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Impact of the Exchange Rate Movement to Individual Stock Return Volatility: A Case Study of the Property Sector in Thailand

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Abstract

As professional investors attempt to understand volatility of the stocks in portfolio risk management, exchange rate is considered as one of the most important economic indicators that can significantly impact on the portfolio risk exposure by several reasons. Therefore, this study investigates the effect of major exchange rate volatilities including THB/USD, THB/EUR, and THB/JPY on single stock return fluctuations with a case study of top 10 most value traded stocks in property sector listed in the Stock Exchange of Thailand. These were examined from the year 2012 to 2014 in daily basis. In order to fulfill each of examined regressions, ARMA model is applied as the mean equation to estimate conditional volatility by GARCH typed models. Interestingly, the regression result shows that 80% of stocks return volatilities have been significantly affected by THB/USD currency fluctuation with negative correlation. In contrast, 40% and 50% of the samples have been positively influenced by the volatilities of THB/EUR and THB/JPY exchange rates respectively excepting the relationship between the volatilities of THB/EUR exchange rate and RML stock return fluctuation which is found negative.

Keywords: Property Sector, Volatility, Stationary Process.

Introduction

Since the recent century, many financial products have been widely launched and developed for investors worldwide. One of the traditional products generally discussed among investors is the single stock. It is also usually used as an important tool in investment and private wealth management.

Normally, most inexperienced investors concentrate on their expected return but are barely concerned with risk exposure. However, as the volatility of a single stock changes, the risk exposure of portfolio is certainly affected. This change in stock return volatility would create difficulties for them to achieve their expected returns and to maintain their portfolio at desired risk levels. With recent empirical evidences, Menggen and Kanas discovered positive risk-return relationships in the Shenzhen Stock Exchange and in the S&P 500 market index (Menggen, 2015; Kanas, 2013). These relationships imply investors require extra returns for additional exposure as the market becomes more volatile.

Hence, it is useful for investors to find an effective method to foresee the changes in stock return volatility which can be examined by relevant, leading, key economic and internal factors. According to Kurihara's research, one of the key factors that significantly affects the stock prices is the exchange rate (Kurihara, 2006). The research of Kim also supported that the exchange rate became one of key stock price and firm profit determinants as widening capital flows and world trade expansion (Kim, 2003).

Even though there are many previous studies attempting to find the relations between exchange rates and stock returns, most of them were tested with market and sector indexes which are somehow difficult to be applied since the investors normally invest in single stocks, not in indexes. Hence, to be able to understand the impacts of exchange rates on single stocks is more meaningful and applicable in reality. To support the above idea, Williamson's research illustrates that the companies under the same industry tend to share common risk exposure and business characteristics (Williamson, 2001).

Thus, this study examines whether the selected exchange rate fluctuation has a significant impact on the selected single stock return volatilities. With mixed explanations and empirical evidences, their relationship are doubted: "Does each of selected exchange rate volatilities significantly affect to individual stock return fluctuation in property sector?"

To narrow down the scope, this study focuses on stock return volatilities of the top 10 most value traded stocks in the property sector of the Stock Exchange of Thailand including BLAND, SIRI, QH, LH, CPN, RML PS, SPALI, AP, and AMATA. To be testified with the stock volatilities, fluctuations of exchange rates in Thailand have been picked up with the world's major exchange rates including THB/USD, THB/EUR, and THB/JPY exchange rates. Data of exchange rates and stock returns are collected from Bank of Thailand and Thomson Reuters respectively during January 2012 to December 2014 in daily basis as time-series data.

However, the findings of the study cannot be immediately applied to other markets, sectors, or stocks. There are also internal factors that can affect companies as unsystematic risks which are unexplainable by this study. Likewise, the predictive exchange rates are limited only as indicated in the study: THB/USD, THB/EUR, and THB/JPY. The model cannot also be directly applied with other currencies. Besides, it does not guarantee that the relationship will persist through time out of the observed period.

By utilizing this research, the investors those who believe in Markowitz' Modern Portfolio Theory, regarding to the optimal risky portfolio and minimum variance portfolio concepts, can respond to the changes in stock return volatility by asset reallocation, hedging activities, to estimate new expected returns, or even to speculate by using financial products such as options (Markowitz, 1952). Furthermore, the changes would become meaningful for the economists and researchers to study further.

Before beginning discussion, however, there are few key terms that should be explained:

Property Sector: In the Stock Exchange of Thailand, the property sector allocated a subgroup in the property and construction industry which also includes the construction material sector, property fund, and REITs. The businesses listed in the property sector generally manage and develop industrial estates, housing estates, and condominiums. Retrieved on Jan 12, 2015 from https://www.set.or.th/en/products/index/files/2015-2-19-SET-Industry-Group-Sector-Classification-En.pdf

Volatility: Volatility models can be mainly grouped as constant volatility and time-varying volatility. The constant volatility models would result in only one constant degree over the observed period as an unconditional volatility. As applied in this paper, in contrast, the time-varying volatility models give various levels of volatility along the period as conditional volatility. (Teresienė, 2009).

Stationary Process: In statistics, it is a stochastic process describing how the data are distributed over time. If the mean and variance of data are significantly inconsistent over time and follow trends, the problem is known as "non-stationary process" which creates difficulties for researchers to be able to predict results accurately. Retrieved on Jan 12, 2015 from http://www.investopedia.com/articles/trading/07/stationary.asp

Literature Review

Since the investments and monetary concerns became more acknowledged and popular among the general public worldwide, many economists and financial experts have attempted to explain the relations and effects among economic indicators and financial instruments. With regard to this paper, the subject of exchange rate and stock return has also widely been an argument among the economists and experts for many decades.

To begin with a notable classic study, the flow-oriented model shows that the exchange rates normally cause stock price changes depending on the international trade characteristics (Dornbusch & Fischer, 1980). The paper of Shapiro also explained similarly that international exposure of a firm varies to the imbalance of international trade between import and export (Shapiro, 1975). Another study added that not only export-import firms are affected, but pure domestic businesses are too as the changes in global prices of inputs also influence the local prices and costs of productions (Adler & Dumas, 1984).

