of Life

Aim: Chronic liver disease creates a reduction in health-related quality of life (HRQL). Disease severity, demographic, alcohol and comorbidity can affect HRQL. A reducing HRQL in chronic hepatitis C may be associated with comorbid medical illness, response to antiviral treatment, psychogenic disorder and diagnosis awareness. The influence of chronic hepatitis B on HRQL is not known. We aimed to compare HRQL in chronic hepatitis B and C, and to study for factors that affected the HRQL in Thai patients with chronic viral hepatitis.

Materials and methods: Normal subjects, subjects with chronic hepatitis B and C performed HRQL questionnaires: the Short-Form (SF) 36 and the Chronic Liver Disease Questionnaire (CLDQ), and the Hospital Anxiety Depression Scale (HADS) questionnaire. Demographic, socioeconomic and clinical data were collected. One-way ANOVA was used to compare mean differences among groups. Stepwise multiple regression analysis was used to assess the independent influence of variables on HRQL. P-value <0.05 was considered statistically significant.

Results: Up to now, 146 subjects were enrolled. Mean ages (range) were 42.8 (20-73) years. The number (%) of male to female ratio was 85: 61 (58.2%: 41.8%). There were 50, 59 and 37 subjects in normal, in chronic hepatitis B and in chronic hepatitis C groups. The greatest number of anxiety disorder was seen in chronic hepatitis C group. Hepatitis C viral infection impaired emotional function and worry subscales of the CLDQ significantly. Female, single status, low socioeconomic factor, viral load, anxiety and depressive disorders, but not the type of viral hepatitis, caused a reduction in HRQL.

Conclusions: HRQL in chronic viral hepatitis are affected by anxiety, depression, female gender, single status, socioeconomic factors and viral load. We do not have enough evidence to conclude that HBV and HCV infection affect HRQL in Thai patients, or if there is any difference of HRQL in chronic hepatitis B and C.

KEYWORDS

Health-related Quality of life, chronic hepatitis B, chronic hepatitis C, SF-36, CLDQ

The Influence of Viral Hepatitis C Infection on Quality of Life

INTRODUCTION

Health-related quality of life (HRQL) encompasses not only the impact of health on well-being but also the economic and environment aspects of an individual[1]. Many studies from other countries and from Thailand confirm that the presence of chronic liver disease creates a reduction in HRQL[1-5]. Recent literature on chronic liver disease and HRQL address the influence of disease severity, type of disease, demographic (:age and gender), alcohol and comorbidity with other medical conditions[1]. Hepatitis B virus (HBV) and hepatitis C virus (HCV) are two most common causes of chronic viral hepatitis leading to cirrhosis and hepatocellular carcinoma. HBV and HCV infection is endemic worldwide[6]. The current global estimates of the number of HBV infected and HCV-infected patients are 350 million and 170 million, respectively[6,7]. In Thailand, the estimate of HBV prevalence based on the presence of HBV surface antigen is 4.6-8% and the estimate of HCV infection based on anti-HCV screening in blood bank is 1.37%[6,8].

Evolving data from numerous studies indicates that HCV infection can diminish HRQL in the absence of advance liver disease[9-17], perhaps as a result of extrahepatic symptoms related to HCV, cognitive dysfunction related to HCV, or a negative synergy between HCV and comorbid psychosocial disorders[18-23]. The presence of comorbid medical illness leads to further diminution in HRQL[16]. Significant improvement in HRQL was observed among the sustained responders to antiviral therapy[9,13,17,24,25]. Nevertheless, disease labeling or awareness of HCV infection might give negative influence on HRQL instead of HCV infection itself[26,27]. Comparing to HCV, the influence of HBV infection on HRQL has not been known because of the shortage of HRQL research in HBV infection. There has been only one study that shows a reduction of mental area of the short-form 36 (SF36) in patients with chronic hepatitis B although the HRQL scores of chronic hepatitis B was higher than those of chronic hepatitis C[16]. The study consisted of 100 patients with chronic viral hepatitis, and the assessment of relating factors was done only for the type of viral hepatitis.

We aim to evaluate the contribution of types of viral hepatitis on HRQL in chronic viral hepatitis by comparing between HBV and HCV, and to study whether the reduction of HRQL in chronic viral hepatitis was determined by other factors, e.g. demographic, socioeconomic, psychosocial factors and severity of liver disease.

