ISSN 2229-6891

INTERNATIONAL RESEARCH JOURNAL OF

APPLIED FINANCE

Volume. IV Issue. 5 May 2013

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An Analysis of the Impact of Continuous Reporting and Continuous Assurance of Financial Data on the Fundamental Fixation of Individual Investors

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Abstract

Prior research has shown that individual investors remain fixated on certain elements of fundamental financial data, including the stock price, when making investment decisions (Ashton, 1976; Tinic, 1990; Hand, 1990; Araunachalam and Beck, 2002). This fixation holds even when presented with additional data or when data is presented in various formats. The impact of continuously reported fundamental financial data, with and without assurance, on the functional fixation of individual investors is the focus of this study.

An experiment was conducted wherein independent variable manipulation was implemented using a 2 X 2 design. Reporting was manipulated at two levels: periodic and continuous. Assurance was manipulated at two levels: no assurance and with assurance. Data were collected on the dependent variables Rank and Reliance.

The results indicate that the fixation remains even when investors are presented with fundamental financial data on a more continuous basis and the presence or absence of assurance does not impact the fixation. However, there is some indication that additional quantities of information presented more continuously may erode the fixation to some degree.

Key words: fundamental fixation, continuous reporting, continuous assurance, individual investors

Introduction

Much research has been done to examine the functional fixation hypothesis: individual investors fixate on certain elements of fundamental financial data when making their investment decisions (Ashton, 1976; Tinic, 1990; Hand, 1990; Araunachalam and Beck, 2002). The extant literature has shown that functional fixation holds even when the data is presented in various formats or in various quantities. The advent of more continuously reported fundamental financial data and the ability to render assurance on the data as it is reported is on the near-term horizon (Vasarhelyi. and Halper,1991; Rezaee, Ford, Elam, 2000; Kogan, Sudit, Vasarhelyi, 1999; Hunton, Wright, Wright, 2003: Alles, Kogan, Vasarhelyi, 2002). This study extends the extant literature by examining functional fixation within an investment environment of continuous reporting (with and without assurance) of fundamental financial data. An experiment was conducted wherein independent variable manipulation was implemented using a 2 X 2 design. Reporting was manipulated at two levels: periodic and continuous. Assurance was manipulated at two levels: no assurance and with assurance. Data were collected on the dependent variables Rank and Reliance to examine the perceived usefulness of the various elements of financial data.

Background Literature and Hypothesis Development

Previous literature regarding functional fixation has focused on both the market as a whole and on individual investors (Ashton, 1976; Tinic, 1990; Hand, 1990; Araunachalam and Beck, 2002). The focus of this study is on individual investors. Prior studies have shown evidence that unsophisticated individual investors fixate on one or more items of fundamental financial data, such as earnings, when making their investment decisions and fail to adjust their decision process when a change is made to the way the data is derived.

Continuous reporting (CR) and continuous assurance (CA) have been discussed in the literature for more than two decades. Alles, et al. (2002) describe the elements of technology that must exist for the implementation of CR and CA. The AICPA and the CICA commissioned a report on the feasibility and implementation of CA (CICA/AICPA 1999), including reports and a variety of other information. Despite the broad based nature of the research involving CR and CA, there is a lack of agreement regarding a precise definition of each. For purposes of this study the following definitions will be used:

Continuous Reporting: The ongoing, real-time reporting of both financial and non-financial information to external parties (Cohen, et al., 2003).

Continuous Assurance: The ongoing, real-time, independent third-party assurance of both financial and non-financial information (Adapted from (CICA/AICPA, 1999).

This study does not address a change in accounting method, but rather a change in the reporting method for the fundamental financial data. A base period is included which acts to 'train' or encourage the investors to fixate on a limited set of data for the decision process. The investor is then informed of a change in the reporting system and is provided with a greater quantity of data (with or without assurance) for the treatment period. The additional quantity of data is reported either periodically or continuously. It is hypothesized that by providing the additional items of fundamental data on a more continuous basis, the individual investor will be prompted to include more elements in their decision process and the effects of functional fixation will be attenuated. Assurance on the data is also expected to reduce the effects of functional fixation

Pursuant to the discussion, the following hypotheses were developed. Each hypothesis is stated in the alternative.

H1: Investors will exhibit a lesser degree of functional fixation when presented with fundamental financial data that is continuously reported than when presented with fundamental financial data that is periodically reported.

H2: Investors will exhibit a lesser degree of functional fixation when presented with fundamental financial data is accompanied by assurance than when presented with fundamental financial data that is not assured.

Experiment Methodology

A behavioral experiment was designed to test the hypotheses, as discussed below.

Research Design

A 2 X 2, experimental design with a base-level period for all groups is utilized. Reporting periodicity is manipulated at two levels, Periodic (modeled as reporting every tenth decision period) and Continuous (modeled as reporting every decision period). Assurance is manipulated at two levels, No Assurance and Assurance. The Base Level (modeled as no reporting, no assurance), represents the current reporting and assurance paradigm. The study was implemented in a laboratory experiment with participants randomly assigned to the treatment conditions. Figure 1 illustrates the manipulation of the independent variables.

Experimental Procedure

The experiment was conducted entirely via an Internet-based research instrument. Multiple pilot tests were conducted and the instrument constructed so that the experiment was completed entirely on-line. Multiple experimental sessions were conducted using volunteer student participants for data collection. Each participant completed the experiment in a classroom lab. Each participant was randomly assigned to one of the four treatment groups. Initially, each participant completed the informed consent form. The participant then received information explaining the task and company data. The participant was allowed to read through the explanatory screens at his/her own pace. When the participant completed reading the explanatory screens, the stock price prediction task began. The stock price prediction task was composed of 65 decision periods and lasted about 45 minutes. After the stock price prediction task was completed, the participant was asked a series of questions to collect demographic data including investing experience, education, major, age and gender. Then the participant was then asked a series of questions to collect dependent variable information. Finally, the participant responded to a series of manipulation check questions and other questions to capture covariate data. The total time for the experiment was less than one hour.

Figure 1 Independent Variable Manipulations
(Note: All Participants are in the same group in the Base Period)

		Reporting Periodicity	Treatment Groups	
		None	Periodic	Continuous
Assurance	No	Base period	I. Periodic reporting without assurance	III. Continuous reporting without assurance
	Yes		II. Periodic reporting with assurance	IV. Continuous reporting with assurance

Task
The experiment was a stock price prediction task. Participants made stock price prediction decisions for 65 prediction periods. The participants were required to make a prediction regarding whether the stock price will go up or down in the next period. The participants were given a maximum of 45 seconds to make each prediction. They were able to move to each subsequent prediction period at their own pace, subject to the 45 second time limit. The financial information and stock price data were developed using the actual 65 day stock price for a widely traded stock. This allowed for determination in advance of the correct prediction.

The stock price prediction task was determined to be a valid proxy for the 'buy or sell' investment decision and was deemed to be a task more appropriate for the student participant pool than other similar tasks, such as predicting the stock price.

During the stock price prediction task, each participant's screen displayed information regarding the prediction period number, the number of seconds left in the prediction period (this counted down from 45 for each period), fundamental financial data for the treatment, and the menu buttons for the two predictions: 'the stock price will go up' or 'the stock price will go down.' Participants were informed that they must make a prediction in each period and would not be allowed to proceed to the next prediction period until they had made a prediction.

During the first 30 prediction periods, the fundamental financial data displayed on the prediction screens included three items: current stock price, previous period stock price, percentage of change in the stock price (either increase or decrease) from the previous period. The first 30 decision periods served as a 'base period' wherein all participants were in the same treatment condition.

At the end of the first 30 decision periods, the participants were informed that the company was testing a new accounting information system and the participants would be using the new system for the remaining predictions. The participants were then provided with fundamental financial data and audit/assurance reporting according to the four treatment groups for 35 more decision periods as now described.

In the second set of 35 prediction periods, participants were provided with the original three

items of financial data plus ten additional items of fundamental financial information (see Figure 1) and auditor reports and assurance reports pursuant to the specific treatment condition. Participants in the Periodic Reporting condition received the original three items in each decision periods and the additional ten items of financial information every tenth decision period. Participants in the Continuous Reporting condition received the original three items plus the additional ten items of financial information in each decision period.
Participants in the Assurance conditions were able to access a standard independent auditor's report in each decision period by clicking on a button 'Audit Report'. The auditor's report referred to a separate assurance probability assessment report that was updated each time new financial data was presented. For participants in the Periodic Reporting with Assurance condition, both reports were available in every tenth decision period. For participants in the Continuous Reporting with Assurance condition, both reports were available in each decision period. The assurance probability assessment reports provided a probability assessment regarding the reliability of the ten items of fundamental financial data. The probabilities used in the reports were generated using a random number generator with values between 87-97% and was displayed in red. A common set of assurance probability reports was used for both assurance conditions. The use of assurance probabilities and displaying the probabilities in red was intended to encourage participants to attend to the reports.

Participants
Participants for the experiment consist of ninety-seven undergraduate students from a large Southeastern university. See Table 1 for participant demographic descriptive statistics. Most of the students were upper-level accounting students enrolled in intermediate accounting (80) and all students were required to participate in a research experiment as part of their course requirements. They received course credit for their participation. Students have been shown to be appropriate surrogates for relatively unsophisticated individual investors in previous studies (Hunton, Reck, Pinsker, 2002; Libby, et al., 2002), In addition, a study conducted in 1989 by Gomez Advisors found "more than 11 percent of all online traders were age 25 or under, with 5 percent of their trades being made from colleges and universities" (Libbon 2001, p.55).
The participant pool contained 55 (57%) female participants and 42 (43%) male participants. The participants ranged in age from eighteen years to fifty-four years, with ninety-three percent between 18-32 years of age. A majority of the participants were accounting majors (80%) and ninety percent had taken three or fewer finance courses. None of the students had taken an auditing class. In addition, most had no previous experience with buying/selling common stock (77%) or mutual funds (78%). However, eighty-seven percent indicated they planned to invest in common stock or mutual funds in the future.

Financial data for research instrument
The set of financial data for the research instrument was developed as follows. Initially, data were collected from a focus group of students (the experimental participant population) regarding the specific items of financial information they would find useful in making a stock purchase/sell decision. The resulting set of student selected items were compared to financial information items found to be predictive of stock price returns in the accounting literature (Ou and Penman, 1989a; Ou and Penman, 1989b; Ou, 1990; Holthausen and Larcker, 1992; Lev and Thiagarajan, 1993). Ten items of financial information were then selected to be used in the research instrument; listed in Figure 2. The initial value of these items is based on the financial statements of the task company. The next step in the development of the financial data used in the research instrument was to collect stock price data for a 65 day period for a

publicly traded company. The financial information items were sorted into primary predictors, secondary predictors and tertiary predictors, as indicated in Figure 2. In the research instrument, changes in the stock price lag changes in the primary predictors by two days, secondary predictors by three days and tertiary predictors by five days. This was accomplished by reverse calculating the financial data based on changes in the stock price. Figure 2 provides the formulae used to calculate each of the three types of predictors.

Table 1 Participant Demographic Data for Initial Data Set

(n = 97)

Demographic Information Items			
Gender:			
Male	42	Female	55
Age:			
18 - 22	57		
23 - 27	23		
28 - 32	10		
33 - 37	4		
38 - 42	0		
43 - 47	1		
48 - 52	1		
53 -57	1		
Major:			
Accounting	80		
Business	8		
Finance	2		
Marketing	3		
Other Majors/Postgraduates	4		
Finance Courses Taken/Taking:			
0-2	88		
3-5	7		
6-11	2		
Accounting Courses Taken/Taking:			
0-2	78		
3-5	19		
Previous Experience Buying/Selling Common Stock			
No	75		
Yes	22		
Previous Experience Buying/Selling Mutual Funds:			
No	76		
Yes	21		
Plan to Invest in Common Stocks or Mutual Funds in Future:			
No	10		
Yes	87		

Table 2 Items of Financial Information Used In Research Instrument

Primary Predictors:	Earnings per Share
	Sales
	Gross Profit Ratio
	Operating Income
Secondary Predictors:	Inventory
	Current Ratio
	Accounts Receivable
Tertiary Predictors:	Return on Equity
	Debt to Equity Ratio
	Return on Total Assets

Predictor Values Were Reverse Calculated Based On Daily Stock Prices:

Primary Predictor Calculations
The change in stock price lagged the Primary predictors by 2 days:
Formula: (1 + (Stock price percentage change from day 2 to day 3)) times Day -1 Primary Predictor Value = Day 1 Primary Predictor Value

Secondary Predictor Calculations
The change in stock price lagged the Secondary predictors by 3 days:
Formula: (1 + (Stock price percentage change from day 3 to day 4)) times Day -1 Secondary Predictor Value) = Day 1 Secondary Predictor Value

Tertiary Predictor Calculations
The change in stock price lagged the Tertiary predictors by 5 days:
Formula: (1 + (Stock price percentage change from day 5 to day 6)) times Day -1 Tertiary Predictor Value) = Day 1 Tertiary Predictor Value

Day -1 is the initial financial data for the fictional company used in the experiment.

Financial Information Item Analysis

Two dependent variables were developed to test the hypotheses: RANK and RELIANCE. A discussion of the variable analysis follows.

Rank

Data were collected in the current study regarding the participants' self-reported use of the items of information provided during the task. Participants were asked to focus on the second set of decisions. They were asked to rank the twelve items of information from 1 to 12, with 1 assigned to the item they found most important in performing the task and 12 assigned to the item they found least important. The item 'yesterday's stock price' was not included in the list. Table 2 shows the summary of these data by treatment group. The total score for each item was derived by summing the rankings assigned to each item by the participants in the group. The average score was derived by dividing the total score by the number of participants in the group. The average score was used to determine the rank of each item, with the lower score awarded the higher ranking (1 = highest, 12 = lowest). The ranking for the three highest ranked items was fairly consistent across the treatment groups:

price percentage change (from the previous day) was ranked number 1 by all groups, today's stock price was ranked number 2 by three of the groups and 'earnings per share' was ranked number 3 by three of the groups. The top 2 rankings are the Base Period information, which indicates functional fixation. The remaining item rankings were fairly inconsistent across the groups. The results of the participants' rankings were an indication that the participants remained fixated on the stock price data (price percentage change and today's stock price) and earnings per share and did not give much attention to the other items. The presence of assurance does not appear to have any affect on the degree of functional fixation. These results provide support for the functional fixation hypothesis and do not support H1 or H2.

Reliance

The participants were also asked to indicate which of the twelve information items they relied upon the most when performing the task by dividing 100% among the twelve items. Table 3 reports the results of the information items reliance, summarized by treatment group. Average reliance was derived by averaging the reported reliance for each information item for each treatment group and a ranking was assigned to the items based on the average reliance. The higher the average reliance, the higher the rank (1 = highest, 12 = lowest). Similar to the participants' ranking results, price percentage change, today's stock price and 'earnings per share' were the three items most relied upon, with consistency across the treatment groups. The combined average reliance percentage for these three items was about 70-73% for the periodic reporting groups and about 52-62% for the continuous reporting groups and further indicated that the participants appeared to be fixated on a few of the information items. The continuous reporting group's percentage of reliance on the top three was less than the periodic reporting group's, which was an indication of their attention being more dispersed among the information items than the periodic reporting groups. The result provides some support for H1, that participants provided with more continuous reporting of fundamental financial data will display a lesser degree of fixation. H2 is not supported.

Limitations and Future Research

The results are naturally subject to limitations. Fixation on a limited subset of the information items may be an indication of information overload or may have been caused by a lack of familiarity with the information items. The use of students as surrogates for unsophisticated investors has been shown to be appropriate, but may not extrapolate to the actual target population.

Table 2 Information Items Ranking

Information Item Ranking from 1 to 12	Periodic Reporting/No Assurance	Periodic Reporting/With Assurance	Continuous Reporting/No Assurance	Continuous Reporting/With Assurance
Today's Stock Price:				
Total Score	76	54	105	84
Average Score	3.8	2.84	5.25	3.82
Rank	2	2	3	2
Price Percentage Change:				
Total Score	43	39	60	81
Average Score	2.15	2.05	3.00	3.68
Rank	1	1	1	1
Earnings Per Share:				
Total Score	99	94	91	93
Average Score	1.95	4.95	4.55	4.23
Rank	3	3	2	3
Return on Equity:				
Total Score	131	112	125	137
Average Score	6.55	5.89	6.25	6.23
Rank	6	4	5	5
Inventory:				
Total Score	205	174	189	179
Average Score	10.25	9.16	9.45	8.09
Rank	12	11	12	10
Sales:				
Total Score	136	124	100	132
Average Score	6.80	6.53	5.00	6.00
Rank	8	6	4	4
Current Ratio:				
Total Score	163	117	145	154
Average Score	8.15	6.16	7.25	7.00
Rank	10	5	8	7
Debt to Equity Ratio:				
Total Score	137	133	134	172
Average Score	6.70	7.00	6.70	7.82
Rank	7	7	6	9
Accounts Receivable:				
Total Score	204	182	159	188
Average Score	10.2	9.58	7.5	8.55
Rank	11	12	10	12
Gross Profit Ratio:				
Total Score	126	143	142	167
Average Score	6.30	7.53	7.10	7.59
Rank	5	8	7	8
Return on Assets:				
Total Score	136	162	146	186
Average Score	6.80	8.53	7.30	8.45
Rank	9	10	9	11
Operating Income:				
Total Score	107	148	164	144
Average Score	5.35	7.79	8.20	6.55
Rank	4	9	11	6
Total Score: Sum of the rankings across each cell (the lower the score, the 'higher' ranked). Average Score: Average of the rankings across each cell (the lower the score the 'higher' ranked).Rank: Based on the Average Score for each cell, the lower the score, the 'higher' the ranking.1 is the highest rank, 12 is the lowest.				