However, the portfolio balancing model (Frankel, 1983) proposes that exchange rate movement doesn't determine stock returns but the stocks cause the movement of exchange rates. The model describes that the inflows of international capital to a local stock market could influence the increases in currency demand as a result of the appreciation in its exchange rate, vice versa in outflows of the capital. Thus, the theoretical works regarding to their relations were explained with contrasted views and rationales as well as the mixed results of relevant empirical studies.

With empirical evidences, there are many supportive studies published in different regions and periods attempting to explain the existence of impact of the currency movement to equity markets. One of the early studies regarding the correlation between the exchange rate and the stock market is of Aggarwal which demonstrated that, under observation with monthly data in U.S. markets from 1974 to 1978, the exchange markets and the US stock prices were positively correlated to each other (Aggarwal, 1981). Anyway, the result of another research explored their significantly negative relationship of a 15 currency-weighted value relative to dollar currency and U.S. stock indexes during 1980-1986 on a monthly basis (Soenen & Hennigar, 1988). Ma and Kao's paper also supported that equity market could be conversely impacted by appreciation in its currency if the market is export-oriented (Ma & Kao, 1990).

In addition, the study applied the Granger causality test between exchange rates and stock prices in four emerging markets examined from 1985 to 1994, it found that the currency movements in Korea, India, and Pakistan cause unidirectional changes in stock prices but vice versa in Philippine (Abdalla & Murinde, 2010). Nevertheless, a remarkable research regarding to the causal relation of equity markets and exchange rates in 7 East Asian countries examined during 1988 to 1998 significantly shows that there are unidirectional causal relations in Malaysia, Thailand, and Japan from exchange rates to stock prices before crisis and the rest are related as bidirectional and reversed relations. Interestingly, during the Asian financial crisis in 1997, all expected Malaysia possessed unidirectional relations from exchange rates to equity markets (Pan, Fok, & Liu, 2007).

Anyway, many opponents proved that stock returns are one of the key determinants of exchange rates, which proved contrary to the above mentioned papers. In accordance with the research of Ajayi and Mougoue, observing 8 advance economic countries during 1985 to 1991 in daily basis, the result of study indicates that the relation runs from stock return to exchange rate movement with positive long-run effect and negative short-run impact (Ajayi & Mougoue, 1996). Besides, a notable study in Malaysia agreed that Malaysia stock market importantly affected RM/US and RM/JPY exchange rates investigated on quarterly data from 1976 to 1996 (Baharumshah, Mansur, Masih, & Azali, 2002). Another supporting paper in Malaysia also states that the appreciation in currency is caused by increases in stock prices especially during currency crisis but exists inconsistently before the crisis (Yong & Isa, 2000).

As investigated in this study, however, some researchers focused on the relationship between exchange and equity fluctuations. One of the notable early papers is Najung and Seifert's suggesting that the volatility of exchange rate approached by GARCH model in daily basis is positively influenced by absolute stock return under observation in Germany, America, United Kingdom, Japan, and Canada (Najung & Seifert, 1992). However, the result of another paper published recently in 2011 gives a different view of factor direction and confirms that the exchange rate risk had a negative impact on U.S. equity returns during 1980 to 2008 by utilizing the residual term from the ARMA model (Sekmen, 2011). Similar result with Sekmen's paper, the study during the year from 2000 to 2008 with daily basis regarding to Thai market applied by GARCH and IGRACH models with a dynamic conditional correlation (DCC) obviously indicates the existence of their relations from the volatility of the exchange rate to stock return volatility with negative relationship (Horng & Chen, 2010).

As the recent study in India, Agrawal also found that there is a causal relation running from the Nifty stock market to INR/USD exchange rate with a negative correlation but it did not find it to be true from the exchange rate to equity return under the observation between 2007 and 2009 (Agrawal, Srivastav, & Srivastava, 2010). Additionally, the studies of volatility spillover in New Zealand (Fu, Fang, & Choi, 2009) and in South Africa (Bonga & Jamela, 2013) by applying GARCH typed models. The studies agreed that there are unidirectional spillovers from stock prices to exchange rates.

Nevertheless, some researchers argued with the interaction between those factors neither from the exchange market to stock return nor vice versa with their empirical evidences. The research of Griffin and Stulz states that the surprises in the exchange rate changes poorly affect the industry indexes under investigation on the weekly data from 320 industries in 6 countries (Griffin & Stulz, 2001). Additionally supporting by the research with Malaysian market, the result of Granger causality test implies that the long-run relationship between RM/USD and stock prices doesn't exist (Ibrahim, 2000). Likewise, another study examining the dynamic linkages of stock return fluctuation and the currency exchange markets in China, Pakistan, and India from 2007 to 2012 on a daily basis found that the co-integration relationship in each market is negligible. A causal relation from the exchange rate to stock return volatility in only Pakistan was discovered while the rest were not found (Hussain & Bashir, 2013).

As this study aims to investigate on an individual level, even though hundreds of researches investigating market indexes are widely provided, the studies working in micro scales can be hardly found. In India, a study examining impact of exchange rate risk and industry stock indexes implies that currency fluctuation negatively impacts to indexes of export intensive industries such as technology, IT, and knowledge-based sectors while it positively affects import dominant industries such as the financial sector (Badhani, Chhimwal, & Suyal, 2009). At the firm level, Aquino examining currency exposure with 15 Philippines firms in Phisix before and after Asian financial crisis suggests that stock return volatility was influenced by currency rate after a crisis but not before the crisis (Aquino, 2005). Besides, the research in U.S. added that the sizes of firms are also relevant to the degree of the exchange rate effect. It means that the larger firms tend to face greater exposure from currency movement rather than small firms (Bodnar & Wong, 2003). Anyway, an evidence with Istanbul Stock Exchange found only 1 out of 9 stocks in the energy sector possess a significant relationship exchange rate risk. (Kapusuzoglu & Karan, 2013).