MATERIALS AND METHODS

Patients

Consecutive patients with chronic viral hepatitis B or C who visited Gastroenterology clinic between 1 March 2005 and 28 February 2006 were invited to participate with the study. Chronic viral hepatitis was defined by persistent elevation of serum transaminases above 1.5 times of upper normal limit for 3 to 6 months and positive of hepatitis B surface antigen (Abbott laboratories, North Chicago, IL) or antibody to hepatitis C virus (HCV) (Abbott laboratories, North Chicago, IL). Patients were excluded from the study if they had non-viral caused chronic hepatitis, had decompensate cirrhosis, were receiving antiviral drugs, had active medical comorbidity, or refused to participate with the study. Normal subjects who were healthy without history of medical illness were enrolled into the study. Data gathered from medical records include underlying disease, current medication, biochemistry testing and staging of liver disease from liver biopsy. The study patients were asked to self-administer the Thai version of Short-Form 36 Heath Survey (SF-36) and Chronic Liver Disease Questionnaire (CLDQ) questionnaires, and the Thai version of the Hospital Anxiety and Depression (HADS) designed for evaluating anxiety and depression. The answered questionnaires were checked for completeness by a research assistant who also helped interviewing illiterate patients. The study protocol was approved by the Hospital Ethical Committee and it was conducted by following the Helsinki Declaration guideline. Written informed consent was obtained prior to the study.

The SF-36 and the CLDQ Questionnaires

The SF-36 consists of 36 items divided into 8 domains of physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional and mental health, ranging from 0 to 100 with higher scores reflecting better perception of health. Physical functioning, role-physical, bodily pain and general health represent physical health scale whereas vitality, social functioning, role-emotional and mental health define mental health scale. The domain scores were calculated according to standard reference[28]. The CLDQ consists of 29 items arranged to 6 subscales of abdominal symptoms, fatigue, systemic symptoms, activity, emotional function and worry. Each item consists of 7 scales. Subscale score was calculated from all of the items of that subscale[29]. Overall CLDQ was calculated form the average of 6 subscales.

The Hospital Anxiety Depression Scale (HADS) questionnaire

There are 2 subscales, anxiety and depression, with seven items for each subscale in the HADS questionnaire. Four scales present in each item of the HADS with higher score, especially with the score over 11, indicates psychological disorders. All of the questionnaires were formally translated from the original versions and the validation of the questionnaires was reported elsewhere[5,30,31].

Data analysis

Data were entered into Excel spreadsheet (Microsoft corporation) and analyzed using SPSS (version 11.5; SPSS, Inc., Chicago, IL) Categorical data are described as number and percentage – n (%). Continuous data are presented as mean $\pm$ standard deviation (SD) and median (range). Statistical analysis of continuous data was performed with One-way Anova or non-parametric methods as appropriate. Chi-Square test was used for analysis of discrete data, which give us the preliminary understanding of the association of the HRQL and studied variables. Stepwise multiple regression analysis was used to study the influence of independent variables on CLDQ and SF-36 domains while controlling the effect of other variables. P-value less than 0.05 was considered as statistical significance. Variables entered to stepwise multiple regression were as following:

- Disease variables: type of chronic viral hepatitis (HBV, HCV), serum alanine aminotransaminase (ALT), viral load and pathological staging from liver biopsy
- Demographic variables: sex and age
- Socioeconomic variables: marital status, education level, presence of financial burden and career type
- Psychiatric comorbidity variables: anxiety and depression subscales of the HAD

If HBV or and HCV infection showed independent association with HRQL, a statistical test (: a Wald test or likelihood ratio test) would be used to compare the beta-coefficient (β) of HBV and HCV.

RESULTS

Characteristics of study patients

A total of 178 subjects were enrolled during the study period. Twenty-five patients were excluded due to the presence of active medical comorbidity, receiving antiviral drugs, non-viral caused chronic hepatitis, and having decompensated cirrhosis in one case. Medical records were unable to find for 7 patients. While this report was being written, data of 146 subjects were summarized for statistical analysis. Mean ages (range) were 42.8 (20-73) years. The number (%) of male to female ratio was 85: 61 (58.2%: 41.8%). There were 50, 59 and 37 subjects in normal, chronic hepatitis B and chronic hepatitis C groups. The details of clinical, demographic and socioeconomic data are showed in table 1. Comparing to both groups of chronic viral hepatitis, normal group consisted of higher number of young, females and singles. Anxiety disorder mostly appeared in patients with chronic hepatitis C but it was not the problem of patients with chronic hepatitis B. Regardless of previous studies that revealed clinical significance of emotional distress and depression specifically in patients with chronic hepatitis C[19-21,23], our study cannot demonstrate the association between depression and chronic hepatitis C or chronic hepatitis B in Thai patients.