Table 3 Information Items Reliance

Information Item Average Reliance out of 100% Ranking from 1 to 12	Periodic Reporting/No Assurance	Periodic Reporting/With Assurance	Continuous Reporting/No Assurance	Continuous Reporting/With Assurance
Today's Stock Price: Average Reliance Reliance Rank	 27.25 2	 32.37 1	 17.25 2	 29.37 1
Price Percentage Change: Average Reliance Reliance Rank	 36.25 1	 32.32 2	 26.60 1	 25.50 2
Earnings Per Share: Average Reliance Reliance Rank	 6.75 3	 8.16 3	 8.15 3	 7.18 3
Return on Equity: Average Reliance Reliance Rank	 3.00 8	 4.21 5	 7.25 5	 5.68 6
Inventory: Average Reliance Reliance Rank	 1.00 12	 2.21 10	 2.85 12	 3.50 9
Sales: Average Reliance Reliance Rank	 5.00 6	 3.79 7	 7.35 4	 6.00 5
Current Ratio: Average Reliance Reliance Rank	 2.85 9	 4.47 4	 5.10 9	 4.18 7
Debt to Equity Ratio: Average Reliance Reliance Rank	 3.10 7	 3.79 6	 6.30 7	 3.50 8
Accounts Receivable: Average Reliance Reliance Rank	 1.10 11	 1.74 6	 3.50 10	 3.05 10
Gross Profit Ratio: Average Reliance Reliance Rank	 6.55 4	 2.63 9	 6.50 6	 2.41 11
Return on Assets: Average Reliance Reliance Rank	 1.75 10	 1.74 11	 6.10 8	 2.32 12
Operating Income: Average Reliance Reliance Rank	 5.40 5	 2.72 8	 3.05 11	 7.05 4
Average Reliance: The average assigned reliance across the cell (the larger the average the 'higher' the ranking). Reliance Rank: The rank assigned based on the relative average reliance across the cell. 1 is the highest rank, 12 is the lowest.				

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Long Memory Features in Return and Volatility of the Macro Variables in the Quantitative Easing Period

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Abstract

This study provides evidence on the predictability and asymmetry effect of macro variables in areas where quantitative easing (QE) has been applied as a monetary policy. First, using the autoregressive fractional integrated moving average–fractional integrated asymmetric power autoregressive conditional heteroskedasticity (ARFIMA–FIAPARCH) and autoregressive moving average–asymmetric power autoregressive conditional heteroskedasticity (ARMA–APARCH) models on bond yield and exchange rate in four areas, namely, the United States, Japan, the United Kingdom, and the Eurozone, this study found that the volatilities of all areas where QE1 and QE2 were applied have long memory properties. Second, a unique feature of the ARFIMA–FIAPARCH and ARMA–APARCH models is their ability to determine the volatility asymmetry effect through the delta parameter. However, this study found that all variables in the four areas demonstrate strong evidence of the volatility asymmetry effect and that positive news has a stronger effect on QE volatilities than negative news when the ARFIMA-FIAPARCH models are employed.

Keywords: Quantitative Easing, ARFIMA-FIAPARCH, ARMA-APARCH models

Introduction

Quantitative easing (QE) was first implemented by the Bank of Japan in 2001. The Plaza Accord discussed the problem of trade account imbalance among countries. The Bank of Japan was forced to allow the Japanese yen to appreciate sharply because of the surplus in the country's trade account. However, such decision tended to decrease the export sector and caused the economy to fall into deflation and recession. To rescue the economy, the Bank of Japan implemented a series of monetary policies; including the ineffective zero-rate policy (from 1999 to 2002). The Bank of Japan also implemented QE (from 2001 to 2006) to solve the problems of recession and deflation. QE was implemented in 2008 when the global financial recession resulted from the US sub-prime mortgage crisis. This situation forced many banks and companies to close down, thus leading to recession and deflation, which had been getting more serious. Thus, a number of governments were forced to implement expansionary fiscal policy and expansionary monetary policy to rescue the economic system and deal with the liquidity risk. Governments and central banks reduced their interest rates and offered short-term borrowing mechanisms for financial institutions as well as financing mechanisms for special credit markets beginning October 2007.

To address the liquidity risk, the US Federal Reserve Bank implemented the unconventional monetary policy of QE in November 2008 for the first time, and QE1[1] and QE2[2] were applied in November 2010. The idea of the QE is to use large-scale asset purchase programs to inject a substantial amount of new money into the market. Longzhen et al. (2011) found that monetary supply responds more actively to both the inflation rate and the real output than to the interest rate. By creating a large amount of money, it decreases the long-term interest rate and relieves the pressure of demand on the capital market. David et al. (2011) revealed that the QE policy offers a significant positive effect of bank liquidity. After implementing QE in November 2008, the GDP growth rate increased and deflation turned into inflation. QE was also implemented by the Bank of Japan, the Bank of England, and the European Central Bank for collateralized debt obligations issued by public enterprises and governments.

[1] QE1 was implemented from November 2008 to March 2010. The policy injected US$200 billion in Agency debt, US$125 trillion in Agency Mortgage-Backed Security, and US$300 billion in government bonds. The total amount was US$1.75 trillion.

[2] QE2 was implemented from November 2010 to June 2011. The total amount injected was US$900 billion in government bonds.

In empirical research, some studies support the effect of QE. Kurihara (2006) and Kimura and Small (2006) show that QE provides a positive benefit to the financial market. By implementing the QE monetary policy, the Bank of Japan helped the Japanese economy to overcome the recession and deflation effectively. However, Eric and Zakaria (2011) argue that QE aims not only to prevent further recession and deflation but also to stimulate both output and prices. Other empirical studies, such as those conducted by Heike and Sebastian (2011), indicate that QE shock not only leads to a significant matter but also to a temporary rise in output. Girardin and Moussa (2011) found that QE has a short-term positive effect on activity and stock prices. The issue of whether QE results in long memory effect has received attention from researchers. Mantegna and Stanley (2000) indicate that when the long-term memory appears, the market will not immediately react to the information in the financial market but will respond to some information gradually over a certain period. Thus, price changes in the past may be used as significant information in the prediction of future price changes. If a variable has a long memory effect, historical data can be used to forecast the future returns so that it helps to increase the probability of speculative profits or the performance of hedging. These observations of long memory processes can provide a good description of various highly persistent financial time series. Tan and Khan (2010) and Baillie (1996) mentioned the significance of long memory in the financial market and also tested for evidence of long memory in volatility.

The motivation of this research is to examine the implementation of QE, which influences the monetary variables (i.e., exchange rate and bond yield) in response to the monetary policy persistence or temporary shocks in Japan, the US, the UK, and the Eurozone. Long memory indicates that the shock of QE is persistent. Hsieh and Lin (2004) revealed that the financial tool with long memory can produce the predictable non-random walk phenomenon, which increases the efficiency of implementing monetary policy. To investigate these hypotheses, this study utilizes the fractionally integrated autoregressive moving average (ARFIMA) processes, which first appeared in the work of Granger and Joyeux (1980) and Hosking (1981), wherein the different parameter is allowed to be a non-integer. The fractional integrated asymmetric power autoregressive conditional heteroskedasticity (FIAPARCH) and the asymmetric power ARCH models are also employed to verify a long memory and asymmetry in the exchange rate and long-term interest rate variables.

The literature relevant to this study includes the work of Kurihara (2006) on the relationship between the exchange rate and stock prices during the QE policy in Japan. Leila et al. (2004) used the iterated cumulative sums squares test the iterated cumulative sums squares (ICSS) model to examine the euro–US dollar exchange rate from 1999 to 2003. The results show that the euro does not have long memory properties and that the time series has an unstable covariance structure. Paul et al. (2009) found that the USD–ZAR exchange rate has a long memory from 1986 to 2007. Many studies have used the ARFIMA–FIAPARCH and ARMA–APARCH models to provide evidence of the dual long memory properties of stock returns and to predict the non-random-walk phenomenon in general. To the best of our knowledge, no formal empirical literature has yet studied the long memory properties of the exchange rate and the long-term interest rate variables in four areas (i.e., Japan, the US, the UK, and the Eurozone) using the ARFIMA–FIAPARCH and ARMA–APARCH models.

As lagged returns can be utilized to predict future returns, the presence of a long memory in stock returns can shake the efficient market hypothesis. Studies on the ARFIMA–FIAPARCH and ARMA–APARCH models not only capture the long memory properties in return and volatilities but are also able to provide strong evidence of volatility asymmetry by examining the APARCH delta (δ) parameter. The works of Mabrouk and Aloui (2010) and

Tan and Khan (2010) provide empirical proof based on the stock market returns of Tunisia, Malaysia, and Thailand.

This paper employed the ARFIMA–FIAPARCH and ARMA–APARCH models on the bond yield and exchange rate, and found that the volatilities of all areas that applied QE1 and QE2 have long memory properties. Second, a unique feature of the ARFIMA–FIAPARCH and ARMA–APARCH models is their ability to determine volatility asymmetry through the delta (δ) parameter. However, this study found that all the variables in four areas show strong evidence of volatility asymmetry and that positive news has a more significant impact on QE volatilities than negative news using the ARFIMA–FIAPARCH and ARMA–APARCH models.

The study is structured as follows. Section 2 explains the methodology of the ARFIMA–FIAPARCH and ARMA–APARCH models. Section 3 presents the data and empirical results. Section 4 provides the conclusion.

Methodology

ARFIMA model

According to Granger and Joyeux (1980) and Hosking (1981), based on the series x_t, t = 1, …,T, the ARFIMA(r, d, s) model can be expressed as follows:

$$\Psi (L) (1 - L)^d (x_t - \mu) = \Theta (L)\varepsilon_t \ , \quad (1)$$

$$\varepsilon_t = z_t \sigma_t \ , \qquad z_t \sim (0,1) \ , \quad (2)$$

where *d* stands for a fractional integration of a real number parameter, μ is the conditional mean, ε_t is the independent and identically distributed (i.i.d.) random variables with a variance σ^2, and L is the lag. Moreover, $\Psi (L) = \psi_1 L + \psi_2 L^2 + \ldots + \psi_r L^r$ and $\Theta (L) = \theta_1 L + \theta_2 L^2 + \ldots + \theta_s L^s$ are the autoregressive (AR) and moving-average (MA) polynomials outside of the unit cycles, respectively.

When d > 0 is in Equation (1), the process of long memory exists in the long run. Specifically, for $d \in (0, 0.5)$ and $d \neq 0$, the series is characterized by a covariance stationary process and mean reversion, with shocks disappearing in the long run; for $d \in (0.5, 1)$, the series implies mean reversion unrelated to the covariance stationary process because there is no long-run impact of an innovation on the future values of the process. For $d \geq 1$, the series represents nonstationarity and non-mean reversion. The process is referred to as the exhibit intermediate memory, for $d \in (-0.5, 0)$.

FIAPARCH model

To insert both the long memory and asymmetry features in the process of conditional variance behavior, Tse (1998) extended the FIGARCH(p, ξ, q) by creating the function $(|\varepsilon_t| - \gamma\varepsilon_t)^\delta$ of the APARCH process. Formally, the FIAPARCH (p, ξ, q) can be shown as follows:

$$\sigma^\delta_t = \omega[1 - \beta(L)]^{-1} + \{1 - [1 - \beta(L)]^{-1} \rho(L)(1 - L)^\xi \} (|\varepsilon_t| - \gamma\varepsilon_t)^\delta, \quad (3)$$

where δ, γ, and ξ are the model parameters. Likewise, $0<\xi<1$ shows the volatility exhibition of a long memory process. The γ is indicated as the volatility asymmetry based on $-1<\gamma<1$, in which both the positive and negative returns of the same magnitude do not generate an equal degree of volatility. When $\gamma>0$, the negative shocks have a relatively greater impact on volatility than positive shocks, and vice versa.

APARCH models

Based on the study of Sébastien (2011), this paper considers a collection of daily returns (in %), $y_t = 100[\log(p_t) - \log(p_{t-1})]$, where t = 1, 2, …T, and p_t is the interest rate and exchange rate at time t. Given that the daily returns are often used to exhibit some serial autocorrelation, an AR(2) structure is fitted in the y_t series for all specifications. Accordingly, the conditional mean of y_t, that is, μ_t, is equal to $\mu + \sum\psi_j (y_{t-j} - \mu)$. Several specifications for the conditional variance of ε_t are also considered.

Normal APARCH

By applying an extension of the GARCH model of Bollerslev (1986), Ding et. al. (1993) measured the normal APARCH. The flexible ARCH-type model has at least seven GARCH specifications. The normal APARCH (1, 1) is defined as follows:

$$\sigma^{\delta}_{t} = \omega + \alpha_1 (|\varepsilon_{t-1}| - \gamma_1\varepsilon_{t-1})^{\delta} + \beta_1 \sigma^{\delta}_{t-1}, \quad (4)$$

where ω, α_1, γ_1, β_1, and δ are the parameters to be estimated. A nonnegative value of δ functions as the transformation of σ_t, and γ_1 ($-1< \gamma_1 <1$) reflects the leverage effect. Black (1976) and French et al. (1987) revealed a positive (negative) value of γ_1, indicating that past negative (positive) shocks have a deeper impact on the current conditional volatility than past positive shocks.

Student APARCH

To illustrate the problem of unrelated "fat tails" of the return distribution for the normal distribution, the Student APARCH was formulated by using the standardized student distribution:

$$\varepsilon_t = z_t \sigma_t, \quad (5)$$

where z_t is i.i.d $t(0,1,v)$.

Skewed-Student APARCH

To extend the Student distribution, Fernández and Steel (1998) proposed the excess skewness and kurtosis by adding a skewness parameter. The innovation process z is skewed Student distributed if:

$$f(z|\xi,\upsilon) = \begin{cases} \dfrac{2}{\xi + \frac{1}{\xi}} sg\left[\xi(sz + m)|\upsilon\right] & \text{if } z < -\dfrac{m}{s}, \\[2ex] \dfrac{2}{\xi + \frac{1}{\xi}} sg\left[(sz + m)/\xi|\upsilon\right] & \text{if } z \geq -\dfrac{m}{s}, \end{cases} \quad (6)$$

where $g(.|v)$ is the symmetric (unit variance) Student density, and ξ is the asymmetry coefficient. Moreover, m and s^2 are the mean and the variance of the non-standardized skewed Student, respectively:

$$m = \frac{\Gamma(\frac{\upsilon - 1}{2})\sqrt{\upsilon - 2}}{\sqrt{\pi}\,\Gamma(\frac{\upsilon}{2})}(\xi - \frac{1}{\xi}), \quad (7)$$

$$s^2 = (\xi^2 + \frac{1}{\xi^2} - 1) - m^2. \quad (8)$$

The density $f(z_t|1/\xi, v)$ is the mirror of $f(z_t|\xi, v)$ with respect to the (zero) mean, that is, $f(z_t|1/\xi, v) = f(-z_t|\xi, v)$. Consequently, the sign of $\log(\xi)$ indicates the direction of the skewness. The third moment is positive (negative), and the density is skewed to the right (left), if $\log(\xi) > 0$ (<0).

Data and Empirical Results

This study focuses on four areas (i.e., Japan, the UK, the US, and the Eurozone) that have implemented QE. The database of this study was collected from the International Financial Statistics, the Taiwan Economic Journal, and the Advanced Retrieval Econometric Modeling System. All variables are dated from 1990 to 2012, and all are monthly data. QE was implemented by the Federal Reserve System [QE1 (November 2008 to March 2010) and QE2

(November 2010 to June 2011], Bank of England [QE1 (March 2009 to February 2010) and QE2 (November 2011 to February 2012], European Central Bank (July 2008 to May 2010), and Bank of Japan (March 2001 to March 2006). This study uses two variables, the exchange rate and long-term interest rate, to examine whether the time series variables have a long memory effect after the QE implementation. The exchange rate used in this study is the US dollar index, GBP/US, EUR/US, and US/JPY. The long-term interest rate is used by the 10-year government bond yield.

Table 1 shows the average exchange rates and the 10-year bond yield returns in four areas since 1990. In the bond yield, Japan had the highest average negative returns posted at -2.14%, whereas the bond yield of the Eurozone and the UK received the lowest average negative returns of -2.51% and -2.67% respectively. The exchange rate of the Eurozone had the highest average negative returns posted at -0.029%, whereas Japan posted the lowest average negative returns at -23.45%. Most of the samples are negatively skewed, and the kurtosis coefficients have leptokurtic distributions. The Jarque–Bera statistic for residual normality illustrates that the bond yield and exchange rate returns of the four areas are under a non-normal distribution assumption.

To eliminate the serial correlation and heteroskedasticity in the data, this study used the augmented Dickey–Fuller test to establish the stationarity. The minimum value of the Akaike information criterion identified the orders of the models. Based on the results of the Lagrange multiplier (LM) test, all exchange rate and bond yield return samples had no serial correlation. The ARCH–LM process was also used to test the ARCH effect, indicating that the GARCH models could be applied in the chosen sample because the null hypothesis was rejected for all the data sets. The exchange rate and the bond yield volatility are illustrated in Figure 1.

Table 2 reports the results of the ARFIMA–FIAPARCH model. With $0 < d < 0.5$, long memory was found in the returns of both variables (i.e., bond yield and exchange rate) in the four areas except bond yield in the Eurozone. When the returns on these variables have a long memory or long-term dependence phenomenon, observations in the long run will have the characteristic of self-correlation. The implication is that historical return data can be used to predict future return data because the observations are not independent of one another. This finding is consistent with the previous research, such as the works of Baillie (1996) and Mantegna and Stanley (2000). In the mean equation, the exchange rate for the Japanese Yen and the bond yields for the Euro area and Japan are non-stationary. The remaining variables of the US, the UK, and the Eurozone are characterized by stationarity. To confirm these findings, the ARFIMA–FIAPARCH models verified that the exchange rate and bond yield volatilities of these areas have long memory properties. The UK's exchange rate does not only have a long memory in its volatilities but also exhibits positive dependence in its returns. The predictable structure in the returns of this country may be a clear sign of market inefficiency, and investors may earn excess returns. This study also found that all of the countries included in the study displayed strong evidence of volatility asymmetry by examining the APARCH delta (δ) parameters in which the values are all positive and significant at the 5% level of significance, except the bond yield of the UK. This result is also in accordance with the study of Kurihara (2006), which illustrates that when the Japanese economy recovered, the exchange rate still influenced the Japanese stock price. Inoue and Okimoto (2008) also found that the influence of the interest rate and exchange rate on the increasing output is effective after QE.

The estimation results of the ARMA–APARCH model that assumes the distributions of the normal and Student-t and Skewed-Student-t innovations in the period from 1990 to 2012 are shown in Table 3. The volatility component and the long memory parameters, (β), are all significant at 1%, thus indicating the long range memory phenomenon for volatilities. Moreover, the estimation of the fat-tailed parameter ν is statistically significant at the 10% level, with the exchange rate of the Japanese yen suggesting the usefulness of the Skewed-Student-t distribution in modeling the leptokurtosis of the estimated residuals. Furthermore, α is positive and significant at the 5% for the bond yield and exchange rate in the US dollar index, the bond yield in Japan, and the exchange rate for the Eurozone, indicating a leverage effect for the negative returns in the conditional variance specification. $\ln(\xi)$ is significant only for the bond yield variable and is positive in the Eurozone (the density is skewed to the right). The implication is that the asymmetry in the Student distribution is not necessary for all variables to have the full model of the distribution of returns. Table 3 also indicates that all the countries included in this study display strong evidence of volatility asymmetry based on the APARCH delta (δ) parameters, in which the values are all positive and significant at the 10% level of significance for the bond yield of the Eurozone. These findings support the conclusions of Kurihara (2006) and Inoue and Okimoto (2008), showing that the exchange rate and interest rate have long memory effects on the economy.