With regards to this study in Thai individual stocks, hence, the understandings of the relevant studies especially studies in Thailand are combined (Pan, Fok, & Liu, 2007; Horng & Chen, 2010). These papers hint that Thai stock market might interact to the changes in major exchange rate volatility with negative correlation. However, it is unnecessary that the relationship can also be predictively expected at an individual level as the mix of firm characteristics and scales (Badhani, Chhimwal, & Suyal, 2009; Bodnar & Wong, 2003).

Research Framework

This chapter indicates the linkages between independent and dependent variables that would help clarify how the model of this study is constructed. The framework of this study would be similar as the Agrawal's paper which examined the dynamics of Nifty return volatility and USD movement relative to Indian Rupee (Agrawal, Srivastav, & Srivastava, 2010). In addition, Badhani's paper which found the relation between INR/USD and returns on different indices categorized by industries and firm sizes was constructed with similar framework (Badhani, Chhimwal, & Suyal, 2009).

Hence, this study setups the fluctuations of exchange rates including USD, EUR and JPY related to THB as our independent variables. Then they are testified with each sample of individual stock return volatility including BLAND, SIRI, QH, LH, CPN, RML, PS, SPALI, AP, and AMATA as our dependent variables. Both variables are plugged into GARCH typed models as time-series data on a daily basis.

Research Methodology

In order to understand and find out if the fluctuations of the exchange rate have any impact on the volatility of individual stock return, this study utilizes the GARCH type models as the main equations. This model has also been similarly applied by many researchers to seek relationships and forecast the volatility of each examined factor (Najung & Seifert, 1992; Sekmen, 2011; Badhani, Chhimwal, & Suyal, 2009). To be described further, GARCH is an acronym for "Generalized Autoregressive Conditional Heteroskedasticity" which was developed by Tim Bollerslev in 1986 from ARCH model by Robert Engle. In this paper, only ARCH, GARCH, and EGARCH are applied. The model aims to forecast the conditional volatility of data. Therefore, the core of variance equation would be constructed as following:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 \quad (1)$$

In the above formula, σ_t^2 is the result of $GARCH(p,q)$ where p and q represent the orders of GARCH and ARCH terms respectively, α_0 is the constant, ε is the residual term.

In order to estimate conditional volatility of the examined factors, however, every GARCH typed model requires two equations: mean equation and variance equation. Thus, the mean equation in this study is generated from the residual terms of the Autoregressive Moving-Average (ARMA) model to find the best fit equations with the lowest Schwarz Criterion (SIC). Besides, the residual terms of candidate variance equations must be significant at 5% confident interval otherwise they would be ignored.

Moreover, the concept of the multiple regression model would be applied to answer the major questions of this paper regarding to the fluctuation of each exchange rate. Therefore, the combination of these models can be rewritten to our model as following:

$$\sigma_t^2 = [Selected\ GARCH\ typed\ models\ variables]_t + \beta_1 \sigma_{USD,t}^2 + \beta_2 \sigma_{EUR,t}^2 + \beta_3 \sigma_{JPY,t}^2$$

Where: σ_t^2 = variance of selected stock return
$\sigma_{(Rate)}^2$ = variance of selected exchange rate
β_i = coefficient of selected exchange rate
t = day t

Thus, the null hypothesis of the study is that there is no significant relationship between selected factors or the correlation coefficient β_i of the selected factors equal to zero. The null hypothesis can be rejected if the result falls in 5% confident interval, or the p-value of t-statistic is less than 0.05. In that case, the existence of relationship between exchange rate fluctuation and stock return volatility can be proved.

Before the data was examined with the research model, the validity of data needed to be verified and the best fit equations for each sample were found. Thus; ADF Test, finding the best ARMA structure, and finding the best GARCH-typed model have been orderly completed before moving on the research model.

Augmented-Dickey Fuller (ADF) Test: In order to examine whether the data is stationary, one popular unit root test is the Augmented-Dickey Fuller (ADF) Test. The results of hypothesis normally show negative numbers. Therefore, the deeper negative numbers are, the more unit root problem will be rejected. If the any data is non-stationary and has trend, it will be justified with first differentiation method to eliminate the issue.

ARMA Model: After the data was applicable, this study would find conditional means by finding the residual term from the best ARMA structure for each variable, e.g. ARMA (1,1), which are estimated by the correlogram from the uses of Autocorrelation (AC) and Partial Autocorrelation (PAC). The candidate models were ranked by lowest Schwarz Criterion (SIC).

Results and Discussion

To test the models, first of all, the Augmented-Dickey Fuller (ADF) Test was done and it found that the raw data containing unit root problems. Therefore, the data was adjusted with the first differentiation and retested again. After adjustment, the data became stationary and applicable.

Then the best fit ARMA model was found with the lowest Schwarz Criterion (SIC) among criteria for each variable. After that, the best GARCH-typed model was fitted for each of them with lowest Schwarz Criterion (SIC) and became applicable for regression as specified in Table 1:

Table 1: Selected Models of Dependent Variables

Variance of Stock Return	Selected ARMA Model	Selected GARCH Typed Model
BLAND	ARMA (7,7)	EGARCH (1,1)
SIRI	MA (6)	GARCH (1,1)
QH	ARMA (2,2)	GARCH (1,1)
LH	ARMA (2,2)	GARCH (1,1)
CPN	ARMA (2,2)	GARCH (1,1)
RML	Ma (3)	GARCH (1,1)
PS	ARMA (4,4)	GARCH (1,1)
SPALI	MA (4)	EGARCH (1,1)
AP	ARMA (8,8)	EGARCH (1,1)
AMATA	ARMA (8,8)	GARCH (1,1)

Before testing, exchange rate volatilities as independent variables must also be estimated so they were also sought for the best fit structures. The following table shows the best ARMA and GARCH typed models for plugging into the multiple regressions:

Table 2: Selected Models of Independent Variables

Variance of Exchange Rate	Selected ARMA Model	Selected GARCH Typed Model
USD	AR (5)	GARCH (1,1)
EUR	AR (9)	EGARCH (1,1)
JPY	ARMA (2,2)	EGARCH (1,1)

After the validity of data and equation have been confirmed with the best fit structure in each model, they would be applied to testify the questions between the examined factors. The null hypothesis can be rejected and the significant relationship between factors is detected if the p-value is less than 0.05. Besides, the coefficient represents the directional relation between them. If the coefficient of rejected null hypothesis is more than zero, they are positively related. The below table shows the regression results:

Table 3: Regression Results

Variance of Stock Return	Variance of Exchange Rate	Coefficient	p-value	Reject H_0
BLAND	USD	0.8831	0.2925	No
	EUR	0.8781	0.4060	No
	JPY	-0.6804	0.1010	No
SIRI	USD	-0.0120	0.0603	No
	EUR	-0.0027	0.4890	No
	JPY	0.0031	0.1230	No
QH	USD	-0.0093	0.0014	**Yes**
	EUR	0.0014	0.4561	No
	JPY	-0.0002	0.8429	No
LH	USD	-0.1415	0.0000	**Yes**
	EUR	0.0226	0.0000	**Yes**
	JPY	0.0217	0.0000	**Yes**
CPN	USD	-1.4152	0.0000	**Yes**
	EUR	0.6011	0.0090	**Yes**
	JPY	-0.0158	0.8255	No
RML	USD	-0.0058	0.0201	**Yes**
	EUR	-0.0047	0.0369	**Yes**
	JPY	0.0028	0.0205	**Yes**
PS	USD	-1.0816	0.0000	**Yes**
	EUR	0.0868	0.3458	No
	JPY	0.0705	0.0001	**Yes**
SPALI	USD	-1.8741	0.0000	**Yes**
	EUR	-0.2723	0.2455	No
	JPY	0.3424	0.0000	**Yes**
AP	USD	-2.2496	0.0000	**Yes**
	EUR	0.0239	0.8035	No
	JPY	0.3237	0.0000	**Yes**
AMATA	USD	-0.3638	0.0000	**Yes**
	EUR	0.1545	0.0108	**Yes**
	JPY	0.0224	0.2704	No

As the above table indicates, it shows that 8 out of 10 of the samples including QH, LH, CPN, RML, PS, SPALI, AP, and AMATA possess negative relationship with the THB/USD exchange rate volatility. Nevertheless, 40% of the samples are found significant with the THB/EUR exchange rate volatilities including LH, CPN, RML, and AMATA while 50% of the samples including LH, RML, PS, SPALI, and AP are significantly affected by the THB/JPY exchange rate volatility. Most of them have a positive relationship except the THB/EUR exchange rate volatility and RML stock return fluctuation.

In accordance with the test results, it clearly indicates the outstanding significance of the THB/USD volatility toward the single stock volatilities in property sector. To be interpreted, if the currency becomes more volatile, the volatility of stocks in the industry can significantly be expected to be flattening. Also, the linkages between the results of this paper and the other previous studies were found (Soenen & Hennigar, 1988; Ma & Kao, 1990; Badhani, Chhimwal, & Suyal, 2009) regarding to their relations and directions. Additionally, it provided similar result with the paper (Horng & Chen, 2010) observed with Thai market index.

Moreover, the result conforms the output from the same period and conditions of the investigation on Thai property industry index. As the mean and variance equations were derived from MA (1) and GARCH (1,1), the result illustrates that the index fluctuation has a negative relationship with the THB/USD with the coefficient at -21.9255 and p-value at 0.0059 while the THB/EUR and the THB/JPY exchange rate volatilities are not found.

In addition, the Bodnar and Wong's paper can somehow interpret those insignificant variables including BLAND and SIRI that regarding to the sizes and exposure (Bodnar & Wong, 2003). The firms such BLAND and SIRI with smaller market capitals, at about 30 and 24 billion THB respectively, would expose lower impact from the exchange rate movement than larger firms such as CPN, LH, and PS with the market capitals at 188, 92, and 53 billion THB respectively (Stock Exchange of Thailand, n.d.).

Conclusions

Nowadays, international trade becomes more widely expanded, financial markets and products have also rapidly developed. Investors also attempt to understand, improve the stock returns, and seek for applicable leading indicators. As many papers found that exchange rate is one of economic indicators, this paper attempts to examine the impact of exchange rate fluctuation on the volatility of each single stock return by GARCH typed model. Thus, 10 sample stocks were picked up from the property sector listed in the Stock Exchange of Thailand and testified with major exchange rates including USD, EUR, and JPY related to THB from the year 2012 to 2014 in daily basis. After investigation, the study found that 80% of samples have negative effect from USD currency fluctuation while about half of the samples were found mostly positive impact with the THB/EUR and THB/JPY exchange rate volatilities excepting the pair of RML with the THB/EUR exchange rate volatility is negatively related.

As the study shows that the exchange rate can significantly impact on stock return volatility, moreover, the investors can utilize the relationship to become a part of leading indicators for volatility prediction. This warns investors to be aware of volatility changes and to determine countermeasures before happening. Also, options traders can take exchange rate fluctuation into consideration for volatility trading.

Moreover, this research can be an academic guideline for further studies on relevant subjects such as the volatilities of different industries, firm sizes, degrees of trade-imbalances, and other economic leading indicators. These explorations would be widely advantageous for the researchers, economists, stock analysts, and general investors worldwide.