Comparing HRQL scores of all groups (Table 2)

When HRQL of the 3 groups was assessed with the SF-36 which is a generic HRQL questionnaire, no significant difference of HRQL scores of each group was seen. However, the CLDQ, a liver disease specific questionnaire, showed that chronic hepatitis C group had impairment of emotional function and worry subscales of the CLDQ significantly.

Variables affect the SF-36 and CLDQ (Table 3 and 4)

For statistical analysis for independent factors associate with HRQL, important variables entering stepwise multiple regression analysis included age, sex, marital status, educational level, employment and career type, financial burden, type of viral hepatitis, serum alanine aminotransmiase, viral load, staging of liver pathology, anxiety and depression scores of the HADS. The type of chronic viral hepatitis (HBV and HCV) did not give any impact on HRQL. Female, single status, unemployed or blue-collar career diminished physical function, mental health and general health subscales of the SF-36, respectively. Viral load gave some minor effect on role-emotion. Anxiety and depression reduced many subscales of the SF-36 and the CLDQ, both mental and physical health areas.

DISCUSSION

A reduction of HRQL in chronic hepatitis C has been an interesting topic of research for many years. Most studies supported the finding that HCV infection diminished HRQL[9-20, 23-5]. There have never been studies of HRQL in chronic viral hepatitis in Asia, which is an endemic area of HBV, or any studies that compare the HRQL in chronic hepatitis B and C with adequate number of sample size. Although the prevalence of HCV infection in Thailand is much lower than that of HBV, the prevalence of 1.37% can be translated into the high number of patients who would suffer from the complication of chronic hepatitis C in the future. Our study is an on-going research and this paper is a preliminary report that reveals what have been found so far. We recruited 50 normal subjects, 59 patients with chronic hepatitis B and 37 patients with chronic hepatitis C. Similar to previous studies in Western population[19-23], psychosocial problems especially anxiety disorder were more prevalent in Thai patients with chronic hepatitis C. Few Thai patients with chronic hepatitis B suffered from anxiety and depressive problems. It may suggest that chronic hepatitis C increase anxiety, but not depression, while compared to chronic hepatitis B in Thai patients.

By univariate analysis, there were no differences of HRQL among three groups except for the lowest scores of emotional function and worry subscales of the CLDQ in chronic hepatitis C group. The reason that our study does not show the homogeneous reduction of all HRQL in chronic hepatitis C may be explained by inadequate sample size. Multiple regression analysis showed the strong influence of anxiety and depression on mental and physical areas of HRQL by both generic and disease-specific questionnaires. Furthermore, other factors that were found to decrease HRQL consisted of female gender, single status, unemployment or blue-collar career and viral load. From our study, HBV and HCV did not diminish HRQL. As far as we know, there have been only 2 studies that could not demonstrate the negative effect of HCV infection on HRQL[26,27].

In summary, our preliminary report reveals a high number of anxiety disorders in Thai patients with chronic hepatitis C. We do not have enough evidence to conclude that HBV and HCV infection affect HRQL in Thai patients, or if there is any difference of HRQL in chronic hepatitis B and C. More patients with chronic viral hepatitis will be enrolled into our study and the final conclusion may be changed.

REFERENCES

Martin LM, Sheridan MJ, Younossi ZM. The impact of liver disease on Health-related quality of life: A review of the literature. *Curr Gastroenterol Rep* 2002:4:79-83.

Marchesini G, Bianchi G, Amodio P, et al. Factors associated with poor health-related quality of life of patients with cirrhosis. *Gastroenterology* 2001;120:170-8.

Younossi ZM, Boparai N, Price LL, et al. Health-related quality of life in chronic liver disease: The impact of type and severity of disease. *Am J Gastroenterol* 2001;96:2199-2205.

Younossi ZM, Boparai N, Cormick M, et al. Assessment of utilities and health-related quality of life in patients with chronic liver disease. *Am J Gastroenterol* 2001;96:580-3.

Sobhonslidsuk A, Silpakit C, Kongsakon R, Satitpornkul P, Sripetch C. Chronic Liver Disease Questionnaire: Translation and validation in Thais. *World Journal Gastroenterology* 2004;10(13):1954-7.

Custer B, Sullivan SD, Hazlet TK, et al. Global epidermiology of hepatitis B virus. *J Clin Gastroenterol* 2004;38:S158-68.

Centers for Disease Control and Prevention (CDC). Recommendations for prevention and control of hepatitis C virus (HCV) infection and HCV-related disease. *MMWR Morb Mortal Wkly Rep* 1998;47:1-40.

Wiwanitkit V. Anti HCV seroprevalence among the voluntary blood donors in Thailand. *Hematology*. 2005 Oct;10:431-3.