If the time series has a long memory, prior observation and post observation are interdependent, indicating that the past shock will influence the series significantly. Xiao and Lin (2009) revealed that, if the time series has the characteristic of long memory, the influence of the random shock will affect the future value for a long time. Hsieh and Lin (2004) found that the financial tool with a long memory can produce the predictable non-random walk phenomenon, which will increase the efficiency of implementing the monetary policy. This study used the dummy variable to represent the QE period, where the DUM1 is used for the QE1 period in all four areas, and the DUM2 is used for the QE2 period in the US and the UK. If QE results in long memory, then it will affect the variables in the long term. These results are presented in Tables 4 and 5 with the ARFIMA–FIAPARCH and ARIMA–ARPARCH models, respectively.

Table 4 describes the results of the ARFIMA–FIAPARCH model with the dummy variables for QE1 and QE2. The long memory was found in the returns of both variables (i.e., bond yield and exchange rate) in the four areas except the bond yield in the UK and the Eurozone with $0 < d < 0.5$. The coefficient of DUM1 (for QE1) is only significant at 5% for the bond yield variable in Japan. The coefficient of DUM2 (for QE2) is only significant at 10% for the bond yield variable in the UK. These results are consistent with those presented in Table 2 (estimated variables without dummy variables). However, in this case, the bond yield variable in the UK is insignificant. To confirm these findings, the ARFIMA–FIAPARCH models verified that the exchange rate and bond yield volatilities of these areas have long memory properties. The predictable structure in the returns for this country may be a clear sign of market inefficiency and may indicate that investors can earn excess returns. By examining the APARCH delta (δ) parameters, this study also found that all the countries investigated have strong evidence of volatility, in which the values are all positive and significant at the 10% level, except the bond yield of the UK. These findings are again in accordance with the findings on the estimation implemented without dummy variables and with the study of Girardin and Moussa (2011). This study proved that QE not only could prevent further recession and deflation but could also stimulate both output and prices considerably. This positive effect was reached through the interest rate factor.

The estimation results of the ARMA–APARCH model, which assumes normal and Skewed-Student innovation distributions with dummy variables in QE1 and QE2, are reported in Table 5. The coefficient of DUM1 (for QE1) is only significant at 5% for the bond yield variable in Japan. The coefficient of DUM2 (for QE2) is insignificant at 10% for all the variables. For the volatility component, the long memory parameters, (β), are significant at

1% for the bond yield and exchange rate of the Japanese yen, the exchange rate of the UK sterling, and the bond yield of the Eurozone, indicating the long-range memory phenomenon for volatilities. In this case, these findings are again in accordance with those of the APARCH estimation without dummy variables. Many variables are significant at 1%, indicating that QE can influence the variables in the long term. Kurihara (2006) and Inoue and Okimoto (2008) demonstrated the influence of the interest rate and the exchange rate on the Japanese stock market, which effectively increased the output after QE. The estimations of the fat-tailed parameter ν are statistically significant at the 1% level for the bond yield of the US and the UK, suggesting the usefulness of the normal distribution in the modeling of the estimated residuals. The α is positive and significant at 5% only for the bond yield in Japan, which indicates a leverage effect for the negative returns in the conditional variance specification. Table 5 also reports that the bond yield in Japan and the UK under this study show strong evidence of volatility asymmetry based on the APARCH delta (δ) parameters, in which the values are all positive and significant at the 1% level. Girardin and Moussa (2011) and Cúrdia and Woodford (2011) argue that the interest rate factor has a positive effect not only on preventing further recession and deflation but also on providing considerable stimulation to both output and prices.

Conclusions

The global financial crisis prompted most major central banks to rely on quantitative easing. The first QE was applied by the Bank of Japan in 2001. Afterwards, the QE continued to be implemented in other places such as England, the US, and the Eurozone. This issue has attracted the attention of researchers, policymakers, and bankers. This study conducted an empirical examination of the long memory effect on the return and volatility of the macro variables in the QE period.

Based on the results, this study makes the following conclusions. First, the results of the ARFIMA–FIAPARCH and ARMA–APARCH models confirm that the volatilities of all areas that applied the QE1 and QE2 as monetary policies have long memory properties. By including dummy variables in the models, this study proved that QE could affect the variables in the long term, as shown by the example of Japan. The variables in the four areas exhibited dual long memory properties in their returns and volatilities, respectively. The predictability in the volatility of these variables is a clear indication of market inefficiency, and it can also be regarded as an effective forecasting tool.

Second, a unique feature of the ARFIMA–FIAPARCH and ARMA–APARCH models is their ability to determine volatility asymmetry through the delta (δ) parameter. However, this study found that all the variables in the four areas show strong evidence of volatility asymmetry, which indicates that positive news has a more significant impact on QE volatilities than negative news when the ARFIMA–FIAPARCH model is employed. The US, the UK, and the Eurozone exhibited higher asymmetries in the exchange rate variables than in the bond yield variables. The bond yield variable demonstrated a lower asymmetry than the exchange rate because Japan was the first country to implement the QE policy. These findings point to the considerations that should be taken by researchers, policymakers, and bankers when they make plans and strategies in response to monetary policy, particularly in implementing another QE.

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Table 1: Descriptive statistics for the variables in QE

Country	US		Japan		UK		EU	
Items	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate
Obs	268	203	265	267	266	267	265	203
Mean (%)	-0.0216	-0.0003	-0.0215	-0.2346	-0.0267	-0.0003	-0.0251	-0.0003
Std.Dev(%)	0.2397	0.0363	0.2313	3.6020	0.1973	0.0468	0.1962	0.0363
Skew.	-0.1364	-0.2326	-0.2338	-0.5266	0.0716	-1.0069	0.3086	-0.2326
Kurt.	1.3252	1.4327	11.024***	2.8971	1.063***	3.4475	0.1409	1.4327
J-Bera	20.4410	19.1920	1339.2000	105.7100	12.752***	177.3400	4.4253	19.1920
Q(10)	24.7649**	12.9391	15.2670	26.1986**	21.1902*	18.9886*	29.0706**	12.9391
$Q^2(10)$	4.8713	58.5716**	51.4471**	14.4882	57.2643**	38.4674**	36.0395**	58.5716**
KPSS	0.0283	0.1718	0.2760	0.0643	0.1102	0.0412	0.2010	0.1718

Note: *, ** and *** are significance at 10, 5 and 1% levels, respectively; p-values are in parentheses.

International Research Journal of Applied Finance ISSN 2229 – 6891
Vol. IV Issue – 5 May, 2013

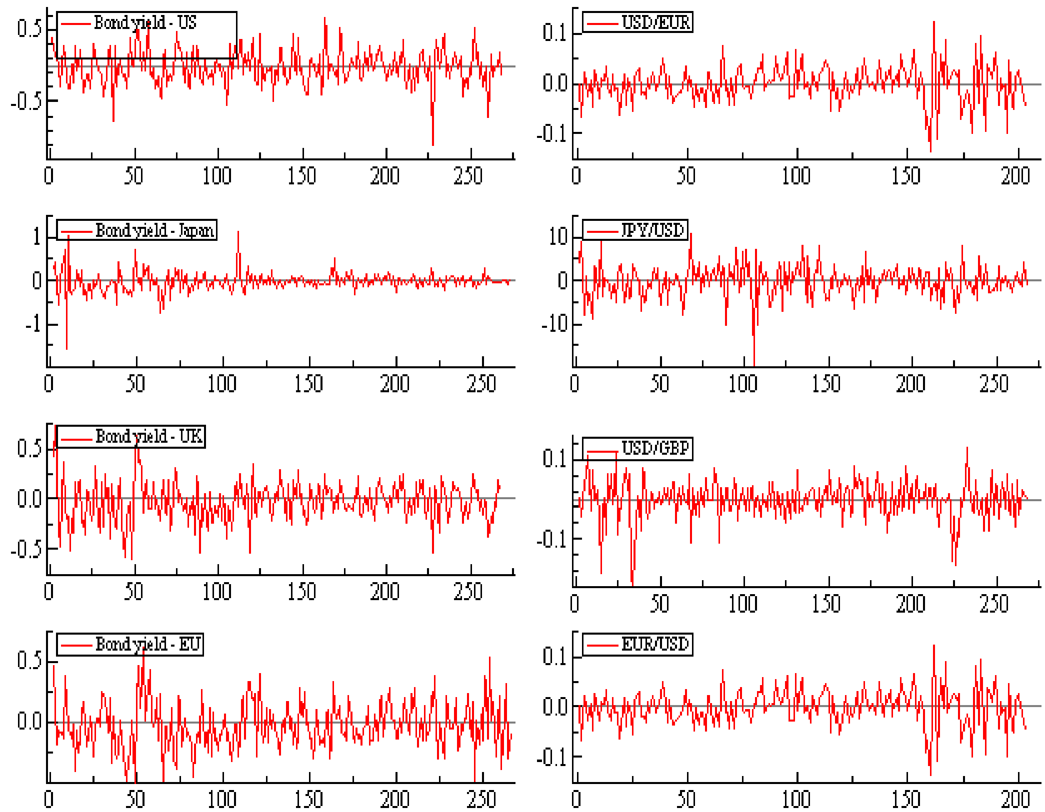

Figure 1: The exchange rate and the bond yield volatility

Table 2: Estimated ARFIMA-FIAPARCH model

Country	US		Japan		UK		EU	
Items	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate
Model	(1,1)	(1,1)	(1,1)	(1,1)	(1,1)	(0,1)	(1,1)	(1,1)
ω	-0.0232 (0.0000)***	0.0002 (0.9542)	-0.0128 (0.0020)***	-0.2414 (0.0536)*	-0.0255 (0.0000)***	0.0009 (0.2304)	-0.0298 (0.2788)	0.0002 (0.9542)
d-ARFIMA	-0.5048 (0.0000)***	0.0051 (0.9817)	-0.1498 (0.2530)	-0.1079 (0.1850)	-0.2057 (0.1123)	-0.8367 (0.0000)***	0.1177 (0.4577)	0.0051 (0.9817)
d	0.7304 (0.0042)***	0.1588 (0.0459)**	0.5654 (0.0194)**	0.7411 (0.0001)***	0.3175 (0.0415)**	0.3309 (0.0649)*	0.5296 (0.2752)	0.1588 (0.0459)**
β	0.9864 (0.0000)***	-0.3447 (0.1673)	0.2720 (0.3522)	0.8968 (0.0000)***	0.2922 (0.1382)	-	0.7618 (0.0000)***	-0.3447 (0.1673)
γ_1	-0.8814 (0.3027)	0.0716 (0.7827)	0.1472 (0.3949)	0.1984 (0.3770)	0.2508 (0.5579)	-0.2850 (0.0459)**	0.3183 (0.3932)	0.0716 (0.7827)
δ	0.9173 (0.0019)***	2.7938 (0.0003)***	2.1502 (0.0000)***	1.0358 (0.0429)**	1.5635 (0.1333)	2.1278 (0.0001)***	1.9299 (0.0014)***	2.7938 (0.0003)***
ν	0.3194 (0.2997)	0.0295 (0.9381)	-0.0010 (0.7727)	0.0791 (0.0780)*	0.0082 (0.7548)	0.3071 (0.9226)	0.0010 (0.6411)	0.0295 (0.9381)
AIC	-0.1159	-3.8370	-0.4740	5.3268	-0.5293	-3.3572	-0.4618	-3.8370
Log(Ln)	26.533	400.4530	71.5620	-698.1330	79.4006	461.1880	72.1929	400.4530
$Q^2(10)$	10.0365	14.1384	1.0890	8.9351	3.9868	27.7104**	9.9470	14.1384

Note: *, ** and *** are significance at 10, 5 and 1% levels, respectively; p-values are in parentheses.

Table 3: Estimated ARMA-APARCH model

Country	US		Japan		UK		EU	
Items	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate
Model	(1,1)	(1,1)	(0,1)	(1,1)	(0,1)	(1,1)	(1,1)	(1,1)
ω	-0.0121 (0.5465)	-0.0002 (0.9296)	-0.0218 (0.0356)**	-0.2630 (0.2554)	-0.0299 (0.1156)	0.0023 (0.3621)	-0.0281 (0.0436)**	-0.0002 (0.9296)
α_1	0.0408 (0.6557)	0.0472 (0.0211)**	0.5344 (0.0182)**	0.0178 (0.3737)	0.0984 (0.3943)	0.1130 (0.4556)	0.0675 (0.2249)	0.0472 (0.0211)**
β_1	0.8948 (0.0000)***	0.7013 (0.0026)***	-	0.9086 (0.0000)***	-	0.7209 (0.0009)***	0.8904 (0.0000)***	0.7013 (0.0026)***
γ_1	-0.3164 (0.0573)*	0.1095 (0.5908)	0.1609 (0.4915)	0.2196 (0.3966)	0.0170 (0.9689)	-0.1458 (0.4777)	0.1589 (0.6144)	0.1095 (0.5908)
δ	2.7520 -0.3913	4.2394 (0.0000)***	1.0816 (0.0377)**	3.1781 (0.0012)***	3.0645 (0.0239)**	2.2646 (0.2472)	1.0980 (0.8065)	4.2394 (0.0000)***
ν	0.0011 -0.7811	0.0008 (0.0003)***	0.1277 (0.2641)	2.1258 (0.4004)	0.0046 (0.6631)	1.4049 (0.8833)	0.0089 (0.9265)	0.0008 (0.0003)***
Asymmetry	0.0969 -0.3475	-0.0746 (0.5339)	0.0549 (0.4873)	-0.0699 (0.4464)	-0.0529 (0.7472)	-0.0548 (0.6619)	0.1589 (0.0646)*	-0.0746 (0.5339)
Tail	6.5974 (0.0113)***	15.2826 (0.3356)	3.2370 (0.0000)***	5.7860 (0.0080)***	6.5218 (0.0626)*	4.9961 (0.0008)***	341.8280 (0.0000)***	15.2826 (0.3356)

Note: *, ** and *** are significance at 10, 5 and 1% levels, respectively; p-values are in parentheses. ξ is the asymmetry coefficient. If Ln(ξ)<0 (or ξ< 1) the density is skewed to the left. Thus, the VaR for long positions will be larger (for the same conditional variance) than the VaR for short positions. If Ln(ξ)>0 (or ξ>1), we have the opposite result.

Table 4: The ARFIMA - FIAPARCH model (with Dummy variables)

Country	US		Japan		UK		EU	
Items	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate
Model	(1,1)	(1,1)	(1,1)	(1,1)	(1,1)	(0,1)	(1,1)	(1,1)
ω	-0.0239 (0.0000)***	0.0010 (0.7333)	-0.0361 (0.0001)***	-0.5570 (0.1270)	-0.0222 (0.0132)**	0.0013 (0.1910)	-0.0316 (0.3115)	-0.0001 (0.9964)
DUM 1	0.0423 (0.2802)	-0.0013 (0.93)	0.0313 (0.0151)**	0.3986 (0.4051)	0.0186 (0.7177)	-0.0078 (0.5236)	0.0043 (0.9505)	-0.0243 (0.2951)
DUM 2	-0.0292 (0.3688)	-0.0107 (0.2955)	-	-	-0.0782 (0.0811)*	-0.0086 (0.2608)	-	-
d-ARFIMA	-0.5199 (0.0000)***	0.0049 (0.9801)	-0.2809 (0.0834)*	-0.1169 (0.5187)	-0.0461 (0.8809)	-0.9331 (0.0000)***	0.1277 (0.5372)	0.2074 (0.5811)
d	0.7014 (0.0034)***	0.1662 (0.0511)*	0.6043 (0.0057)***	0.5435 (0.0126)**	0.3586 (0.1257)	0.3663 (0.0785)*	0.5414 (0.2379)	0.2106 (0.0445)**
β_1	0.9884 (0.0000)***	-0.3444 (0.0936)*	0.2682 (0.3409)	0.6641 (0.0000)***	0.3653 (0.2979)	-	0.7649 (0.0000)***	-0.3935 (0.0391)**
γ_1	-0.7628 (0.1205)	0.0849 (0.7011)	0.1858 (0.2787)	-0.0911 (0.7169)	0.3150 (0.7401)	-0.2549 (0.0656)*	0.3592 (0.4065)	0.2205 (0.5352)
δ	0.7536 (0.0820)*	2.7262 (0.0000)***	2.2730 (0.0000)***	1.7411 (0.0886)*	1.2703 (0.3148)	2.0542 (0.0000)***	1.8690 (0.0003)***	2.5046 (0.0000)***
ν	0.3576 (0.2546)	0.0539 (0.8980)	-0.0011 (0.6297)	0.3826 (0.4095)	0.0146 (0.7865)	1.0004 (0.7995)	0.0012 (0.5708)	0.2118 (0.8285)
AIC	-0.1010	-3.8233	-0.4954	5.3915	-0.5274	-3.3502	-0.4589	-3.8488
Log(Ln)	26.5300	401.0610	75.3889	-707.7630	83.1456	462.2480	71.8066	402.6540
$Q^2(10)$	9.9630	16.3736*	1.3278	7.8751	4.5752	25.3208**	9.2057	12.7201

Note: *, ** and *** are significance at 10, 5 and 1% levels, respectively; p-values are in parentheses

Table 5: Estimated ARMA-APARCH model (with Dummy variables)

Country	US		Japan		UK		EU	
Items	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate	Bond yield	Exchange rate
Model	(0,1)	(1,1)	(0,1)	(1,1)	(0,1)	(1,1)	(1,1)	(1,1)
ω	-0.0248	0.0009	-0.0411	-0.0416	-0.0316	0.0024	-0.0290	0.0001
	(0.1516)	(0.8904)	(0.0292)**	(0.9337)	(0.0806)*	(0.3574)	(0.079)*	(0.972)
DUM 1	0.0590	0.0040	0.0330	-0.3540	0.0520	0.0040	0.0040	-0.0105
	(0.512)	(0.859)	(0.191)	(0.585)	(0.416)	(0.795)	(0.926)	(0.453)
DUM 2	-0.019	-0.008	-	-	-0.039	-0.003	-	-
	(0.712)	(0.656)			(0.587)	(0.707)		
α_1	0.0278	0.1047	0.4587	0.0346	0.0785	0.1043	0.0740	0.1190
	(0.2801)	(0.3870)	(0.0838)*	(0.7228)	(0.5042)	(0.4057)	(0.168)	(0.225)
β_1	-	0.8509	-	0.9304	-	0.7254	0.8700	0.7260
		(0.1446)		(0.0000)***		(0.0001)***	(0.0000)***	(0.113)
γ_1	-0.2146	0.1017		0.0075	0.0037	-0.1486	0.1590	0.1330
	(0.2765)	(0.8719)	(0.6159)	(0.9921)	(0.9918)	(0.4945)	(0.697)	(0.465)
δ	4.5517	1.7787	0.8432	1.8804	3.8332	2.4097	0.9780	2.7890
	(0.0000)***	(0.6966)	(0.3666)	(0.6068)	(0.0000)***	(0.2094)	(0.725)	(0.542)
ν	0.0011	1.4472	0.1882	0.3809	0.0012	0.8721	0.0138	0.0930
	(0.0000)***	(0.9210)	(0.5206)	(0.8247)	(0.0002)***	(0.8788)	(0.888)	(0.942)
Asymmetry	0.1022	0.0057	0.0935	-0.0984	-0.0701	-0.0538	-	-0.0490
	(0.4132)	(0.9617)	(0.2822)	(0.5040)	(0.7498)	(0.6399)		(0.705)
Tail	8.0315	9.7556	3.2180	4.8633	6.9247	5.0047	-	18.6290
	(0.0247)**	(0.4563)	(0.0000)***	(0.0082)***	(0.2255)	(0.0011)***		(0.469)

Note: The bond yield variables of Japan and Euro zone are estimated by Normal APARCH. *, ** and *** are significance at 10, 5 and 1% levels, respectively; p-values are in parentheses. ξ is the asymmetry coefficient. If $\ln(\xi)<0$ (or $\xi< 1$) the density is skewed to the left. Thus, the VaR for long positions will be larger (for the same conditional variance) than the VaR for short positions. If $\ln(\xi)>0$ (or $\xi>1$), we have the opposite result.