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Appendix

Table 5: List of Stock Symbols

Symbol	Full Name
BLAND	Bangkok Land Public Company Limited
SIRI	Sansiri Public Company Limited
QH	Quality Houses Public Company Limited
LH	Land And Houses Public Company Limited
CPN	Central Pattana Public Company Limited
RML	Raimon Land Public Company Limited
PS	Pruksa Real Estate Public Company Limited
SPALI	Supalai Public Company Limited
AP	AP (Thailand) Public Company Limited
AMATA	Amata Corporation Public Company Limited

Source: Created by author from the data from www.set.or.th

The Impact of the Macroeconomic Factors and Their Unexpected Values on the Energy Sector Return Volatility: A Case study of Stock Exchange of Thailand during the Period of 2005 to 2015

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Abstract

The purpose of this paper is to examine the effect of the macroeconomic factors and their unexpected values on the Energy sector return volatility in the Stock Exchange of Thailand during period 2005 to 2015. The method is separated in two cases. The first case is to study the impact of macroeconomic variables on the Energy sector return volatility which the macroeconomic factors consist of; agriculture producer price index, consumer price index, current account, employment, exchange rate, industrial production index, interest rate, money supply (M2), oil price, producer price index, rubber producer price index, and trade balance. The second case is to study the impact of unexpected macroeconomic values on the Energy sector return volatility which the unexpected macroeconomic are derived from the residual of the regression model and the volatility of Energy sector return is calculated by using Exponential General Autoregressive Conditional Heteroskedastic (E-GARCH) model. From the empirical results show the unexpected employment has the positive relationship with the Energy sector return volatility. The unexpected interest rate and the unexpected trade balance have the negative relationship with the Energy sector return volatility.

Keywords: Volatility, the macroeconomic variables, the unexpected macroeconomic values, the stock of Energy sector return, Thailand.

1. Introduction

Nowadays, energy resources have become more important as the world is developing continuously. Today, almost all industrial groups need energy to create technology. Meanwhile, compared to many other countries, Thailand does not have many energy sources. Therefore, it needs to import energy from other countries (Surachai and Mantana, 2012). Capital is the most important factor for developing the economy of Thailand which influences investment and affects macroeconomic factors. Thus, the financial market is the capital for mobilizing assets and liberating funds. The financial market that has a financial institution is the center to mobilize and liberate assets from the people, both the business part and the government sector. The Thai stock market, which is a financial market, has an important role to develop Thai economy. Although, the Thai stock market has developed continuously in quality and operation, in quantity (trading) it depends on macroeconomic factors (Supachai, 2004). Since the Thai stock market has always been volatile, this study will investigate the impact of macroeconomic and unexpected macroeconomic variables on the Thai stock market with a focus on the Energy index.

There are many studies to have focused the significant relationship between stock return volatility and the macroeconomic variables like Granger et al. (2000) mentioned the change of stock prices and exchange rates might affect more of the capital movement than current account imbalance. Ma and Kao (1990) commented that if exchange rated increased, stock return would decreased. Aggarwal (1981) detected the confident association in the middle of exchange rates also stock price gains within the united state of America. Anderson and Subbaraman (1996) examined the oil price's influence on stock exchange or stock incomes volatility. They located, if oil expense increased, the energy moreover production price would increase that it means, oil prices had a negative relationship with stock market or stock returns volatility. Kling (1985) inspected the change of oil price and stock returns in period 1973 to 1982 in united state of America. The results showed oil priced affected to stock returns. Jones and Kaul (1996) studied the oil expense's influence on stock gains fluctuation. Jaffe and Mandelker (1976) concluded, there was the significance that share price incomes associated with consumer price indicator or stock market returns related to buyer price pointer. Bodie (1976) also studied the consequence of consumer price index on the stock market gains also he indicated, share exchange market gains also consumer price pointer had the significant relationship each other. Nelson (1976) researched the impact of consumer price index on stock profit also he concluded that there were the significance which consumer price index related to stock exchange returns.

2. Review of related studies

To analyze the cause of the stock market volatility which relate to the macroeconomic factors and these are previous studies that study the impact of macroeconomic factors in stock returns volatility or stock market volatility.

Adjasi (2009) had studied the effect of macroeconomic variables on stock market returns in Ghana. He showed the positively significant relationship such as cocoa costs and interest rates. And other macroeconomic factors which were gold prices, oil prices and money supply, they had the negatively significant relationship with stock market returns volatility. Babatunde, Adenikinjiu, and Adenikinjiu (2013) had studied the significant relationship between oil price and Nigeria stock market. And they examined stock market returns had the positive but had insignificant responsibility to oil price (Short-term interest rate, CPI, and Industrial sector GDP). But it had the negative impact to oil price. So they concluded, there was the positive effect but insignificant responsibility. The fluctuation of oil price reduced stock market returns. Finally, both of oil price and stock market had significant relationship each other. Tsoukalas (2003) had inspected the interactive association between macroeconomic factors and share price incomes within Cyprus by utilizing Vector Autoregressive imitation. He examined that there was the significant relationship between exchange rates and stock price returns. Industrial production had the interactive relationship with stock price returns. Consumer price index also had the significant relationship with stock price returns and there was the valuable association in the middle of fiscal policy and share price profits. Maghyereh and Kandari (2007) researched the interactive relationship between oil prices and stock market in Gulf Cooperation Council (GCC) countries. They concluded oil price had the significant relationship with stock exchange within Gulf Cooperation Council countries and they indicated which oil expenses could predict stock exchange in Gulf Cooperation Council countries. Rjoub, Tursoy, and Gunsel (2009) had inspected the efficiency of arbitrage pricing theory in Istanbul Stock Exchange (ISE). From their research showed that unexpected inflation, risk premium, term structure of interest rate, and money supply had the significant relationship with the stock market return but exchange rate and unemployment rate didn't had the impact on the stock market return. Liow, Ibrahim, and Huang (2006) investigated the interactive relationship between expected risk premium on property stocks and some kind of macroeconomic risk factors which reflected to the financial conditions and the general business. There were six macroeconomic variables, consisted of gross domestic product growth, industrial output index, unanticipated inflation, exchange rate, interest rate, and money supply also they used the GARCH moreover GMM to calculate the fluctuation. Their result explained, the macroeconomic variables had the significant relationship with expected risk premium on property stocks. West and Worthington (2006) examined the impact of macroeconomic variables on property of Australian gains in the term 1985 to 2002. So they concluded that there was a lot of fluctuation that related to macroeconomic variables; unexpected inflation had the significant relationship inner bureau, sale, and commercial incomes. Interest rates had the interactive relationship with total categories of asset portfolios, as the market returns was the interactive variables within sale, commercial, record property trusts also property stocks. Nguyen (2011) studied the spillover impact of the US macroeconomic news on the Vietnamese stock market returns. Form his research detected that both of general the US real economic news had the positive relationship with the conditional mean of the Vietnamese stock index returns each other. And The Us genuine economic news also had the negative influence on the conditional variance of the Vietnamese share price index profits.