Bonkovsky HL, Woolley JM. Consensus Interferon Study Group. Reduction of health-related quality of life in chronic hepatitis C and improvement with interferon therapy. *Hepatology* 1999;29:264-70.

Foster GR, Goldin RD, Thomas HC. Chronic hepatitis C virus infection causes significant reduction in quality of life in the absence of cirrhosis. *Hepatology* 1998;27:209-12.

Hunt CM, Dominitz JA, Bute BP, et al. Effect of interferon treatment of chronic hepatitis C on health-related quality of life. *Dig Dis Sci* 1997;42:2482-6.

Bayliss MS, Gandek B, Bungay KM, et al. A questionnaire to assess generic and disease specific health outcomes of patients with chronic hepatitis C. *Qual Life Res* 1998;7:39-55.

Ware JE, Bayliss MS, Mannocchia M, et al. Health-related quality of life in chronic hepatitis C. Impact of disease and treatment response. *Hepatology* 1999;30:550-5.

Davis GL, Balart LA, Schiff ER, et al. Assessing health-related quality of life in chronic hepatitis C using the Sickness Impact Profile. *Clin Ther* 1994;16:334-43.

Chong CA, Gulamhussein A, Heathcote J, et al. Health-related utilities and quality of life in hepatitis C patients. *Am J Gastroenterol* 2003;98:630-8).

Hussain KB, Fontana RJ, Moyer CA, et al. Comorbid illness is an important determinant of health-related quality of life in patients with chronic hepatitis C. *Am J Gastroenterol* 2001;96:2737-44.

Spiegel B, Younossi ZM, Hays RD, et al. Impact of hepatitis C on health-related quality of life: A systematic review and quantitative assessment. *Hepatology* 2005;41:790-800.

Nocente R, Ceccanti M, Bertazzoni G, et al. HCV infection and extrahepatic manifestations. *Hepatogastroenterology* 2003;50:1149-54.

Fontana RJ, Hussain KB, Schwartz SM, et al. Emotional distress in chronic hepatitis C patients not receiving antiviral therapy. *J Hepatol* 2002;36:401-7.

Forton DM, Thomas HC, Murphy CA, et al. Hepatitis C and cognitive impairment in a cohort of patients with mild liver disease. *Hepatology* 2002;35:433-9.

Forton DM, Taylor-Robinson SD, Thomas HC. Cerebral dysfunction in chronic hepatitis C infection. *J Viral Hepat* 2003;10:81-6.

Forton DM, Allsop JM, Main J. Evidence for a cerebral effect of the hepatitis C virus. *Lancet* 2001;358:38-9.

Hauser W, Zimmer C, Schiedermaier P, et al. Biopsychosocial predictiors of health-related quality of lifer in patients with chronic hepatitis C. *Psychom Med* 2004;66:954-8.

Bernstein D, Kleinman L, Barker CM, et al. Relationship of health-related quality of life to treatment adherence and sustained response in chronic hepatitis C patients.

Hepatology 2002;35:704-8.
McHutchison JG, Ware JE, Bayliss MS, et al. The effect of interferon alpha-2b in combination with ribavirin on health related quality of life and work productivity. *J Hepatol* 2001;34:140-147.
Dalgard O, Egeland A, Skaug K, et al. Health-related quality of life in active injecting drug users with and without chronic hepatitis C virus infection. *Hepatology* 2004;39:74-80.
Rodgers AJ, Joller D, Thompson SC, et al. The impact of diagnosis of hepatitis C virus on quality of life. *Hepatology* 1999;30:1299-1301.
Ware JE, Snow KK, Kosinski MK, Gadnek B. *Scoring the SF-36. In: SF-36 Health Survey: Manual and interpretation Guide*. Boston, MA: Nimrod Press, 1992.
Younossi ZM, Guyatt G, Kiwi M, Boparai N, King D. Development of a disease specific questionnaire to measure health related quality of life in patients with chronic liver disease. *Gut* 1999;45:295-300.
Kongsakon R, Silpakit C. Thai version of the medical outcome study in 36 items short form health survey: an instrument for measuring clinical results in mental disorder patients. *Rama Med J* 2000;23:8-19.
Nilchaikovit T, Lotrakul M, Pisalsutidech U. Thai HADS. *J Psychiatr Assoc Thailand* 1996;41:18-30.