Credit Card Behavior Tells the Risk of Unsecured Consumer Credit Loan _ Application of Survival Table

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Abstract

To improve the efficiency of unsecured consumer credit loan grant decision model, not only personal loan application data but also credit card behavioral variables of applicants are included among the explanatory variables in this study because the dynamic variables capture the consuming behavior of applicants that contains more information about credit risk. Based on above explanatory variables, a survival model is built in this study for unsecured consumer credit loan grant decision since it tells the expected default and prepayment probability at every time point in the loan term. This study also introduces survival table as a tool for unsecured consumer credit loan grant decision. Similar to life table in insurance, survival table makes the risk management of unsecured consumer credit loans simple and easy. Evidence from Taiwan shows that both of survival model and survival table are competitive with logistic model, one of the most widely used credit models.

JEL Code: G21

Keywords: Survival Analysis, Unsecured Consumer Credit Loan, Survival Table, Credit Card, Loan Grant Decision

Since the 1997 Asian financial crisis, financial institutions in Taiwan focused on consumer credit market because of the recession of corporate finance. In order to enlarge the profit, financial institutions increased the weight of consumer credit loans gradually and this changed consuming habit of individuals and increase their consumption cost in daily life. Consumer credit loans have increased rapidly in recent years and accompanied with this growth, the profits and losses of consumer credit loans have great effects on the revenue of a financial institution. Unfortunately, the over-expansion of consumer credit market brought not only high return but also high risk. The credit card debt crises and subprime mortgage debacle occurred in Asia, United States and Europe since 2003 brought financial institutions dramatic loss and led to the depression of consumer loan market. The economic impacts caused by the turmoil of consumer financial market are so critical that governments are now urged to take measures to combat the spread of financial collapse. Although credit risk is getting higher and higher, it is not smart for financial institutions to deflate consumer credit business because the global economic recession has already reduced their profits substantially. Facing the dilemma of increasing the profit or reducing the risk, an efficient grant decision process of consumer credit loans is indispensable for financial institutions. Credit debt crises have caused academic and industrial notices about consumer credit risk and relative researches bloomed. Prior consumer credit models, such as logistic regression, discriminant analysis and artificial neural networks, focus on the question whether consumer credit loans default by a given time in the future or not (Hayhoe et al, 1999; David, 2001; Thomas at el, 2002; Limsombunchai et al, 2005). Based on the analysis results, a conservative financial institution may reject a consumer credit loan which has high probability to default in the loan term. However, rejecting all loans which may default in the loan term may be inappropriate because a loan defaults near the end of the loan term may bring a profit more than its cost before it defaults. Therefore, not only if but also when will a consumer credit loan default become a more important question (Thomas, Banasik and Crook, 1999). To deal with the new concern, Narain (1992) first adopted survival analysis (Cox, 1972), a methodology usually used in medical science and biology, to build consumer credit models because it provides not only the expected default time but also the default probability of each time point in the future which is very helpful in consumer credit loan grant decision.

Although survival analysis has been widely applied to consumer credit loans in prior studies, one kind of risky loans, unsecured consumer credit loans (also known as personal loans), has seldom been discussed because the major consumer credit loans traded in market were loans that have collateral, such as mortgage loans and auto loans. Accompanied with the popularity of credit cards, the use of small amount unsecured consumer credit loans grows rapidly because most of financial institutions provide personal loans to their credit card clients with a simple application procedure. Although the credit risk of unsecured consumer credit loans is higher than other consumer credit loans since there is no collateral, the high interest brought by personal loans makes abandoning all unsecured consumer credit loans regrettable for a financial institution. To diminish the credit risk as well as to enlarge the profit of their consumer credit loan portfolios, improving the efficiency of unsecured consumer credit loan grant decision is in haste for financial institutions. Therefore, this study focuses on the credit risk of unsecured consumer credit loans and uses survival analysis and survival table as tools for personal loan grant decision. What is the main limitation of current unsecured consumer credit loan grant decision process? Most of personal loan grant decisions nowadays are made based on application data, including loan characteristics and demographic data. However, these static data cannot capture the consuming behavior of applicants that contains more information about credit risk of unsecured consumer credit loans. To solve this problem, not only unsecured consumer credit loan application data but also credit card behavioral variables of applicants are included in the unsecured consumer credit loan grant decision model because credit card is the most commonly held nonfinancial asset and most of unsecured consumer credit loan applicants have credit cards. Two more contributions about unsecured consumer credit loan grant decision are built in this study. First, this study builds a survival model of personal loans based on application data and credit card behavioral variables. Second, a process of building survival table for unsecured consumer credit loan grant decision is introduced in this study. A survival table, like a life table in insurance, provides the default probabilities at every time point in the future. The user-friendliness of survival table reduces the difficulty of unsecured consumer credit loan grant because every employee can find out default risk of every personal loan applicant whether he can build a survival model himself or not. This study also contains an empirical study based on unsecured consumer credit loan and credit card data of a major Taiwan financial institution to compare the prediction capabilities of survival model and survival table with logistic model, the most widely-used model in current consumer financial market.

The study is structured as follows. The next section outlines proportional hazards model, one of the expensively-used survival analysis methods. It also describes the method of building survival table. The subsequent section outlines the empirical data and prediction variables of survival model. The following section contains the results of empirical study which includes the comparison of the survival model, survival table, and traditional logistic model. The final section concludes and outlines some directions for further research.

I. Proportional Hazards Model and Survival Table

Proportional hazards model (Cox, 1972) is one of the most widely-used survival model that connects the explanatory variables to survival time. The survival time of a sample is defined as the period since the beginning of observation to the time of default event. A sample is called a complete data if this sample default event occurs in the period of research whose beginning and end of survival time can be observed. Otherwise, it is called a censored data or an uncompleted data. Suppose that the default event happens at time T, the probability for a sample to survive at time t before time T is represented by the survival function, and the default probability of unit time is measured by hazards function which means a sample defaults at the next moment in case that this sample is survival at time t. The relationship between survival function and hazards function is

$$S(t) = P(T \geq t) = \lim_{\Delta\tau_k \to 0} \prod_{k=0}^{r-1} [1 - h(\tau_k)(\tau_{k+1} - \tau_k)] \tag{1}$$

where $0 = \tau_0 < \tau_1 < ... < \tau_{r-1} < \tau_r = t$

The proportional hazards function is defined as

$$h(t; X) = h_0(t)\exp(\beta X(t)) \tag{2}$$

where $h_0(t)$ represents the baseline hazards function at time t when $X(t) = 0$.

Cox models use maximum likelihood method to estimate the coefficients β. If an unsecured consumer credit loan debtor i defaults at time t_i, than the information ratio of this sample compared with the whole risk set is

$$\frac{\exp\{\beta X_i(t_i)\}}{\sum_{l \in R\{t_i\}} \exp\{\beta X_l(t_i)\}} \tag{3}$$

where $R\{t_i\}$ is the whole risk set at time t_i and $X_l(t_i)$ is the explanatory variables matrix of unsecured consumer credit loan l. Assuming there are n unsecured consumer credit loans default in the observation period and the default times are $t_1, t_2, .., t_n$ in turn, the Log-likelihood function could be obtained by summing up the log value of risk information:

$$L(\beta) = \sum_{i=1}^{n} \left(\beta' X_i(t_i) - \log\left[\sum_{l \in R\{t_i\}} \exp\{\beta' X_l(t_i)\} \right] \right) \tag{4}$$

For an unsecured consumer credit loan, there are two competing risks in survival models: default and prepayment. According to rule of thumb, an unsecured consumer credit loan is defined as default if the time of overdue is more than 90 days, which is usually called as M3 status in consumer loan market. The survival function can be used to estimate the distribution of both T_d, the lifetime of the unsecured consumer credit loan until default, and T_p, the lifetime of the personal loan until early repayment. Define T_m as the end of loan term, and the lifetime of an unsecured consumer credit loan is

$$T = \min\{T_d, T_p, T_m\} \tag{5}$$

The observation time period of this study is the first twelve months of loan term. That is, the survival time for a censored unsecured consumer credit loan is from P+1 to P+12 where P is the initial time of personal loan. Otherwise, survival time is from P+1 to T.

One of the most important contributions of this study is building survival table that contains default probabilities of all groups at every time point in the future, just like the widely-used life table in insurance industry. The first step of constructing a survival table is giving credit scores to all unsecured consumer credit loan after building a proportional hazards model based on training samples. For each significant ordinal explanatory variable, give every unsecured consumer credit loan a score from zero point to nine points based on the ordinal number. As for significant nominal variables, add different scores to personal loans according to their classification. By summing up all scores of significant variables, the credit score of every unsecured consumer credit loan can be obtained and all personal loans can be sorted into groups with the credit scores. The credit score is connected to survival probability and the higher credit score one unsecured consumer credit loan has the higher probability it may default. Therefore, unsecured consumer credit loans in the first group have the highest survival probabilities and loans in the last group have the highest default probabilities.

Survival table is constructed as following steps. First, build a proportional hazards model with training data and get the value of baseline hazards function at every time point and coefficient matrix β. Second, give every unsecured consumer credit loan a credit score based on above process and sort all personal loans into groups with their credit scores. Third, based on the coefficient matrix, compute the average value of βX for every group for training data as well as testing samples. Compare the average βX curves of training set and testing set, it is found that there is a smooth shift which may be attributed to the macroeconomic changes in different time horizon. Since the differences of these two curves are close to a constant, the average value of these differences between training groups and testing groups, defined as increment C, can capture the effect of macroeconomic change. Add the average increment to the value of βX for every group in testing set, the values of modified $\beta X'$ can be obtained. Then compute the hazard rate and survival probability of every group based on the values of baseline function and modified $\beta X'$, the survival table is now completed. Survival table that contains prepayment risk information can be easily constructed by the same method, too. It should be noted that the increment is also engaged in the survival model because removing the effect of macroeconomic changes will improve the efficiency of model.

II. Loan Data and Prediction Variables

The proportional hazards model of unsecured consumer credit loans contains two kinds of prediction variables: unsecured consumer credit loan application variables, including loan characteristics and demographic data, and credit card behavioral variables. The application characteristics include five variables: application date, application amount, loan amount, loan duration, and loan purpose. Demographic data include twelve variables: gender, education level, marriage status, number of child, occupation, job title, work experience, annual income, income certificates, house type, house ownership, and housing time. It is noted that there are 7 kinds of income certificates, such as certificate of deposit and tax deductible receipt, provided by unsecured consumer credit loan applicants to support their income status. The behavioral variables of credit cards include the monthly performance data in the performance period, the last twelve months before observation period, i.e. P-1 to P-12. There are seven performance items: previous balance, sales amount, cash advanced amount, total amount payable, repayment amount, minimum repayment, and minimum repayment of last transaction.

In addition to monthly behavioral variables for the last twelve month, there are some extended variables. For each repayment item, there are two dimensions in concern: duration and statistic values. The duration defined in this study includes short-term data, mid-term data and long-term data, which means data of the last quarter (P-1 to P-3), the last six months (P-1 to P-6), and the last twelve months (P-1 to P-12), respectively. Moreover, to capture the deviant performance, two increments are included: the difference between long-term and mid-term and the difference between mid-term and short-term. The statistic values include mean, standard deviation, maximum, minimum, and summation. Finally, there are total 259 behavioral variables engaged in survival model. Because there are so many prediction variables in survival analysis which makes the model very complicated and the behavioral variables seem to be linear dependent that makes the model unreliable, the method of principal component is adopted in dealing with the behavioral variables to simplify the model and ensure the linear independence of variables. Keep the components whose eigenvalues are greater than one, there are twenty-three principal components, called factor 1, factor 2, etc. Besides these principal components, four more credit card behavioral variables are included in the model: overdue, time of over due, block code, and time of block code. Overdue is a dummy variable that represents if the credit card is in the status of overdue. Block code represents the last record of overdue, reissue, over-consumption, and suspension. Finally, total forty-four variables, including unsecured consumer credit loan application information and credit card behavioral variables, are contained in survival model.

Since the 1997 Asian financial crisis, financial institutions in Taiwan focused on consumer credit market because of the recession of corporate finance. In order to enlarge the profit, financial institutions increased the weight of consumer credit loans gradually and this changed consuming habit of individuals and increase their consumption cost in daily life. The rapid growth of consumer credit market finally led a serious double card debt crisis in the fourth quarter of 2005. To compare the prediction power of candidate models, about ten thousand unsecured consumer credit loan samples of a major Taiwan financial institution are engaged in the empirical study. To test the prediction capability of survival model in dramatic fluctuation, unsecured consumer credit loan samples are divided into two sets, training set and testing set, according to their initial dates are before or after September 2005 because the consumer financial market in Taiwan expanded significantly before the double card debt crisis. That is, samples approved before September 2005 are included in training set to build the model. Since the observation period is the first twelve months in the loan term, the modeling structure is incomplete until September 2006 so that personal loan samples approved after October 2006 are included in the testing set. In order to make sure the completeness of credit card behavioral variables, unsecured consumer credit loan samples are excluded if the applicants do not have complete credit card behavioral data before application date *P*. Finally, there are total 9573 unsecured consumer credit loan samples included in the empirical study, 6056 of them are training samples and other 3517 samples are used to test the model. Table I shows the repayment behavior of unsecured consumer credit loans in training set and testing set during the observation period.

Refer Table I

III. Results of Empirical Study

Most financial institutions nowadays take logistic regression into consideration when they make loan grant decisions because it is one of the simplest credit models. To fit the need of financial industry, reducing the complication of survival analysis by including the method of principal component is the first step and ensuring the simplification will not reduce the prediction power of survival model is the second step. This section will show the results of empirical study based on unsecured consumer credit loan samples of a major Taiwan financial institution. Furthermore, a comparison of survival model and survival table with logistic regression will show that both of survival model and survival table are competitive with the major tool used in unsecured consumer credit loan grant decision. To test the practicability of including credit card behavioral variables, two survival models and two logistic models are built in empirical study. First, survival model and logistic model are built based on application variables. Then based on not only application variables but also credit card behavioral variables, advanced survival model and advanced logistic model are built.

The results show that survival model contains eight significant explanatory variables in default prediction: application date, loan duration, gender, education level, marriage status, occupation, income certificates, and house ownership. And the logistic model contains all significant explanatory variables except marriage status, income certificates, and house ownership. On the other hand, advanced survival model contains not only all significant explanatory variables of survival model, but also block code and five significant principal components of credit card behavioral variables: factor 1, 3, 4, 18, and 21. Similarly, advanced logistic model contains block code and three principal components, factor 1, 3, and 4, besides all significant explanatory variables of logistic model. As for prepayment prediction, survival model contains eight significant explanatory variables in default prediction: application date, loan amount, loan duration, gender, marriage status, occupation, work experience, and house ownership. And the logistic model contains all significant explanatory variables except marriage status. On the other hand, besides all significant explanatory variables of survival model, advanced survival model also contains three significant principal components of credit card behavioral variables: factor 1, 18, and 20. Similarly, advanced logistic model contains not only all significant explanatory variables of logistic model but also two principal components, factor 1 and 18.

After constructing proportional hazards models for default and prepayment, the process of building survival table is applied to set up two survival tables for default and prepayment. Based on the results of advanced proportional hazards model for default prediction, most unsecured consumer credit loan samples get credit scores in the interval between twenty points and one hundred and twenty points. Therefore, this study categorizes these loan samples into twenty-three groups. The first group includes unsecured consumer credit loans whose credit scores are lower than thirty-six points and the last group includes loans that get credit scores higher than one hundred points. Other unsecured consumer credit loans are divided into twenty-one groups with their credit scores. Fig. 1 shows the number of loans in every group. It also shows and the proportion of unsecured consumer credit loan samples not default in the observation period the expected probability of every group. It is shown that realized survival rates are close to the expected survival probabilities and both of them reduce with groups. And the descending survival probabilities from the first group to the last group show the validity of grouping rule and hence ensure the practicability of survival table. Similar results were obtained for prepayment prediction.

To simplify the illustration, this study only shows part of survival table for default prediction in Table II to describe the structure of this credit scoring system. Survival table enable financial institutions know the change of an unsecured consumer credit loan easily even for a staff not familiar with modeling approaches of survival model. To find the future survival probabilities of an unsecured consumer credit loan, the staff only needs to calculate its credit score then he can find its survival probability for every time point in the future. For example, if an unsecured consumer credit loan has a credit score of fifty points, then it belongs to the sixth group. If the staff wants to find the expected default rate of the loan at the two and half year after approved, he can easily find the expected survival probability in the survival table so that he will know that the expected default probability of the loan after two and half year is 1.53%.