3. Data and methodology

This research aims to investigate the impact of macroeconomic variables and unexpected macroeconomic values on Energy sector return volatility. For the macroeconomic variables or independent variables of the exchange rate, money supply (M2), oil price, interest rate, current account, trade balance, and employment, the data will be collected from the Bank of Thailand. For the consumer price index, industrial production index, producer price index, agriculture producer price index, and the rubber producer price index. The data will be collected from the Bureau of Trade and Economic Indices. The dependent variables or Thai stock indexes are collected from the Wall Street Journal. All data are monthly data from the period Jan 1, 2005 to Jan 1, 2015.

In this part, researcher will describe the analysis of data which consists of unit root test analysis, ARMA model, unexpected factor process, and GARCH type model. First step is the unit root test analysis; it is the analytic instrument to change the non-stationary data to be the stationary data because all of data need to be stationary data to evaluate in ARMA and GARCH types model. Second step is ARMA model; it is the model to specify the other models or predict many values in the future. Unexpected factor process; in this part, macroeconomic factors will separate in two types. First type is macroeconomic factors and second type is unexpected macroeconomic factors which can be calculated from the difference between actual value and expected value. Finally is the GARCH types model to test the fluctuation.

The ARMA model is combination of the AR (p) and MA (q) models. It was introduced by Box and Jenkin in 1970. So the formula of ARMA (p, q) model is;

$$X_t = \emptyset_1 X_{t-1} + \emptyset_2 X_{t-2} + \ldots + \emptyset_p X_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q}$$

That: X_t is the data value at the time t

$\emptyset$ is the estimated auto regressive coefficient at lag p.

θ is the estimated moving average coefficient at lag q.

ε_t is the error term or conditional residual at time t.

The ARCH model is introduced by Engle (1982). The Formula for The ARCH (q) model is;

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \ldots + \alpha_q\varepsilon_{t-q}^2$$

That: α_q is the ARCH coefficient of the conditional variance at lag q

ε_{t-q}^2 is the conditional of error at the time t which depends on q lag squared error

For the conditional variance is positive, it requires the parameter $\sigma_0 > 0$ and $\varepsilon_{t-q}^2 \geq 0$

Bolerslev (1986) developed the ARCH model into GARCH model. Generally the GARCH (p,q) can be described by this formula;

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \ldots + \alpha_q\varepsilon_{t-q}^2 + \beta_1\sigma_{t-1}^2 + \ldots + \beta_p\sigma_{t-p}^2$$

That: α_0 is the unchanging term.

α is the GARCH the conditional diversity's coefficient on lag q.

β is the GARCH coefficient of the conditional variance on lag p.

ε is the error term.

σ_t^2 is the conditional variance of stock return at time t.

Nelson (1991) created the EGARCH model to address the problem of asymmetry. The EGARCH (p,q) model is;

$$\ln \sigma_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j\left(\left|\epsilon_{t-j}\right| + \gamma_j\epsilon_{t-j}\right) + \sum_{i=1}^{p} \beta_i \ln \sigma_{t-i}^2$$

That

: α_0 is the constant term.

α_j is the parameter of ARCH component model.

β_i is the parameter of GARCH component model.

σ_t^2 is the conditional variance of stock return at the time t.

$\in_{t-j}$ is the conditional error at time t

The unexpected macroeconomic values are estimated by applying the regression concept (Brown & Matysiak, 2000). The expected value is equal to the fitted value from a regression of the selected macroeconomic variable on its own lagged values (up to lags = 6). The unexpected macroeconomic value could be calculated from the following concept;

$$unexpected\ actual\ value\ of\ X =$$
$$actual\ value\ of\ X - expected\ value\ of\ X$$

Because of the regression model, the unexpected value could be simply derived from the residual of the regression model.

In order to test the relationship of macroeconomic variables and unexpected macroeconomic variables on ENERGY index return volatility and to find out whether the macroeconomic variables and unexpected macroeconomic variables have a significant relationship with ENERGY index return volatility, the model of research will be as follows from twenty four hypotheses that will be presented next.

$\sigma_{energ,t}^2$ = [selected GARCH typed model variables] + μ_1 agr + $\mu_2$cpi + μ_3 ca + $\mu_4$ep + $\mu_5$ex + $\mu_6$ipi + $\mu_7$int + μ_8 m2 + $\mu_9$oil + μ_{10}ppi + μ_{11}rub +μ_{12}tb

$\sigma_{energ,t}^2$ = [selected GARCH typed model variables] + μ_{13} agr_u + μ_{14}cpi_u + μ_{15} ca_u + μ_{16}ep_u + μ_{17}ex_u + μ_{18}ipi_u + μ_{19}int_u + μ_{20} m2_u + μ_{21}oil_u + μ_{22}ppi_u + μ_{23}rub_u + μ_{24}tb_u

Where:

σ_{energ}^2 = The volatility of ENERGY index return

μ = Test coefficients

t = The time period "Monthly"

<u>Macroeconomic factors</u>

agr = Agriculture producer price index
cpi = Consumer price index
ca = Current account
ep = Employment
ex = Exchange rate
ipi = Industrial production index
int = Interest rate
m2 = Money supply (M2)
oil = Oil price
rub = Rubber producer price index
tb = Trade balance
ppi = Producer price index