Table 1

Characteristics of study patients

Variables	Normal	Chronic Hepatitis B	Chronic Hepatitis C	*P*-value
Number	50	59	37	
Mean (SD) age, year	38.9 (11.4)	43.1 (10.9)	47.8 (11.1)	.001
Sex, n (%) **- Male**	20 (40.0%)	43 (72.9%)	22 (59.5%)	0.00
Marital status*, n (%) **- Single**	24 (48.0%)	22 (37.3%)	8 (21.6%)	0.04
Educational level*, n (%) **- Lower than bachelor degree**	18 (36.0%)	26 (44.1%)	20 (54.1%)	0.24
Career, n (%) **- Unemployed or blue collar**	6 (12.0%)	6 (10.2%)	4 (10.8%)	0.95
Financial burden, n (%) **- Present**	16 (32.0%)	16 (27.1%)	12 (32.4%)	0.81
Anxiety score	5.8 (3.0)	6.1 (2.7)	7.4 (3.8)	0.07
Anxiety score ≥11	4 (8.0%)	2 (3.5%)	6 (18.8%)	0.048
Depression score	4.2 (3.4)	4.1 (3.0)	4.4 (3.0)	0.94
Depression score ≥11	3 (6.0%)	2 (3.5%)	1 (3.1%)	0.76

Table 2

HRQL scores in each group of patients

HRQL scores	Normal	Chronic Hepatitis B	Chronic Hepatitis C	*p*-value
Mean (SD) SF36 scores				
Physical functioning	75.3 (19.4)	73.9 (19.1)	71.6 (25.6)	0.72
Role-physical	75.5 (38.3)	69.1 (39.2)	71.6 (39.2)	0.69
Bodily pain	69.7 (23.2)	76.1 (22.1)	73.5 (24.0)	0.36
General health	61.0 (21.0)	54.0 (21.8)	55.3 (19.9)	0.20
Vitality	63.0 (16.0)	65.4 (17.0)	61.0 (14.3)	0.40
Social functioning	79.0 (22.8)	79.2 (20.6)	77.7 (18.7)	0.94
Role-emotional	75.3 (37.4)	75.1 (38.4)	67.6 (39.7)	0.58
Mental health	67.4 (17.1)	73.9 (17.0)	69.7 (15.0)	0.12
Mean (SD) CLDQ Scores				
Abdominal symptoms	5.6 (1.2)	5.4 (1.3)	5.4 (1.1)	0.58
Fatigue	5.0 (1.1)	4.8 (1.1)	4.8 (1.0)	0.58
Systemic symptoms	5.6 (1.1)	5.5 (1.0)	5.3 (1.0)	0.48
Activity	5.5 (1.2)	5.4 (1.2)	5.4 (1.2)	0.73
Emotional function	5.3 (1.1)	5.3 (1.0)	4.8 (1.1)	0.03
Worry	6.0 (1.0)	5.1 (1.2)	4.7 (1.3)	0.00
Overall CLDQ	5.5 (1.0)	5.2 (1.0)	5.1 (1.0)	0.08

Table 3

Variables affect SF-36 domains*

	Physical function	Role-physical	Bodily pain	General health	Vitality	Social function	Role-emotion	Mental health
Anxiety				-3.1 (0.7)		-3.4 (0.60)		-2.2 (0.5)
Depression	-2.3 (0.9)	-5.0 (1.6)	-2.8 (0.9)		-3.7 (0.5)		-6.6 (1.4)	-2.3 (0.6)
Female	-16.2 (5.4)							
Single								-9.0 (2.9)
Unemployed /blue collar				-15.7 (7.0)				
Viral load							-1.3×10^{-7} (0.00)	
F-Statistic	$8.8^{\#}$	$9.9^{\#}$	$9.7^{\#}$	$12.2^{\#}$	$46.3^{\#}$	$32.0^{\#}$	$14.4^{\#}$	$25.9^{\#}$
R^2	0.21	0.13	0.13	0.27	0.41	0.33	0.31	0.62

*Only data with p-value <0.05 are expressed as β-coefficient (SEM)

$^{\#}p < 0.005$

Table 4

Variables affect CLDQ domains*

	Abdominal symptoms	Fatigue	Systemic symptoms	Activity	Emotional function	Worry	Overall CLDQ
Anxiety	-0.2 (0.0)	-0.1 (0.0)	-0.2 (0.0)	-0.2 (0.0)	-0.2 (0.0)		-0.1 (0.0)
Depression					-0.1 (0.0)	-0.3 (0.1)	-0.1 (0.1)
F-Statistic	28.5[#]	15.3[#]	24.9[#]	20.1[#]	42.3[#]	36.4[#]	29.7[#]
R^2	0.3	0.20	0.27	0.23	0.6	0.4	0.5

*Only data with p-value <0.05 are expressed as β-coefficient (SEM)

[#]$p < 0.001$