Refer Fig. 1

Refer Table II

Table III and Table IV show the comparisons of using survival models, survival tables and logistic models as tools for unsecured consumer credit loan grant decision about default and prepayment, respectively. It is shown that the prediction capabilities of these three methods are risen by including the credit card behavioral variables because the type I and type II errors of all advanced methods are much lower than these of their corresponding original models. Thus, it is concluded that the efficiency of unsecured consumer credit loan grant decision models is improved by including credit card behavioral variables among explanatory variables.

The results also show that survival method is competitive with the logistic regression approach since the type I and type II errors of advanced survival models are lower than these of their corresponding logistic models in default and prepayment prediction. Moreover, the characteristic of survival model that tells the default probability of every time in the loan term ensures the practicability of survival model because it helps financial institution to monitor the expected cash flow of every personal loan in the future. It is concluded that survival model, with the simplification of principle component method, is superior to logistic model in unsecured consumer credit loan grant decision.

Similar results are found about using survival table as a tool of unsecured consumer credit loan grant decision. In prepayment prediction, the type I and type II error of advanced survival table are lower than the corresponding errors of advanced logistic model. Although advanced survival table has higher type II error than advanced logistic model in default prediction, the lower type I error make it qualified for unsecured consumer credit loan grant decision method. Furthermore, the characteristic of user-friendliness reduces the difficulty of unsecured consumer credit loan grant decision and ensures the practicability of survival table. It should be noted that, like other credit models, re-building a survival table once or twice a year will promise the accuracy of survival table.

Refer Table III & IV

IV. Conclusion and Further Research

Three contributions about unsecured consumer credit loan grant decision are made by this study. In addition to application data, credit card behavioral variables are included in unsecured consumer credit loan grant decision models because credit card is the most commonly held nonfinancial asset and most of unsecured consumer credit loan applicants have credit cards. Second, this study constructs a pre-warning survival model, proportional hazards model, for unsecured consumer credit loan grant decision. This study also establishes survival table as a tool for personal loan grant decision. An empirical study based on personal loan samples of a major Taiwan financial institution shows that the efficiency of unsecured consumer credit loan grant decision models is improved by including credit card behavioral variables among explanatory variables. It also shows that both of survival model and survival table are competitive with logistic model, the most widely-used model in current financial world because both of them have lower possibility of mistaking a loan with high probability of default or prepayment for a good loan. Moreover, the characteristic of survival model that tells the default probability of every time in the loan term ensures the practicability. Like life table in insurance industry, the user-friendliness of survival table makes it a doorkeeper in unsecured consumer credit loan grant decision because every staff of financial institutions can easily find the default and prepayment probabilities of an unsecured consumer credit loan at every time point in the future by checking survival tables instead of building a complicated model himself.

The empirical data of this study is the internal data of a major Taiwan financial institution which contain only application data of unsecured consumer credit loans and behavioral data of credit card in the institution. To consider the completeness of data and the speed of data-updating, if further researches can operate survival model and survival table in coordination with the internal data and nationwide data, such as data of Joint Credit Information Center, may raise the accuracy of models. On the other hand, these two survival methods can be widely used in other similar consumer loans such as mortgage loans in further researches with different explanatory variables setting.

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Table I. Repayment Performance of Unsecured Consumer Credit Loan Samples

	Training Set		Testing Set	
Default	748	12.35%	104	2.96%
Not Default	5308	87.65%	3413	97.04%
Prepaid	1182	19.52%	366	10.41%
Not Prepaid	4874	80.48%	3151	89.59%
Censored	3889	64.22%	2949	83.85%
total	6056	100.00%	3517	100.00%

Table II. Survival Table for Default Prediction (Part)

Group / Time	…	25	26	27	28	29	30	…
1	…	0.9997	0.9996	0.9996	0.9996	0.9995	0.9995	…
2	…	0.9973	0.9969	0.9965	0.9962	0.9958	0.9955	…
3	…	0.9960	0.9954	0.9948	0.9944	0.9938	0.9933	…
4	…	0.9948	0.9940	0.9932	0.9926	0.9919	0.9912	…
5	…	0.9929	0.9918	0.9908	0.9900	0.9890	0.9880	…
6	…	0.9909	0.9895	0.9882	0.9872	0.9860	0.9847	…
⋮	…	⋮	⋮	⋮	⋮	⋮	⋮	…
20	…	0.9628	0.9573	0.9520	0.9481	0.9430	0.9381	…
21	…	0.9533	0.9465	0.9398	0.9350	0.9287	0.9226	…
22	…	0.9436	0.9354	0.9274	0.9216	0.9140	0.9068	…
23	…	0.9204	0.9090	0.8979	0.8898	0.8794	0.8695	…

Table III. Prediction Capabilities of Survival, Logistic Model, and Survival Table for Default

	Survival Model		Logistic Model		Survival Table	
	Original	Advanced	Original	Advanced	Original	Advanced
Predict Good and Result in Good	3345	3391	3325	3387	3319	3337
Predict Good but Result in Bad	60	22	71	46	63	23
Predict Bad but Result in Good	68	22	88	26	94	76
Predict Bad and Result in Bad	44	82	33	58	41	81

Table IV. Prediction Capabilities of Survival, Logistic Model, and Survival Table for Prepayment

	Survival Model		Logistic Model		Survival Table	
	Original	Advanced	Original	Advanced	Original	Advanced
Predict Good and Result in Good	3066	3083	2890	3003	2922	3059
Predict Good but Result in Bad	103	85	135	112	111	93
Predict Bad but Result in Good	85	68	261	148	229	92
Predict Bad and Result in Bad	263	281	231	254	255	273

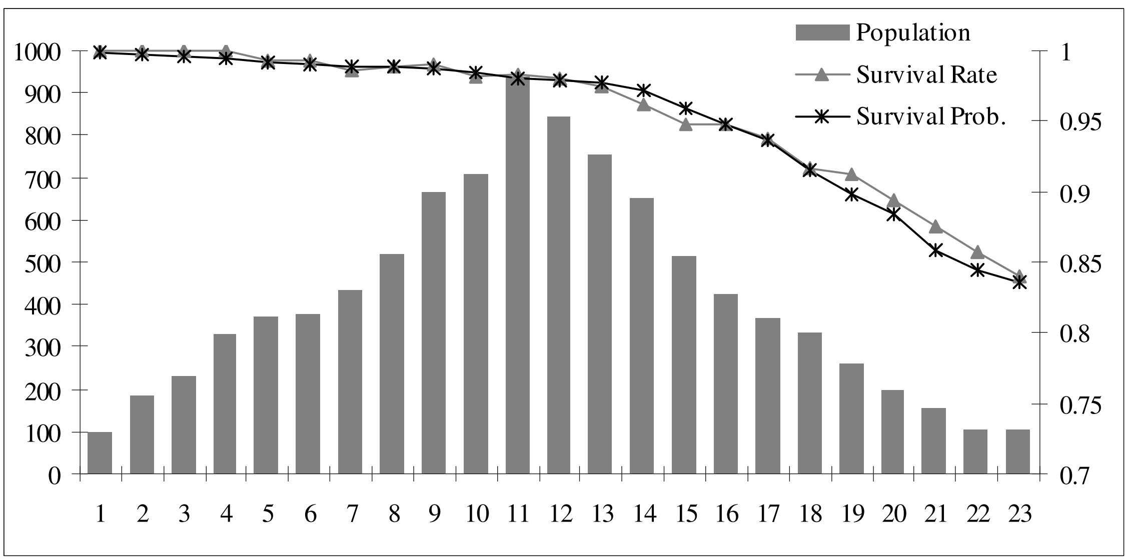

Fig. 1: Group Information for Default Prediction

Country-Specific Risks and Cross-Country Correlations of Consumption and Stock Returns

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Abstract

I examine equity premiums and international risk sharing simultaneously. I study the effect of idiosyncratic risks by differentiating shareholders' portfolios in each country from the world or local market portfolio. I also investigate the role of limited asset market participation by deriving shareholders' consumption in each country from the country's aggregate consumption and labor income. A model that incorporates idiosyncratic risks and limited participation fits equity premiums with reasonable risk aversion coefficients and bridges the gaps between consumption and asset-based risk sharing for multiple countries. While limited participation help explain the equity premium puzzle, idiosyncratic, country-specific risks are crucial for explaining both equity premiums and international risk sharing.

Key Words: Idiosyncratic risks, Limited asset market participation, Asset pricing tests
JEL classification: G15, G12

Studies of aggregate asset market and consumption data have produced several well-known puzzles. For example, consumption growth rates are too smooth to explain the aggregate equity premiums and Sharpe ratios (Mehra and Prescott (1985), Hansen and Jagnnathan (1991)). The consumption growth rates are too weakly correlated across countries compared with the asset market returns (Brennan and Solnik (1989), Tesar (1993), and Lewis (1996, 2000), Gomes and Michaelides (2008)).

The objective of this article is to examine the two issues simultaneously. I consider the effect of idiosyncratic risks by differentiating shareholders' portfolios in each country from the world or local market portfolio. I also investigate the role of limited asset market participation by distinguishing shareholders' consumption in each country from the country's aggregate consumption. Shareholders' consumption in each country is derived from the country's aggregate consumption and labor income

I consider the effects of idiosyncratic risks and limited participation for the following reasons. First, idiosyncratic risks and limited participation imply higher volatility of shareholders' portfolios and higher volatility of shareholders' consumption growth, respectively. Second, idiosyncratic risks also imply lower cross-country correlations of shareholders' portfolio returns. As a result, a model that incorporates idiosyncratic risks and limited participation bears the potential to explain not only the equity premium puzzle but also the international risk sharing puzzle.

The paper contributes the existing literature by offering a way to measure the relative importance of idiosyncratic risks and limited participation for explaining both the equity returns and consumption data. Asset pricing theory suggests that each investor's consumption-based stochastic discount factor is any asset-based stochastic discount factor plus risks unspanned by asset markets (see, e.g., Cochrane (2001)). When the unspanned risks are negligible (e.g., in a complete market), the theory implies that cross-country correlations of shareholders' portfolio returns are equalized to cross-country correlations of their consumption growth. By exploring this implication, I estimate the size of idiosyncratic risks and the degree of limited participation and simultaneously test the model's restrictions.

The assumption on the idiosyncratic portfolio risks are consistent with many domestic and international asset pricing models which suggest that investors do not hold the domestic or world market portfolios. In the domestic finance case, see Merton (1971) for the effect of hedging demands, Black (1972) for the effect of restricted borrowing, Mayers (1972) for the effect of nontradable human capital, Merton (1987) for the effect of information-segmented market, Levy (1978), Delong, et al. (1990), Barberis and Huang (2001) for effects of the behavioral bias, and Roussanov (2010) for the effect of quest for social status. There are also numerous papers which demonstrate that investors do not hold diversified portfolios because of wealth constraints or by choice, and hence they should be careful about the specific risk of the securities they hold (Blume and Friend (1975), Odean (1998), Barber and Odean (2000), Liu (2008)). In the case of international finance, see Solnik (1974), Stulz (1981), Eun and Janakiramanan (1986) for the effects of exchange rates, barriers on cross-country holdings and other market frictions. Moreover, idiosyncratic risk has been the subject of a great deal of empirical research in recent years. For example, Campbell et al. (2001) document that idiosyncratic risk is the largest component of total risk and is time-varying. Goyal and Santa-Clara (2003) find that aggregate measures of idiosyncratic volatility predict one-month-ahead excess market returns. Ang et al. (2006, 2009) report a negative and significant relation between idiosyncratic risk and cross-sectional stock returns in the U.S. and international markets. Recent research has also produced some mixed results on the significance of idiosyncratic risks (e.g., Xu et al. (2003) and Turan et al. (2005)).

Besides idiosyncratic risks, another subject of recent research in finance deals with the effect of limited asset market participation on the behavior of asset prices. The literature suggests that shareholders' consumption volatility is higher than the aggregate consumption volatility of both shareholders and non-shareholders and as a result, the investor risk aversion coefficient estimated from the shareholders' consumption is much lower than that estimated from the aggregate consumption volatility. In this literature, shareholders' consumption is often based on the consumer expenditure survey data for high income households (e.g., Mankiw and Zeldes (1991), Attansio, Banks, and Tanner (2002), Brav, et al. (2002), Vissing-Jørgensen (2002), Gomes and Michaelides (2008)) or based on sales of luxury goods (Aït-Sahalia, et al. (2004)). In this article, however I obtain the implied consumption volatility of market participants from country-specific aggregate data of consumption and labor income. I find the implied volatility of consumption growth for the U.S. or other countries' shareholders to be much higher than that of aggregate consumption growth or labor income growth, and the implied risk aversion coefficients to be consistent or lower than those reported in the existing literature on limited asset market participation.

The rest of the article is organized as follows. In Section I, I present the model. I describe data sources and summary statistics in Section II. In Section III I discuss results of estimation. In the last section I present conclusions.

I. The Model

1.1. The effects of idiosyncratic portfolio risk

Suppose that there is a representative investor in each of N countries, indexed by $j,k=1,2,\cdots,N$. The portfolio returns for investors satisfy

$$r^j = r_m + e^j + \varepsilon^j, \quad j=1,2,\cdots,N, \tag{1}$$

$$\mathrm{cov}(r_m + e^j, \varepsilon^k) = 0, \quad j,k=1,2,\cdots,N \tag{2}$$

$$\mathrm{cov}(\varepsilon^j, \varepsilon^k) = 0, \quad j \neq k. \tag{3}$$

Here r^j represents portfolio returns for the country *j*'s investor in local currency, r_m represents the aggregate world or local market return in U.S. dollars, e^j represents changes in the exchange rates for converting U.S. dollars into the country *j*'s local currency and ε^j is the country *j*-specific, idiosyncratic component with mean zero and standard deviation $\sigma[\varepsilon^j]$. For simplicity, let $r_m^j = r_m + e^j$ denote market returns in the country *j*'s local currency. Equation (1) is similar to a single-index model where all securities' returns are related to the common world or local market index. Since r^j represents the returns on country-specific representative agents, I make the simplifying assumption that the intercepts are all zero and the portfolio beats are all unity. Equation (2) says that idiosyncratic components are uncorrelated with market returns in local and other currencies. Equation (3) says that idiosyncratic components are uncorrelated across countries.

I now examine the implications of idiosyncratic portfolio risk on the volatility and correlations of portfolio returns across countries. To this end, let

$$\kappa = \frac{\sigma[\varepsilon^j]}{\sigma[r_m^j]} \tag{4}$$

be the ratio of the idiosyncratic standard deviation to the market standard deviation, or simply speaking, idiosyncratic risk ratio. Then the portfolio standard deviation is

$$\sigma[r^j] = \sigma[r_m^j]\sqrt{1+\kappa^2}. \tag{5}$$

Equation (5) implies that the volatility of each investor's portfolio returns is greater than the market volatility because of the idiosyncratic risk. Let $S^j = \left(E[r^j] - r_f^j\right)/\sigma[r^j]$ denote the Sharpe ratio for each investor's portfolio and similarly let $S_m^j = \left(E[r_m^j] - r_f^j\right)/\sigma[r_m^j]$ denote the Sharpe ratio of the market portfolio. Then from equations (1) and (5), the Sharpe ratio for each investor's portfolio is

$$S^j = \frac{S_m^j}{\sqrt{1+\kappa^2}}. \tag{6}$$

Equation (6) says that the investor's Sharpe ratio is lower than the Sharpe ratio for the market portfolio since the idiosyncratic risk increases the volatility of the investor's portfolio but it does not affect the risk premium of the investor's portfolio.

The assumptions given by equations (1)-(3) imply that the covariance between two countries' portfolio returns is

$$\mathrm{cov}(r^j, r^k) = \mathrm{cov}(r_m^j, r_m^k) \tag{7}$$

which implies

$$\rho(r^j, r^k)\sigma[r^j]\sigma[r^k] = \rho(r_m^j, r_m^k)\sigma[r_m^j]\sigma[r_m^k] \tag{8}$$

Substituting equation (5) into equation (8) implies that the correlation of two countries' portfolio returns is

$$\rho(r^j, r^k) = \frac{1}{1+\kappa^2}\rho(r_m^j, r_m^k). \tag{9}$$

Equation (9) says that the correlation of investors' portfolio returns between pairs of countries is lower than that between market returns and is inversely related to the idiosyncratic risk ratio κ. The correlation approaches zero if the idiosyncratic risk ratio increases to infinity. As a result, a high idiosyncratic risk ratio in the investor's portfolios can simultaneously reduce their portfolios' Sharpe ratios and return correlations. In other words, idiosyncratic portfolio risk may help explain both the equity premium and the international risk sharing puzzles.

1.2. Effects of limited market participation

In addition to the limited number of investors as shareholders, assume that in each country there are a number of non-shareholders who are restrained from trading in asset markets. Unlike shareholders, the consumption growth of non-shareholders is obtained from labor income growth only. Each country's aggregate consumption growth is a weighted average of consumption growth of shareholders and non-shareholders.

Specifically, let L^j be the aggregate labor income in country *j*. Assume that the consumption of non-shareholders in country *j* is $C_o^j = \xi^j L^j$, where $0 < \xi^j \leq 1$ is the nonshareholders' share of aggregate labor income in country *j*. Then (log) consumption growth of each non-shareholder satisfies

$$\Delta c_o^j = \Delta l^j, \tag{10}$$

In the finance literature, labor income growth is commonly used to represent returns on human capital (see Fama and Schwert (1977), Campbell (1996), Jagannathan and Wang (1996)). In this regard, equation (10) says that nonshareholders' consumption growth is derived entirely from returns from human capital instead of financial wealth.

Let ϕ be the non-shareholders' share of total consumption in each country's economy. Then country *j*'s aggregate consumption growth is

$$\Delta c_a^j = (1-\phi)\Delta c^j + \phi \Delta l^j. \tag{11}$$

Analogous to the case of a two-security portfolio, equation (11) implies that the standard deviation of aggregate consumption growth should be lower than the weighted average of the standard deviations of shareholders' and non-shareholders' consumption growth, as long as they are not perfectly correlated. If the standard deviation of the later is much lower, the standard deviation of aggregate consumption growth should be much lower than that of shareholders' consumption growth.

From equation (11), for each country shareholders' consumption growth can be derived from aggregate consumption growth and labor income growth:

$$\Delta c^j = \frac{1}{1-\phi}\Delta c_a^j - \frac{\phi}{1-\phi}\Delta l^j, \tag{12}$$

which implies that the variance of consumption growth is

$$\sigma^2[\Delta c^j] = \frac{1}{(1-\phi)^2}\left[\sigma^2[\Delta c_a^j] + \phi^2 \sigma^2[\Delta l^j] - 2\phi \operatorname{cov}(\Delta c_a^j, \Delta l^j)\right]. \tag{13}$$

Next I discuss the correlation of consumption growth between pairs of countries. From equation (12), the following holds:

$$\operatorname{cov}(\Delta c^j, \Delta c^k) = \frac{1}{(1-\phi)^2}\left[\operatorname{cov}(\Delta c_a^j, \Delta c_a^k) + \phi^2 \operatorname{cov}(\Delta l^j, \Delta l^k)\right] - \frac{\phi}{(1-\phi)^2}\left[\operatorname{cov}(\Delta c_a^j, \Delta l^k) + \operatorname{cov}(\Delta c_a^k, \Delta l^j)\right]. \tag{14}$$

Then the correlation of shareholders' consumption growth for any country pair can be inferred from the correlation of aggregate consumption growth and the correlation of labor income growth as well as cross-correlations between aggregate consumption and labor income growth between the countries. A high correlation of labor income growth implies a high correlation of shareholders' consumption growth. However, cross-correlations between aggregate consumption and labor income growth have the opposite effects. Equations (13) and (14) together can be used to compute the correlation between shareholders' consumption growth,

$$\rho(\Delta c^j, \Delta c^k) = \frac{\text{cov}(\Delta c^j, \Delta c^k)}{\sigma[\Delta c^j]\sigma[\Delta c^k]}. \tag{15}$$

Since the volatility of shareholders' consumption growth is likely higher than that of aggregate consumption growth, incorporating limited market participation should lower the investor risk aversion needed to explain the aggregate market risk premium. However, its effect on the consumption correlation is not as apparent, depending on the second moments of consumption growth and labor income growth.

1.3. Risk aversion and risk sharing

In what follows I assume a continuous time economy for the sake of tractability, so the expected return in simple compounding in excess of the local riskfree rate satisfies (see, e.g., Cochrane (2001)):

$$E[r^j] - r_f^j = -\text{cov}(r^j, m^j), \tag{16}$$

where m^j is a log stochastic discount factor. Assume that the preferences of country j's shareholders are given by power utility with the log stochastic discount factor:

$$m_c^j = \ln\eta - \gamma^j \Delta c^j \tag{17}$$

where η is the time discount factor and γ^j is the relative risk aversion coefficient for the country j's shareholders. Equation (17) implies

$$\sigma[m_c^j] = \gamma^j \sigma[\Delta c^j], \tag{18}$$

$$\rho(m_c^j, m_c^k) = \rho(\Delta c^j, \Delta c^k), \tag{19}$$

where $\sigma[\Delta c^j]$ is given by equation (13).

Next consider the portfolio-based log minimum-variance discount factor in continuous time for country j's shareholders:

$$m_r^j = E[m_r^j] - \frac{r^j - E[r^j]}{\sigma[r^j]} S^j, \tag{20}$$

where S^j is the Sharpe ratio. It is well known that m_r^j satisfies equation (16). Note that equation (20) implies

$$\rho(m_r^j, m_r^k) = \rho(r^j, r^k). \tag{21}$$

From equations (1) and (5), the standard deviation of the log discount factor in equation (20) is

$$\sigma[m_r^j] = S^j = \frac{S_m^j}{\sqrt{1+\kappa^2}}. \tag{22}$$

Note that the asset-based discount factor represents the linear projection of m_c^j on r^j:

$$m_c^j = m_r^j + \varepsilon_c^j, \qquad j = 1, 2, \cdots, N.. \tag{23}$$

where ε_c^j represents part of shareholders' consumption growth unspanned by the asset market and uncorrelated with their portfolio returns: $\text{cov}(m_r^j, \varepsilon_c^j) = 0$. In a complete market, there is unique discount factor for every country (currency) and hence $\varepsilon_c^j = 0$.

Note that equation (23) implies the volatility bound:

$$\sigma[m_c^j] \geq \sigma[m_r^j].. \tag{24}$$

Substituting from equations (18) and (22), one can solve the investor risk aversion coefficient as

$$\gamma^j \geq \frac{S_m^j}{\sigma[\Delta c^j]\sqrt{1+\kappa^2}} \tag{25}$$

From equation (25), either a high volatility of shareholders' consumption growth associated with limited market participation or a high idiosyncratic risk in shareholder's portfolio lowers the investor risk aversion coefficient needed to satisfy the volatility bound.

In what follows I assume that unspanned risks are negligible (e.g., there is a complete market). Equation (23) then implies

$$\rho(m_c^j, m_c^k) = \rho(m_r^j, m_r^k). \tag{26}$$

Substituting from equations (19) and (21), equation (26) implies

$$\rho(\Delta c^j, \Delta c^k) = \rho(r^j, r^k). \tag{27}$$

Equation (27) says that the correlation between shareholders' consumption growth across a pair of countries equals the correlation between their portfolio returns.

II. Data and Summary Statistics

I use the world equity index from the Morgan Stanley Capital International (MSCI) to represent the aggregate market component of the shareholders' portfolios for each of countries. The MSCI world equity index is a free float-adjusted market capitalization weighted indices designed to measure the equity market performance of developed markets. I also obtain quarterly data of three-month Treasury bill rates, seasonally adjusted aggregate consumption, labor income, exchange rates, and Consumer Price Indices (CPI) for the four countries from the International Financial Statistics (IFS). Per-capita seasonally adjusted real consumption for each country is the aggregate consumption deflated by the country's CPI and population. To be consistent with the consumption data for each country, I convert returns into local currency returns deflated by local inflation rates. In this way, returns for each country's investors are measured in the units of the investors' local consumption goods. The excess returns are local currency real returns in excess of local real risk free rates. Give the availability of data, I choose four countries including Germany, Japan, U.K. and U.S. for the empirical analysis and the sample period spans from the first quarter of 1970 to the fourth quarter of 2006.

Table 1 presents summary statistics for excess stock returns, consumption growth and labor income growth. Stock returns are computed with simple compounding. Other variables are expressed as the first difference in logs. Panel A presents means and standard deviations. For the world index returns in local currencies, the differences in returns across countries result only from the exchange rate variation across countries. The mean excess returns for the world index is 1.47% in real U.S. dollars. During the sample period, U.S. dollars depreciate against the rest of currencies in real terms, so world index returns are lower after converting from U.S. dollars to other currencies. The mean consumption growth is higher than that of labor income growth for each country. However, the standard deviations of consumption growth are similar to those of labor income growth. The cross-country average of mean consumption growth is 0.48%, with an average standard deviation of 1.20%, while the cross-country average of mean labor income growth is 0.38%, with an average standard deviation of 1.23%. It is noticeable that the standard deviations of U.S. consumption and labor income growth are respectively 0.83% and 0.79%, both much lower than those of other countries.

Next I examine the implied Sharpe ratios and investor risk aversion coefficients reported in panel B, under the assumption of no idiosyncratic risks and full market participation. The Sharpe ratios range from 0.12 for the U.K. to 0.18 for the U.S., averaging 0.14 for the four countries. The risk aversion coefficients, have a minimum of 8.92 for Japan and maximum of 21.84 for the U.S., averaging 12.87. The high U.S. risk aversion is a result of a high Sharpe ratio and low consumption volatility, which is the well known equity premium puzzle.

Finally I discuss the results in panel C about the correlations of stock returns, consumption, labor income growth and cross-correlations of consumption and labor income growth for each country pair. Consistent with the literature, the correlations of stock returns are 0.79 or higher, averaging 0.84. However, correlations of consumption growth are 0.29 or lower, averaging 0.23. The average correlation of labor income growth (0.17) and the average cross-correlation of consumption and labor income growth (0.16) are even lower. The large discrepancy between stock return correlation and consumption correlation illustrates the international risk sharing puzzle.

III. Estimation

Equation (27) says that the correlation between shareholders' consumption growth of any country pair equals the correlation between their portfolio returns. In this section, I present the procedure for estimating the model parameters and testing the restrictions imposed by equation (27) for a set of countries.

I use the generalized method of moments (GMM) for estimation and testing. To estimate the means and standard deviations of consumption growth and stock returns, I consider the following disturbance terms:

$$u_m^j = r_m^j - \mu_m^j, \ \ j = 1, 2, \cdots, N, \tag{28}$$

$$u_c^j = \Delta c_a^j - \mu_c^j, \ \ j = 1, 2, \cdots, N, \tag{29}$$

$$v_m^j = (u_m^j)^2 - (s_m^j)^2, \ \ j = 1, 2, \cdots, N, \tag{30}$$

$$v_c^j = (u_c^j)^2 - (s_c^j)^2, \ \ j = 1, 2, \cdots, N. \tag{31}$$

For the model with limited market participation, I add the following disturbance terms to estimate the first two moments of labor income growth and the covariance of labor income growth with consumption growth:

$$u_l^j = \Delta l^j - \mu_l^j, \ \ j = 1, 2, \cdots, N, \tag{32}$$

$$v_l^j = (u_l^j)^2 - (s_l^j)^2, \ \ j = 1, 2, \cdots, N, \tag{33}$$

$$w_{cl}^j = u_c^j u_l^j - \mathrm{cov}_{cl}^j, \ \ j = 1, 2, \cdots, N. \tag{34}$$

Note that the system (28)-(34) is just identified, with 7N orthogonality conditions and the same number of parameters. Given the correlations between shareholders' consumption growth in equations (13)-(15), I include the following set of disturbance terms:

$$w_c^{jk} = \frac{u_c^j u_c^k + \phi^2 u_l^j u_l^k - \phi(u_c^j u_l^k + u_c^k u_l^j)}{\sqrt{(s_c^j)^2 + \phi^2 (s_l^j)^2 - 2\phi \mathrm{cov}_{cl}^j}\sqrt{(s_c^k)^2 + \phi^2 (s_l^k)^2 - 2\phi \mathrm{cov}_{cl}^k}} - \rho_c^{jk}, \quad j < k; j, k = 1, 2, \cdots, N, \tag{35}$$

$$w^{jk} = \frac{u_c^j u_c^k + \phi^2 u_l^j u_l^k - \phi(u_c^j u_l^k + u_c^k u_l^j)}{\sqrt{(s_c^j)^2 + \phi^2 (s_l^j)^2 - 2\phi \mathrm{cov}_{cl}^j}\sqrt{(s_c^k)^2 + \phi^2 (s_l^k)^2 - 2\phi \mathrm{cov}_{cl}^k}} - \frac{1}{1+\kappa^2}\frac{u_m^j u_m^k}{s_m^j s_m^k}, \quad j < k; j, k = 1, 2, \cdots, N. \tag{36}$$

Equation (35) estimates the correlations of shareholders' consumption growth and equation (36) imposes the equality restrictions (27) that portfolios correlations are equalized to consumption correlations for shareholders. The system (35)-(36) have N(N-1) equations and N(N-1)/2+2 parameters, contributing d.f.=N(N-1)/2-2=4 overidentifying restrictions to the system (28)-(36). To estimate the portfolio return correlations, I replace equation (35) with the following set of disturbance terms:

$$w_r^{jk} = \rho_r^{jk} - \frac{1}{1+\kappa^2}\frac{u_m^j u_m^k}{s_m^j s_m^k}\ ,\ j,k=1,2,\cdots,N,\ j<k. \qquad (37)$$

The orthogonality conditions defined by equation (37) are just identified, like equation (35), and hence do not contribute to any overidentifying restrictions. The systems of equations are estimated with the GMM using continuously updated weighting matrix.

IV. Empirical Results

A. The main results

I now study the empirical effects of idiosyncratic portfolio risks and limited asset market participation. The results of estimating the complete model are presented in Tables 2 and 3. First of all, as shown in panel A of Table 2, the test of overidentifying restrictions produces a *J*-stat. of 5.60 with a *p*-value of 0.23. So the model is not rejected ay any conventional levels. The most striking result here is that the idiosyncratic risk parameter κ and the limited participation parameter ϕ are both statistically significant at the 1 percent level. The estimated parameter κ is 2.35 with a standard error of 0.74 and the parameter ϕ is 0.43 with a standard error of 0.15. The estimated parameters suggest that the idiosyncratic standard deviation is 2.35 times the market standard deviation and the share of consumption by non-market participants is 43 percent, slightly below that of participants but is by no means negligible. The size of idiosyncratic risks is consistent with empirical evidence that most investors hold non-diversified portfolios.[3]

Next I discuss the equity premium puzzle. While the estimated market Sharpe ratios are very similar to earlier estimates in Table 1, the Sharpe ratio for each country's shareholder portfolios, however, is less than half of the market Sharpe ratio for the country, as a result of country-specific, idiosyncratic risks in the portfolios. The portfolio Sharpe ratios are 0.07 for the U.S., 0.05 for Germany and 0.04 for Japan and U.K., averaging 0.05. The estimated standard deviations of shareholders' consumption growth are however, uniformly higher than those of aggregate consumption growth and labor income growth given on Tables 1. The average is 1.64 here compared with an average of 1.20 for aggregate consumption growth and an average of 1.23 for labor income growth in Table 1. This is consistent with the model's prediction that shareholders' consumption growth should be more volatile than aggregate consumption growth, which is a weighted average of shareholders' consumption growth and labor income growth. As a result of high volatility of shareholders' consumption growth and reduced Sharpe ratios, the implied risk aversion coefficients of shareholders are much lower. The coefficients range from 2.38 for Japan to 5.50 for the U.S. with an average of 3.25 for the four countries, which are approximately one quarter of those reported in Table 1 estimated under zero idiosyncratic risks and full market full participation. The implied volatility of consumption growth is below the range for the U.S. or U.K. household consumption growth reported by Mankiw and Zeldes (1991), Attansio, Banks, and Tanner (2002), Brav, et al. (2002), and Vissing-Jørgensen (2002)

[3] See., e.g., Barber and Odean (2000) and Polkovnichenko (2003).

and below the standard deviation for U.S. luxury goods obtained by Aït-Sahalia, Parker and Yogo (2004). However, the implied risk aversion coefficients for the U.S. and other countries' shareholders are consistent or lower than those reported in the existing literature on limited asset market participation.

Finally I examine results in Table 3 about the correlations. Consistent with the result of the goodness-of-fit test, the portfolio correlations are equalized to the consumption correlations for each country pair. It is quite noticeable that shareholders' consumption correlations here are a lot lower than the aggregate consumption correlations. The correlations in Table 3 both average 0.13 across all country pairs, in contrast to the averages of 0.23 for aggregate consumption correlations and 0.84 for market returns in Table 1. The declines in the consumption correlations are largely the result of increased standard deviations of shareholders' consumption growth compared with those of aggregate consumption growth. This implies that introducing limited participation into the model dramatically widens the gap between market return correlations and shareholders' consumption correlations and makes the international risk sharing puzzle more difficult to explain in the absence of idiosyncratic portfolio risks. Fortunately, idiosyncratic risks in shareholders' portfolios diminish the cross-country correlations of their portfolio returns to match the corresponding low correlations of their consumption growth. Overall, the results suggest that the model is capable of explaining the equity premiums and bridging the gap between consumption and asset-based risk sharing for the four countries studied here.

B. Alternative specifications

To gain further insight, I estimate the model under alternative specifications. First I report the results of estimating the model under full market participation. Assuming $\phi = 0$, shareholders' consumption in each country equals the country's aggregate consumption, $c_a^j = \Delta c^j$. Tables 4 and 5 are results of estimating the model. First note that the *J*-stat. in Table 4 for the overidentifying restrictions with 5 degrees of freedom is 6.07, which implies a *p*-value of 0.30. So like the unrestricted model, the model here is not rejected any conventional levels. The parameter κ in Table 4 is 1.69 with a standard error of 0.23, implying that the idiosyncratic standard deviation is 1.69 times the market standard deviation. The lower bound of the 95 percent confidence interval of κ is 1.23, suggesting that the idiosyncratic standard deviation is significantly positive and greater than the market standard deviation. The estimated idiosyncratic risk parameter here under full market participation is approximately half of the earlier estimate under limited participation.

Next let us examine results in panel B of Table 4. The implied market Sharpe ratios here are similar to those in Tables 1 and 2, with an average of 0.13 for four countries. The Sharpe ratios for shareholders' portfolios are nearly half the size of the market Sharpe ratios, as a result of country-specific, idiosyncratic risks in the portfolios. The portfolio Sharpe ratios are 0.09 for the U.S. and 0.06 for each of the other countries, averaging 0.07. Compared with those in Table 2, the differences between the market and portfolio Sharpe ratios are smaller because the idiosyncratic risk parameter here is lower than that in Table 2 for the case of limited participation. The aggregate consumption standard deviations in Table 4 are only slightly lower than those in Table 1. However, the risk aversion coefficients in Table 4 are approximately half of those in Table 1, reflecting the differences in the Sharpe ratios between the two tables. The highest risk aversion in Table 4 is 11.11 for the U.S. with a standard error of 5.59. For the other countries, the coefficients vary from 4.35 for U.K. to 5.44 for Germany. While these coefficients are lower than those in Table 1 for the case without idiosyncratic risk, they are approximately twice of those in Table 2 where limited participation is also a feature of the model. Overall, the results indicate that the presence of country-specific, idiosyncratic risks greatly reduces the levels of investor risk aversion but assuming full market participation rather than limited participation erodes the ability of the model to better explain the equity premiums.

Table 5 summarizes the estimates of correlations. The estimated correlations of aggregate consumption growth are similar to those in Table 1, with an average of 0.22 and each is precisely estimated and statistically significant at the 1 percent level. What is interesting is that the estimated correlation of portfolio returns for each country pair is equalized, up to the reported precision, to that of consumption correlation for the same country pair. Since the gaps between aggregate consumption correlations and market return correlations in the full participation model here are much narrower than those between shareholders' consumption correlations and market return correlations in the limited participation model, the idiosyncratic risk parameter here in Table 4 is much smaller than that in Table 2.

I next reexamine the previous model under the restriction that the idiosyncratic risk parameter is zero: $\kappa = 0$. The results are presented in Table 6. The resulting estimated parameter ϕ representing non-shareholders' share of consumption is -0.98 with a standard error of 0.86. Thus the parameter is within two standard errors from zero and statistically insignificant. The point estimate is negative since a greater share of consumption by shareholders implies increased market participation, reduced volatility of shareholders' consumption growth and higher consumption correlations. The *J*-stat. with 5 degrees of freedom is 84.47 with a *p*-value of virtually zero. Hence the model is strongly rejected, implying that limited participation alone cannot explain the risk sharing puzzle.

Lastly I investigate what happens when the world market index is replaced with local market indices.[4] Tables 7 and 8 present the results. As shown Table 7, the *J*-stat. for the testing over-identifying restrictions with 4 degrees of freedom is 3.18 with a *p*-value 0.53. Thus just like the model in Table 2, the model here does a good job of equalizing correlations of shareholders' portfolio returns with those of consumption growth.

Reported in Table 7 are also the idiosyncratic risk parameter κ, which is 1.14 with a standard error of 0.36 and the limited participation parameter ϕ, which is 0.28 with a standard error of 0.19. The country-specific, idiosyncratic risks in addition to the local stock market risks are approximately half of those in Table 2, where the portfolio risks are world market risk plus the idiosyncratic risks. But the idiosyncratic risk parameter estimate is still two standard errors away from zero and statistically significant at the 1 percent level. From panel B of Table 7, the local market Sharpe ratios with an average of 0.15 are slightly higher than the world market Sharpe ratios with an average of 0.13. The implied Sharpe ratios of the shareholders' portfolios average 0.10, which are 1/3 lower than the local market Sharpe ratios because idiosyncratic risks increase shareholders' total portfolio risks.

Since the limited market participation parameter is positive, though estimated imprecisely and smaller than that in Table 4, the average standard deviation of shareholders' consumption growth here is 1.39, higher than the average of 1.20 for aggregate consumption growth reported in Table

[4]This assumption is consistent with the "home bias" literature. French and Poterba (1991) find that U.S. investors hold mostly U.S. stocks while Japanese investors mostly hold Japanese stocks. Coval and Moskowitz (1999) find that investors tend to hold more stocks in companies near them or their industries, Heaton and Lucas (2000), Benartzi (2001) and Benartzi and Thaler (2001) report concentration of investments in firms where investors work.

1. The increased volatility of shareholders' consumption growth, along with more evident reductions in Sharpe ratios, produces risk aversion coefficients, ranging from 4.94 for Japan to 11.76 for the U.S. with an average of 7.59. The estimated coefficients are slightly more than twice of those in Table 2 where the world market index is used but they are still nearly half of those in Table 1, although the average local market Sharpe ratio (0.15) are similar to the average world Sharpe ratios (0.14).

Finally I examine results in Table 8. Just like before, each estimated correlation or risk sharing index is precisely estimated and significant at the 1 percent level. The average shareholders' consumption correlation is 0.21, slightly lower than the aggregate consumption correlation of 0.23 given in Table 1, because of the small and insignificant limited participation parameter. The shareholders' portfolio correlation for each country pair once again matches exactly the corresponding consumption correlation for the same country pair. Similar results are found for the risk sharing indices, except that average consumption and portfolio-based risk sharing indices are both 0.20, slightly lower than average correlations. Overall, the results here indicate that, when the world stock index is replaced with local indices, the model still explains the international risk sharing puzzle and simultaneously lowers the risk aversion coefficients to help resolve the equity premium puzzle.

IV. Conclusions

In this article I study how a model with idiosyncratic, country-specific portfolio risks along with limited asset market participation can help explain some long outstanding puzzles in domestic and international finance literatures. First, the model explains the aggregate world equity premium with economically plausible levels of investor risk aversion for market participants of multiple countries. Second, the model produces the same levels of asset and consumption-based risk sharing for asset market participants. Therefore, unlike the risks uncorrelated with asset-based discount factors, which imply unreasonably high volatility of consumption-based discount factors, the risks inherent in investors' portfolios but uncorrelated with asset market indices can lower the risk sharing of investor portfolios and simultaneously produce low risk aversion coefficients to fit the observed aggregate equity premiums.

A close examination reveals that a restricted model under the assumption of full market participation can still match the asset-based and consumption-based international risk sharing. Idiosyncratic portfolio risks lower portfolio Sharpe ratios and investor risk aversion coefficients substantially but the coefficients needed to explain the equity premiums are higher than those needed for the full model under limited market participation. In contrast, a restricted model under the assumption of zero idiosyncratic portfolio risks is strongly rejected since limited market participation alone tends to imply increased volatility of shareholders' consumption growth and reduced cross-country correlations of their consumption growth, widening the gap between asset market-based risk sharing and consumption-based risk sharing. Further, when asset market participants' portfolio risks are assumed to be local market risks plus idiosyncratic risks, the model is still capable of explaining the risk sharing puzzle and part of the equity premium puzzle. In this case, the idiosyncratic risks remain statistically significant but the limited participation effects are diminished.

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Table 1. Summary Statistics

Market excess returns are for MSCI world index in local currencies deflated by local inflation rate in excess of local real Treasury bill rates. Consumption growth and labor income growth are country-specific aggregate per capita data deflated by local inflation rates. Risk aversion coefficients equal Sharpe ratios divided by standard deviations of consumption growth. The time period is from the first quarter of 1970 to the fourth quarter of 2006.

		Germany	Japan	U.K.	U.S.	Average
Panel A. Means and Standard Deviations, %						
World Returns	Mean	1.15	1.11	1.10	1.47	
	Std Dev	8.80	8.31	8.88	8.14	
Consumption	Mean	0.43	0.48	0.56	0.43	
Growth	Std Dev	1.14	1.50	1.33	0.83	
Labor Income	Mean	0.36	0.37	0.49	0.32	
Growth	Std Dev	1.43	1.30	1.40	0.79	
Panel B. Implied Sharpe Ratios and Risk Aversion						
Sharpe Ratio		0.13	0.13	0.12	0.18	0.14
Risk Aversion		11.46	8.92	9.28	21.84	12.87
Panel C. Correlations						
Market Excess Returns						
World Returns	Japan	0.84				
	U.K.	0.89	0.80			
	U.S.	0.83	0.79	0.85		0.84
Consumption Growth						
Consumption	Japan	0.08				
Growth	U.K.	0.24	0.27			
	U.S.	0.20	0.29	0.29		0.23
Labor Income Growth						
Labor Income	Japan	0.21				
Growth	U.K.	0.11	0.20			
	U.S.	0.11	0.10	0.08		0.13
Consumption Growth						
Labor Income	Japan	0.08				
Growth	U.K.	0.07	0.28			
	U.S.	0.13	0.21	0.17		0.16

Table 2. Estimating the Model with Idiosyncratic Risks and Limited Market Participation

The portfolio return for each country is the world market return r_m^j in local currency plus an idiosyncratic component. κ is the idiosyncratic standard deviation divided by the market standard deviation. Aggregate consumption growth in each country is the weighted average of the shareholders' consumption growth Δc^j and labor income growth. ϕ is the non-shareholders' share of aggregate consumption. The parameters are estimated by matching shareholders' cross-country portfolio correlations with their consumption correlations:

$$\rho(\Delta c^j, \Delta c^k) = \frac{1}{1+\kappa^2}\rho(r_m^j, r_m^k).$$

J-Stat. is for testing overidentifying restrictions. Standard errors are in parentheses. Consumption standard deviations are in percent.

***,**,*Significant at 1,5 and 10 percent, respectively.

Panel A. Parameter Estimates

		κ	ϕ		*J*-Stat. (4)	*p*-value
		2.35***	0.43***		5.60	0.23
		(0.74)	(0.15)			

Panel B. Implied Values

		Germany	Japan	U.K.	U.S.	Average
Market Sharpe Ratios	S_m^j	0.11	0.11	0.11	0.17**	0.13
		(0.09)	(0.08)	(0.08)	(0.08)	
Portfolio Sharpe Ratios	S^j	0.05	0.04	0.04	0.07*	0.05
		(0.04)	(0.04)	(0.04)	(0.04)	
Consumption Std Dev	$\sigma[\Delta c^j]$	1.66***	1.85***	1.82***	1.24***	1.64
		(0.45)	(0.47)	(0.42)	(0.36)	
Risk Aversion	γ^j	2.71	2.38	2.41	5.50	3.25
		(2.42)	(2.15)	(2.07)	(3.79)	

Table 3. Estimated Correlations in the Model with Idiosyncratic Risks and Limited Market Participation

Standard errors are in parentheses.
***,**,*Significant at 1,5 and 10 percent, respectively.

		Germany	Japan	U.K.	Average
Portfolio Returns	Japan	0.13*			
		(0.07)			
	U.K.	0.14*	0.13*		
		(0.07)	(0.07)		
	U.S.	0.13*	0.12*	0.13*	0.13
		(0.07)	(0.06)	(0.07)	
Consumption Growth	Japan	0.13*			
		(0.07)			
	U.K.	0.14*	0.13*		
		(0.07)	(0.07)		
	U.S.	0.13*	0.12*	0.13*	0.13
		(0.07)	(0.06)	(0.07)	

Table 4. Estimating the Model with Idiosyncratic Risks only

The portfolio return for each country is the market return plus an idiosyncratic component. κ is the idiosyncratic standard deviation divided by the market standard deviation. ϕ is the non-shareholders' share of aggregate consumption. The parameters are estimated by matching shareholders' cross-country portfolio correlations with aggregate consumption correlations:

$$\rho(\Delta c_a^j, \Delta c_a^k) = \frac{1}{1+\kappa^2}\rho(r_m^j, r_m^k).$$

J-Stat. is for testing overidentifying restrictions. Standard errors are in parentheses. Consumption standard deviations are in percent.

***,**,*Significant at 1,5 and 10 percent, respectively.

Panel A. Parameter Estimates

Restriction	κ	J-Stat. (5)	p-value
$\phi = 0$	1.69***	6.07	0.30
	(0.23)		

Panel B. Implied Values

		Germany	Japan	U.K.	U.S.	Average
Market Sharpe Ratios	S_m^j	0.11	0.12	0.11	0.17**	0.13
		(0.08)	(0.08)	(0.08)	(0.08)	
Portfolio Sharpe Ratios	S^j	0.06	0.06	0.06	0.09**	0.07
		(0.04)	(0.04)	(0.04)	(0.04)	
Consumption Std Dev	$\sigma[\Delta c_a^j]$	1.07***	1.38***	1.28***	0.78***	1.13
		(0.10)	(0.19)	(0.10)	(0.07)	
Risk Aversion	γ^j	5.44	4.43	4.35	11.11**	6.33
		(4.03)	(3.12)	(3.36)	(5.59)	

Table 5. Estimated Correlations in the Model with Idiosyncratic Risks only

Standard errors are in parentheses.
***,**,*Significant at 1,5 and 10 percent, respectively.

		Germany	Japan	U.K.	Average
Portfolio Returns	Japan	0.22***			
		(0.04)			
	U.K.	0.23***	0.21***		
		(0.04)	(0.04)		
	U.S.	0.22***	0.21***	0.22***	0.22
		(0.04)	(0.04)	(0.04)	
Consumption Growth	Japan	0.22***			
		(0.04)			
	U.K.	0.23***	0.21***		
		(0.04)	(0.04)		
	U.S.	0.22***	0.21***	0.22***	0.22
		(0.04)	(0.04)	(0.04)	

Table 6. Estimating the Model with Limited Market Participation only

The portfolio return for each country is the world market return in local currencies plus an idiosyncratic component. Aggregate consumption growth in each country is the weighted average of the shareholders' consumption growth and labor income growth. κ is the idiosyncratic standard deviation divided by the market standard deviation. ϕ is the non-shareholders' share of aggregate consumption. The parameters are estimated by matching shareholders' cross-country market return correlations with their consumption correlations:

$$\rho(\Delta c^j, \Delta c^k) = \rho(r_m^j, r_m^k).$$

J-Stat. is for testing overidentifying restrictions. Standard errors are in parentheses.
***,**,*Significant at 1,5 and 10 percent, respectively.

Restriction	ϕ	*J*-Stat. (5)	*p*-value
$\kappa = 0$	-0.98	84.47	0.00
	(0.86)		

Table 7. Estimating the Model with Idiosyncratic Risks and Limited Market Participation – Local Market Indices

The portfolio return for each country is the local market return in local currencies plus an idiosyncratic component. κ is the idiosyncratic standard deviation divided by the market standard deviation. Aggregate consumption growth in each country is the weighted average of the shareholders' consumption growth and labor income growth. ϕ is the non-shareholders' share of aggregate consumption. The parameters are estimated by matching shareholders' cross-country portfolio correlations with their consumption correlations:

$$\rho(\Delta c^j, \Delta c^k) = \frac{1}{1+\kappa^2}\rho(r_m^j, r_m^k).$$

J-Stat. is for testing overidentifying restrictions. Standard errors are in parentheses. Consumption standard deviations are in percent.

***,**,*Significant at 1,5 and 10 percent, respectively.

Panel A. Parameter Estimates

κ	ϕ		*J*-Stat. (4)	*p*-value
1.14***	0.28		3.18	0.53
(0.36)	(0.19)			

Panel B. Implied Values

		Germany	Japan	U.K.	U.S.	Average
Market Sharpe Ratios	S_m^j	0.14*	0.12	0.15**	0.19**	0.15
		(0.09)	(0.08)	(0.07)	(0.09)	
Portfolio Sharpe Ratios	S^j	0.10	0.08	0.10*	0.12*	0.10
		(0.06)	(0.06)	(0.06)	(0.06)	
Consumption Std Dev	$\sigma[\Delta c^j]$	1.33***	1.65***	1.55***	1.05***	1.39
		(0.29)	(0.32)	(0.29)	(0.24)	
Risk Aversion	γ^j	7.13	4.94	6.55	11.76	7.59
		(5.18)	(3.70)	(3.99)	(7.04)	

Table 8. Estimated Correlations in the Model with Idiosyncratic Risks and Limited Market Participation – Local Market Indices

Standard errors are in parentheses.
***,**,*Significant at 1,5 and 10 percent, respectively.

		Germany	Japan	U.K.	Average
Portfolio Returns	Japan	0.15***			
		(0.05)			
	U.K.	0.21***	0.18***		
		(0.07)	(0.06)		
	U.S.	0.24***	0.20***	0.28***	0.21
		(0.08)	(0.07)	(0.09)	
Consumption Growth	Japan	0.15***			
		(0.05)			
	U.K.	0.21***	0.18***		
		(0.07)	(0.06)		
	U.S.	0.24***	0.20***	0.28***	0.21
		(0.08)	(0.07)	(0.09)	

International Research Journal of Applied Finance ISSN 2229 – 6891
Vol. IV Issue – 5 May, 2013

Determinants of Supply of U.S. Treasury Securities: A Cointegration Analysis

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Abstract

This article analyses the supply of US Treasury securities over the 2000-2008 period. A long-run equilibrium and a short-run dynamic model are estimated, using the ARDL Bounds Testing co-integration methodology, to quantify the significant factors that can explain the supply dynamics in this market. The estimated results suggest that federal budget balance, exchange rates and returns from Treasury substitutes are significant determinants of Treasury supply in both short and long run, but expected Treasury yields do not seem to play any role either in the long or short run. Given that this is the world's largest debt market, the estimated results are important.

Key Words: U.S. Treasury supply, U.S. federal budget balance.

I. Introduction

The US Treasury securities are debt instruments, issued by the US Treasury to raise money as needed by the federal government. Treasury securities are widely regarded as a safe and secure investment option, as they are highly liquid and, more importantly, the interest and principal payments are backed by the full faith and credit of the US government. Scholars also hold that, among all US dollar assets, Treasury securities generally have the lowest total financial risk, which comprises credit, market and liquidity risks (Schinasi et al, 2001).

The supply of Treasury securities is mostly determined by "the need to finance the cumulative budget deficits of the US government" (Dupont et al, 1999) and the demand depends on their functionality as investment and hedging instruments to various entities, including individual investors, commercial banks, investment banks, insurance companies, state and local governments and foreign central banks, among others.

There are two principal types of Treasury securities: marketable securities (may be traded after initial purchase) and non-marketable securities (may not be traded after initial purchase). Marketable securities comprise four types of instruments - Treasury bills or T-Bills (maturity of one year or less), Treasury notes or T-Notes (maturity of one to 10 years), Treasury bonds or T-Bonds (maturity of 30 years) and Treasury Inflation-Protected Securities or TIPS (offered in 5-year, 10-year and 30-year maturities). T-Notes, T-Bonds and TIPS pay semiannual interest payments until maturity and the principal value of TIPS is adjusted for inflation. Nonmarketable securities comprise Government Account Series (held mainly by government programs, such as social security), State and Local Government Series (held by state and local governments) and savings bonds. Marketable securities amount to nearly 55% of all securities and the non-marketable securities comprise the rest (Dupont et al, 1999).

Participants trade in the Treasury securities market on a bilateral basis. These participants include primary dealers and non–primary dealers and their customers, including individuals and financial and non-financial institutions. Nearly 2,000 Treasury securities brokers and dealers are registered with the Securities and Exchange Commission (SEC) to trade in this market. However, most active participation is concentrated among a small number of dealers, known as the Primary Dealers, who are selected by the Federal Reserve Bank of New York. Due to the consolidation of the financial industry, the number of primary dealers has gradually decreased from a peak of 46 in 1988 to 30 in 1999 and then to 18 in 2010 (Federal Reserve Bank of New York, 2010).

The market for Treasury securities plays a very significant role in world financial markets. Saxton (2002) aptly states, "As the world's most liquid debt security, Treasuries lubricate global financial markets". This also happens to be the largest and the most active debt market in the world (Dupont et al, 1999). Tens of billions of dollars worth of Treasury securities are traded every business day. In January of 2000, total monthly transactions by primary dealers in Treasury securities were $753.43 billion, which has gradually increased to $2.01 trillion in December of 2009. The highest monthly transaction of Treasury securities during this period was recorded in August of 2007 at nearly $3.8 trillion. It is worthwhile to analyze the factors that can explain the supply dynamics of this market.

The objective of this article is to take a closer look at the supply of US Treasury securities and identify the significant factors that can explain the huge growth in the last decade. To the best of the authors' knowledge, no other study has analyzed the determinants of US Treasury supply. Therefore, as the first study of its kind, this article makes a unique contribution to the literature. The rest of the article is organized as follows – the second section presents a brief review of the literature, the third section describes the model, the fourth section discusses data, methodology and results and the last section concludes the article.

II. Literature Review

Although there are many studies on the macroeconomic effects of Treasury securities and Treasury yields, there is no study on the determinants of Treasury supply. The studies summarized below are relevant to the broad topic of Treasury supply.

Wojnilower (2000) discusses the financial implications of the diminishing supply of US Treasury securities in the mid-late 1990s, when the US faced record budget surpluses. The study argues that the absence of Treasury securities would profoundly and adversely affect portfolio management and handling of financial crises. Given the many vital functions the Treasury securities perform, such as "riskless assets in portfolios; benchmarks in the pricing of private securities; reliable hedges for market makers in debt securities and derivatives; safe havens for funds; and, as was formerly the case with gold, the chief international money", the study contends, the US Treasury should keep some securities outstanding even when there is a budget surplus. In a similar study, Schinasi et al (2001) focuses on the huge budget surpluses during the Clinton era and the impact of the concurrent shrinking supply of Treasury securities on financial markets and Federal Reserve assets.

In a Joint Committee Report to the US Congress, Saxton (2002) discusses the many benefits of Treasury securities to the US and global economy. The report finds that during an economic expansion, Treasury securities enhance the efficiency of financial markets and during a recession, Treasury securities provide financial markets with a "unique, exogenous" source of liquidity that the private sector cannot provide. The report also cites Hong Kong and Singapore as examples of countries that decided to issue government securities, despite the fact that neither had any fiscal deficit, to increase the efficiency of domestic financial markets and to lower the borrowing costs for domestic firms.

In an intriguing study of securities trade in New York vis-à-vis London and Tokyo, Fleming (1997) found that compared with the overseas trading centers, trading volume and price volatility are highly concentrated in New York trading hours. The study also found that notwithstanding the lower liquidity in overseas locations, overseas price changes of Treasury securities are accurate predictors of overnight price changes in New York.

Among other studies, Roley (1981) uses a disaggregated structural model of the Treasury securities market to jointly estimate investors' demand for securities and the yield curve. The results suggest that depending on investors' wealth flows, Treasury securities can exhibit significant, but volatile effects on the yield curve. Bikhchandani and Huang (1993) discuss the implications of altering the auction mechanism in the market for Treasury securities. They examine the susceptibility of the existing auction mechanism to manipulation by buyers and analyze if modifying the auction format would generate greater revenues for the US Treasury. Fleming (2000) analyzes the characteristics of the US Treasury market and other factors that have positioned it as the most widely accepted financial benchmark in the world. The study also examines the market's recent performance, including yield changes relative to other fixed-income assets and changes in liquidity.

As mentioned previously, none of the studies cited above directly deal with the central theme of this article – analyzing the significant determinants of supply of Treasury securities. Therefore, this article fills a critical void in the literature.

III. Model

Consistent with the objective mentioned above, this article focuses on the supply side of the market for US Treasury securities. The market supply of these securities is an aggregate of the supplies originating from domestic and foreign investors as well as the US Treasury. Domestic investors include individuals and financial institutions like commercial banks, mutual funds, pension funds, insurance companies, etc. Foreign investors include individuals, financial institutions and central banks. The market supply of Treasury securities should depend on the following factors:

1. *Federal budget balance:* The US Treasury routinely sells securities in the market to finance deficit in the federal budget. Primary dealers who buy these securities from the Treasury offer these for sale in the secondary market. Therefore, the supply of Treasury securities is expected to depend negatively on the size of federal budget balance. An increase in federal budget deficit (or decrease in surplus) will increase the supply of Treasuries and vice versa.

2. *Exchange rate:* If the US dollar appreciates against foreign currencies, local currency return on the US securities for foreign investors would increase and this would encourage foreigners to sell Treasuries. A depreciation of the dollar is expected to have the opposite effect – with an increase in the value of local currency, they would be encouraged to buy more Treasury securities. Accordingly, we would expect to see a direct or positive relationship between exchange rate and supply of Treasury securities when the rate is defined as the value of one dollar in foreign currency. An increase in exchange rate would indicate appreciation of US dollar and a decrease would show depreciation of dollar.

Foreign central banks also play an important role in the currency market and intervene to maintain the value of their local currencies vis-à-vis US dollar when it goes beyond a "tolerable" range and this has implications on the demand/supply of Treasury securities. When local currency appreciates (or dollar depreciates) beyond this range, the central bank would buy US dollar with local currency and may invest the dollar holdings in US Treasury securities; conversely, when the local currency depreciates (or dollar appreciates), they would sell Treasuries for dollars and then dollars for local currency hoping to push the value of their currency up. Therefore, from the foreign central banks' perspective, we expect to see a direct relationship between exchange rate and supply of T-securities, as argued above in connection with foreign investors' portfolio investment.

However, "expectations" about the future movement of exchange rate could affect the supply of Treasury securities in the *opposite* direction. For example, if depreciation of US dollar (which would decrease the supply of securities as argued above) is expected to continue in the future, foreign investors may decide to sell their securities in the market sooner than later to avert future losses, which will increase the supply of securities. Therefore, we see two opposite forces affecting the supply of these securities, which makes the net effect of exchange rate change on the supply of Treasury securities indeterminate, at least theoretically.

3. *Returns on Treasury substitutes*: If returns on alternative investments (such as stocks or Eurodollar deposits) rise, investors may decide to sell Treasury securities and invest the proceeds in alternative investments. Likewise, if returns on alternative investments fall, investors should face diminished incentives to sell their securities. In that case, we expect a positive relationship between returns from alternative investments and the supply of securities

4. *Expected price of Treasury securities relative to comparable investments:* An increase in the expected (future) price of these securities relative to alternative investments would increase the future supply (and conversely, decrease the current supply) of these securities. Likewise, a decrease in the expected price would decrease the future supply (and increase the current supply) of these securities. Since yield data on Treasury securities are readily available than the price data, yield is used as a proxy of the price variable. Due to the inverse relationship between the price of a security and its yield and the inverse relationship between expected price and current supply, we expect to see a positive relationship between expected yield and current supply.

In order to estimate the effects of the aforementioned factors on the supply of Treasury securities, we formulate the following model.

$$TSUPPLY_t = \alpha_0 + \alpha_1\, BUDGET_t + \alpha_2\, EXRATE_t + \alpha_3\, SUB_t + \alpha_4\, EYLD_t + \varepsilon_t \quad (1)$$

Where,
TSUPPLY = Supply of Treasury securities
BUDGET = Federal budget surplus/deficit (+/–)
EXRATE = Exchange rate defined as the price of one US dollar in foreign currency
SUB = Returns from Treasury substitutes
EYLD = Expected yield of Treasury securities
Based on the discussions above, we expect the following signs for the coefficients: $\alpha_1 < 0$, $\alpha_3 > 0$, $\alpha_4 > 0$ and α_2 could be either positive or negative.

IV. Data, Methodology and Results

Monthly data from 2000 to 2008[1] were used to estimate the parameters of the model. Daily average volume of transactions of US Treasury securities, published by the US Treasury (2010), was used to compute the dependent variable – monthly supply of Treasury securities (TSUPPLY). Monthly data on US budget surplus/deficit (BUDGET) was collected from the Financial Management Service, US Treasury (2010). Since data is not readily available for expected yield (EYLD), we used six-month moving average of actual yield as a proxy for expected yield for the next period. Three measures of yield on Treasury securities were used, namely, the yield on securities with remaining maturities of 6 months (YLD6M), 1 year (YLD1Y) and 5 years (YLD5Y). These yield data were collected from the Office of Domestic Finance, US Treasury (2010). Two alternative measures of returns from Treasury substitutes

(SUB) were used, namely, yield on 6-month Eurodollar deposits (EDYLD) and return on S&P 500 index (SNP). The data on Eurodollar deposit yield were collected from the Federal Reserve Bulletin (2010a) and the data on S&P were collected from Standard & Poor's (2010). The US Dollar Index (Broad), published by the Federal Reserve Bulletin (2010b), was used to measure the dollar exchange rate (EXRATE).

Time-series studies since the mid-1980s have generally accepted the notion that a regression analysis is valid only if the data used are stationary, i.e. the variables are not subject to any stochastic or deterministic trend. Running ordinary regressions among a set of non-stationary variables may yield spurious results (Granger and Newbold, 1974). A high R^2 among a set of non-stationary variables may only reflect the presence of a common trend even though there is no meaningful economic relationship among them. If the variables in equation (1) above are non-stationary, the error term of the equation is also likely to be non-stationary. A non-stationary error term is inconsistent with the underlying assumptions of OLS. Particularly, if the residuals in the regression equation have stochastic trends, any error in period *t* never decays, so that the deviation from the model is permanent. Therefore, it is important to check for non-stationarity of the variables in question. If the variables turn out non-stationary, it is important to "detrend" these variables appropriately with cointegration methods.

Various unit root tests have been developed to test for non-stationarity, of which the most common test is the Augmented Dickey Fuller (ADF) test. The ADF test is based on the statistical significance of the lagged value of a variable, when the first difference of the variable is regressed on the lagged values of the variable itself and the lagged values of the first differences. Table 1 in the Appendix section shows the computed ADF test statistics for all variables, which suggest that BUDGET and EXRATE are *I(0)* (i.e. integrated of order zero) and the rest of the variables are *I(1)* (i.e. integrated of order one).

Several cointegration methods, such as the Engel-Granger (1987) procedure, Johansen's (1996) full information maximum likelihood procedure, Phillips-Hansen's (1990) fully modified OLS procedure and the Bounds Testing (henceforth BT) procedure, developed by Pesaran et al (2001), have been proposed in the econometric literature for investigating long-run equilibrium relationships among time-series variables. The Engel-Granger, Johansen and Phillips-Hansen procedures require that the variables included in the model are *I(1)*; however, the BT procedure is applicable irrespective of whether the underlying variables are either purely *I(0)* or purely *I(1)*. Another important advantage of the BT procedure is that estimation is possible even when the explanatory variables are endogenous[2].

Since the ADF test finds a mixed order of integration for variables included in this study, we apply the BT procedure to analyze the long-run and the short-run behavior of supply of Treasury securities. First, the existence of a long-run relationship has to be determined for valid estimation and inference about the parameters of the models. If a long-run equilibrium relationship is found, we can follow the two-step strategy of the ARDL procedure to estimate the long-run and short-run coefficients on the basis of the selected ARDL models (Pesaran and Shin, 1999). The choice of the correct lag structure is crucial for the ARDL procedure. There are many information criteria (e.g. Akaike Information Criterion, Hannan-Quinn Criterion, Schwarz Bayesian Criterion, etc.) that can be used to determine the lag length. In this study, we rely on the more commonly used Akaike Information Criterion (AIC), which selects an ARDL (3,0,0,0,0) for all three models.

The *F statistic* and *Wald statistic* reported in Table 2 (the last two rows) indicate that there exists a long-run relationship among the specified variables and that the independent variables can be treated as the "long-run forcing" variables for Treasury supply. Given the existence of a long-run relationship, the next step is to use the ARDL approach to estimate the parameters of this relationship. This method has the additional advantage of yielding consistent estimates of the long-run coefficients that are asymptotically normal irrespective of the order of integration of the variables (Pesaran and Shin, 1999). The long-run coefficients based on ARDL (3,0,0,0,0) models are reported in Table 2. As can be seen from the results, except for expected yield of Treasury securities in all three models (i.e. EYLD6M, EYLD1Y and EYLD5Y), all other estimated coefficients are statistically significant with the *a priori* expected signs.

The negative coefficient of federal budget balance (BUDGET) confirms the hypothesis that budget surpluses reduce (and budget deficits increase) Treasury supply. This result explains the huge growth in the supply of Treasury securities throughout this decade, as the federal budget situation has continually deteriorated and the deficit has steadily widened. Exchange rates (EXRATE) exhibit a very strong and significant negative effect on Treasury supply. As explained previously, although a depreciation of US dollar should decrease Treasury supply, however, foreign investors, fearful of a further slide in the exchange rate, may decide to sell their securities to the market sooner than later to avert future losses, which will increase the supply of securities. Between these two opposite forces, evidently (at least for this sample) the negative effect dominates the positive effect and hence the model produces a negative coefficient. The positive coefficient of SNP, which is used as a proxy for returns from Treasury substitutes, confirms the hypothesis that if returns from alternative investments (such as stocks) rise, investors switch from Treasury securities to alternative investments[3]. Finally, the expected yield of Treasury securities in all three models (i.e. EYLD6M, EYLD1Y and EYLD5Y) is found to be statistically highly insignificant, which suggests that the expected yield of Treasury securities has no long-run effect on supply of Treasury securities. This may not be surprising since the most important supplier of these securities, the US Treasury via primary dealers, does not base its supply decisions on yield. Also, many portfolio investors do not buy/sell these securities for yield, but for safety and liquidity.

Next, we turn to the dynamic short-run error correction models. The ECMs of Treasury supply based on ARDL (3,0,0,0,0) are reported in Table 3 for all three models. The results show that in the short run all estimated coefficients, except expected yields (EYLD6M, EYLD1Y and EYLDY), again turn out statistically significant with the *a priori* expected signs in all three models. The coefficient of BUDGET suggests that in the short run federal budget balance has almost a one-to-one relationship with Treasury supply, i.e. budget surplus reduces (and budget deficit increases) Treasury supply by almost an equal amount.

To understand the short-term adjustment process, we need to analyze the sign and the magnitude of the coefficient of the error correction term (ECM_{t-1}). If the value of this coefficient is between 0 and -1, the correction to Treasury supply (TSUPPLY) in period *t* is a fraction of the error in period *t-1*. In that case, the ECM tends to cause TSUPPLY to converge monotonically to its long-run equilibrium path in relation to changes in the exogenous "forcing variables". The error correction term (ECM_{t-1}) turns out negative and highly significant in all three models. The coefficients (-0.56 in all three models) suggest that the dependent variable (ΔTSUPPLY) adjusts in the next period by 56% to correct departures from the equilibrium in the previous period. The statistical significance and the correct sign of the ECM_{t-1} coefficients further confirm the presence of a long-run equilibrium relationship in all three models.

V. Conclusion

This study analyzed the supply of US Treasury securities over the 2000-2008 period. Our findings are important since no such study has been done in the past on this issue and the results confirm some anecdotal beliefs about the largest and most widely held debt security in the world. Using the bounds testing (BT) autoregressive distributed lag (ARDL) cointegration methodology, a long-run equilibrium and a short-run dynamic model were estimated. We found that there exists a long-run equilibrium relationship between the supply of US Treasury securities and three independent variables, namely, the federal budget balance, exchange rate and the yield on substitute products, such as stocks. In other words, changes in one or more of the explanatory variables would lead to consequent changes in the supply of Treasury securities over time. The three variables, taken together, accounted for 59% of the variations of the supply of Treasury securities (from the adjusted R^2 values). The significance of the federal budget balance variable simply reaffirms the dominant position of the US Treasury as a supplier of Treasury securities. In view of the global market for Treasury securities, the significance of the exchange rate variable is hardly surprising. Finally, like any product or service, the price or yield on a substitute product also affects its supply.

The results of the error correction model are more revealing. It shows whether and how quickly the relationship would readjust to the equilibrium once disturbed. The negative sign of the error correction term confirms that any over-reaction (or under-reaction) to the supply of Treasury securities will be corrected downward (upward) in the next period, thereby propelling the relationship back toward equilibrium. The coefficient of the budget balance variable is especially interesting – one dollar increase in budget balance would lead to an equivalent decrease in the supply of Treasury securities, *ceteris paribus*, which makes perfect sense.

End Notes

1. Although data are available for 2009-10, given the unusual impact of the current financial crisis on the Treasury securities market, it seemed appropriate to exclude data from this "unusual" period.
2. For a comprehensive description of this technique, see Pesaran et al (2001).
3. The models were also estimated with another proxy variable for return from Treasury substitutes - EDYLD (yield on 6-month Eurodollar deposits). The estimated results exhibited poor statistical properties and hence are not reported in the study.

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Appendix

Table 1: Testing for Unit Root – Augmented Dickey Fuller (ADF) Test

	Lags[a]	Intercept, Trend[b]	ADF Statistics
TSUPPLY	2	Intercept and trend	-1.97
ΔTSUPPLY	1	None	-15.47**
BUDGET	3	None	-2.43**
EXRATE	1	Intercept and trend	-3.43*
ΔEXRATE	1	None	-6.72**
SNP	1	None	-1.43
ΔSNP	1	None	-7.28**
EYLD6M	2	Intercept	-1.67
ΔEYLD6M	1	None	-2.02**
EYLD1Y	2	Intercept	-1.67
ΔEYLD1Y	1	None	-2.21**
EYLD5Y	2	Intercept	-1.61
ΔEYLD5Y	1	None	-3.55**

Notes: * significant at 10%; ** significant at 5%

[a] The optimum number of lags is selected by the Akaike Information Criterion (AIC). Lags selected by the Hannan-Quinn Criterion and Schwarz Bayesian Criterion yield similar results.

[b] Selection of intercept and trend are based on inspection of graphs for each variable at level and first difference.

Table 2: Estimated Long Run Coefficients using the ARDL Approach

Dependent Variable: TSUPPLY	Model 1	Model 2	Model 3
	Coefficient (t-stat)	Coefficient (t-stat)	Coefficient (t-stat)
Intercept	5595.9	5575.7	5560.7
BUDGET	-1.78 (-1.72)*	-1.80 (-1.74)*	-1.82 (-1.73)*
EXRATE	-35.67 (-3.75)**	-35.53 (-3.74)**	-35.50 (-3.85)**
SNP	9.69 (2.29)**	9.71 (2.29)**	9.72 (2.29)**
EYLD6M	-2.74 (-0.07)		
EYLD1Y		-0.75 (-0.02)	
EYLD5Y			2.41 (0.03)
F statistic	4.01*	3.97*	3.93*
Wald statistic	20.03*	19.86*	19.67*

Notes: *significant at 10%; **significant at 5%
These models pass the diagnostic tests for serial correlation, functional form, normality of residuals and heteroscedasticity. The results are available from the authors.

Table 3: Short-run Error Correction Model
Dependent Variable: ΔTSUPPLY

Independent Variables	Model 1	Model 2	Model 3
	Coefficient (t-stat)	Coefficient (t-stat)	Coefficient (t-stat)
$\Delta TSUPPLY_{t-1}$	-0.54 (-3.96)**	-0.54 (-4.00)**	-0.54 (-3.97)**
$\Delta TSUPPLY_{t-2}$	-0.39 (-3.99)**	-0.39 (-4.01)**	-0.39 (-4.00)**
ΔBUDGET	-1.00 (-2.03)**	-1.01 (-2.04)**	-1.01 (-2.05)**
ΔEXRATE	-20.05 (-2.13)**	-19.88 (-2.13)**	-19.78 (-2.21)**
ΔSNP	5.44 (2.49)**	5.43 (2.48)**	5.42 (2.46)**
ΔEYLD6M	-1.54 (-0.07)		
ΔEYLD1Y		-0.42 (-0.02)	
ΔEYLD5Y			1.34 (0.03)
ECM_{t-1}	-0.56 (-3.63)**	-0.56 (-3.64)**	-0.56 (-3.58)**
Adj R^2	0.59	0.59	0.59
F Stat (p-value)	21.18 (0.00)**	21.17 (0.00)**	21.17 (0.00)**
DW-statistic	1.91	1.91	1.91

Notes: *significant at 10%; **significant at 5%