<u>Unexpected macroeconomic factors</u>

agr_u = Unexpected agriculture producer price-index
cpi_u = Unexpected consumer price index
ca_u = Unexpected current account
ep_u = Unexpected employment
ex_u = Unexpected exchange rate
ipi_u = Unexpected industrial production index
int_u = Unexpected interest rate
m2_u = Unexpected money supply (M2)
oil_u = Unexpected oil price
rub_u = Unexpected rubber producer price index
ppi_u = Unexpected producer price index
tb_u = Unexpected trade balance

4. The empirical result

Table I Descriptive statistic of dependent variable and independent variables

	agr_pi	cpi	ca	ep	ex	ipi
Mean	83.28099	95.99314	17920.29	85.8595	33.66127	98.68417
Median	93.3	96.06	18185.92	84.6	32.7814	99.65
Maximum	114	107.9	178067.3	141.7	41.7064	109.2
Minimum	42	80.4	-116080.9	55.1	29.0697	80.3
Standard	20.44564	7.704145	48857.49	18.11033	3.168107	9.302254
Skewness	-0.497836	-0.096505	0.245179	0.713224	0.926258	-0.312035
Kurtosis	1.784131	1.866459	3.690717	3.399815	2.951262	1.587652
Observation	121	121	121	121	121	121

*Notes: agr_pi = agricultue producer price index, cpi = consumer price index, ca = current account, ep = employment, ex = exchange rate, ipi = industrial production index.

Table I Descriptive statistic of dependent variable and independent variables (continue)

	int	m2	gas95	ppi	rub_pi	tb	energ
Mean	2.795455	9753761	10773218	31.55339	95.58926	49353.33	7991.365
Median	2.75	8733364	9773345	31.72	99.6	52195.45	6964.92
Maximum	5	14996237	16435283	41.02	109.2	165533.6	66968.62
Minimum	1.25	6675758	7374891	16.99	72.3	-96171.1	2634.283
Standard	1.047318	2631357	2870775	6.426713	11.17569	45096.07	5954.611
Skewness	0.401607	0.708648	0.672239	-0.248021	-0.443452	-0.2662	8.101796
Kurtosis	2.517264	2.015152	1.98186	1.950133	1.708913	3.358769	80.938
Observation	121	121	121	121	121	121	121

*Notes: int = interest rate, m2 = money supply, gas95 = gasoline 95, ppi = producer price index, rub_pi = rubber producer price index, tb = trade balance, energ= the sector of energy index

Table II Descriptive statistic of dependent variable return and independent variables return

	r_agr_pi	r_cpi	r_ca	r_ep	r_ex	r_ipi
Mean	0.007443	0.002305	1102.935	0.001778	-0.001396	0.002246
Median	0.006935	0.002135	346.94	0.001692	-0.002302	0.001852
Maximum	0.171586	0.021522	158238.4	0.117914	0.034566	0.038372
Minimum	-0.136287	-0.030657	-163110.9	-0.275921	-0.036131	-0.060867
Standard	0.054534	0.006029	51439.79	0.056675	0.013654	0.012747
Skewness	0.144205	-1.288889	0.114029	-1.298923	0.003087	-1.474503
Kurtosis	4.207997	10.94191	3.743612	8.105589	3.11639	9.947518
Observation	120	120	120	120	120	120

*Notes: r_agr_pi = argriculture producer price index return, r_cpi = consumer price index return, r_ca = current account return, r_ep = employment return, r_ex = exchange rate return, r_ipi = industrial production index return.

Table II Descriptive statistic of dependent variable return and independent variables return (continue)

	r_int	r_m2	r_gas95	r_ppi	r_rub_pi	r_tb	r_energ
Mean	-4.21	0.006735	0.00665	0.004253	0.002892	560.3623	0.003706
Median	0	0.006665	0.006023	0.005544	0.003697	8151.28	0.002644
Maximum	0.182322	0.035354	0.031236	0.218546	0.044353	156014.9	2.484657
Minimum	-0.318454	-0.037819	-0.033982	-0.214242	-0.067488	-119036.4	-2.342239
Standard	0.07377	0.01091	0.010655	0.054967	0.015583	48517.52	0.31917
Skewness	-1.505889	-0.550085	-0.163496	-0.88021	-0.642357	-0.133776	0.609718
Kurtosis	9.383764	4.841639	4.219568	8.229325	6.24934	3.256167	55.67624
Observation	120	120	120	120	120	120	120

*Notes: r_int = interest rate return, r_m2 = money supply return, r_gas95 = gasoline 95 return, r_ppi = producer price index return, r_rub_pi = rubber producer price index return, r_tb = trade balance return, r_energ = the sector of energy index return.

From the table I and II the first row is the name of the macroeconomic variables and energy index which these macroeconomic variables are the independent factors and energy index is the dependent factor. Mean value is; the summation of total values divide by the amount of data. Median is the middle value between the maximum value and the minimum value. Maximum value is the highest value among many values. Minimum value is the lowest value among many values. Standard deviation is the calculation which finds the distribution of data and it indicates the volatility of data. If standard deviation is high, the volatility of data is also high. It means that the volatility directs variation with the standard deviation. Skewness is the class of inclination in the data which can examine in two methods; consists of calculating to find the coefficient and consider from the frequency curve. Skewness can explain easily; if mean value is equal to median value, it will be called "Normal Distribution". If mean value is more than median value, it will be called "Skewness to the right". And if mean value is less than median value, it will be called "Skewness to the left". Kurtosis is the class of height in enumerating the data which can inspect this value from finding the coefficient. Observation is the amount data which is investigated. The difference between Table I and Table II is; the data from Table I is the non-stationary data which cannot use to evaluate in ARMA and GARCH types model. The data from Table II is the stationary data which can use to evaluate in ARMA and GARCH types model

4.1 t-test statistics

In this part time series data need to test whether it is the stationary data or non-stationary data by using Augmented Dickey-Fuller unit root test (Dickey & Fuller, 1979). It means; if t- statistic is less than the critical value, the data will be the stationary data or has the unit root but if t-statistic is more than the critical value, the data will be the non-stationary data or hasn't the unit root. So in this test can specify the hypotheses as follows:

H_0: The data has unit root
H_1: The data hasn't unit root

Table III ADF statistic test of dependent variable and independent variables

	t-statistic	1% critical value	5% critical value	10% critical value	Probability	Result
agr_pi	0.973101	-2.584707	-1.943563	-1.614927	0.9119	N
cpi	2.338719	-2.584539	-1.94354	-1.614941	0.9954	N
ca	-6.141401	-2.584375	-1.943516	-1.614956	0	S
ep	-0.2384	-2.584539	-1.94354	-1.614941	0.5984	N
ex	-0.896373	-2.584539	-1.94354	-1.614941	0.3259	N
ipi	0.52731	-2.584707	-1.943563	-1.614927	0.8284	N
int	-0.606475	-2.584539	-1.94354	-1.614941	0.4527	N
m2	2.857846	-2.585405	-1.943662	-1.614866	0.9989	N
gas95	3.512635	-2.584707	-1.943563	-1.614927	0.999	N
ppi	-0.133802	-2.584539	-1.94354	-1.614941	0.6356	N
rub_pi	0.848822	-2.584539	-1.94354	-1.614941	0.8924	N
tb	-1.551762	-2.584707	-1.943563	-1.614927	0.113	N
energ	-1.38828	-2.584877	-1.943587	-1.614912	0.1528	N

Notes: agr_pi = agriculture producer price index, cpi = consumer price index, ca = current account, ep = employment ex = exchange rate, ipi = industrial production index, int = interest rate, m2 = money supply, gas 95 = gasoline 95, ppi = producer price index, rub_pi = rubber producer price index, tb = trade balance, energ = the sector of energy index. N = non stationary data, S = stationary data.

From Table III can indicate that most of data contains the unit root or hasn't the unit root (non-stationary data) because the t-statistic values are more than the critical value. Except one variable; it is the current account doesn't contain the unit root or has the unit root (stationary data) because the t-statistic value is less than the critical value. So most of data that contains the unit root or hasn't the unit root (non-stationary data); they need to convert to be the stationary data by using log difference.

Table IV ADF statistic test of dependent variable return and independent variables return

	t-statistic	1% critical value	5% critical value	10% critical value	Probability	Result
r_agr_pi	-9.556633	-2.584707	-1.943563	-1.614927	0	S
r_cpi	-6.603751	-2.584539	-1.94354	-1.614941	0	S
r_ca	-11.67604	-2.584707	-1.943563	-1.614927	0	S
r_ep	-8.299306	-2.584539	-1.94354	-1.614941	0	S
r_ex	-7.209018	-2.584539	-1.94354	-1.614941	0	S
r_ipi	-5.035933	-2.584707	-1.943563	-1.614927	0	S
r_int	-6.298543	-2.584539	-1.94354	-1.614941	0	S
r_m2	-2.117417	-2.585405	-1.943662	-1.614866	0.0334	S
r_gas95	-2.861161	-2.584877	-1.943587	-1.614912	0.0045	S
r_ppi	-6.392517	-2.584539	-1.94354	-1.614941	0	S
r_rub_pi	-6.65676	-2.584539	-1.94354	-1.614941	0	S
r_tb	-15.25985	-2.584707	-1.943563	-1.614927	0	S
r_energ	-12.23419	-2.584707	-1.943563	-1.614927	0	S

Notes: r_agr_pi = agriculture producer price index return, r_cpi = consumer price index return, r_ca = curent account return,
r_ep = employment return, r_ex = exchange rate return, r_ipi = industrial production index return, r_int = interest rate return,
r_m2 = money supply return, r_gas95 = gasoline 95 return, r_ppi = producer price index return,
r_rub_pi = rubber producer price index return, r_tb = trade balance return, r_energ = the sector of energy index return. S = stationary data.

From Table IV all of the data are converted to be the stationary data by using log difference which these data can be evaluated to the next step. For macroeconomic variables consist of Agriculture producer price index, Consumer price index, Current account, Employment, Exchange rate, Industrial production index, Interest rate, Money supply (M2), Oil price, Producer price index, Rubber price index, and Trade balance. These factors can be applied to be the unexpected factor by choosing the best ARMA model which will describe the details in the next topic. And ENERGY index return can be evaluated in ARMA model and GARCH type model.

4.2 The methodology of ARMA model

After changing the non-stationary data to be the stationary data, next step is the process of ARMA model which can separate two parts; the first part is to find the best ARMA model from dependent variables that is the energy index return. And the second part is to find the best ARMA model from independent variables that are the unexpected variables. For finding the best ARMA model; AR can be estimated from partial correlation function (PACF) and MA can be estimated from auto correlation function (ACF). Next process is estimate equation with constant value. When finishes this process, next method is check the serial correlation LM test. If the prob. F and prob. Chi-square value in the serial correlation LM test is less than 5% level (0.05), it means that the serial correlation LM test has the problem and so the ARMA process needs to be estimated the ACF and PACF again. To pass the serial correlation LM test; prob. F and prob. Chi-square value should have the value more than 5% level (0.05).

After pass the serial correlation LM test, next process is the heteroskedasticity test which can be checked by ARCH test. If the prob. F and prob. Chi-square value in the heteroskedasticity has value less than 5% level (0.05), it means that there is the problem in the heteroskedasticity test. So it needs to solve by white heteroskedasticity consistent standard errors. The next process is inspecting the value for AR, MA, and constant value by cutting off the value which has value more than 5% level (0.05). Finally the ARMA model is complete but in one variable of dependent and independent variable, the ARMA model can be estimated more than one. So the best ARMA model can be chosen by comparing the Schwarz criterion value (SIC). If any ARMA model has the lowest SIC value, it means the best ARMA model.

Table V The best ARMA model of expected independent variables return

Variable	ARMA model
Expected Agriculture producer price index	ARMA(2, 12)
Expected Consumer price index	AR(1)
Expected Current account	ARMA(1,12)
Expected Employment	ARMA(2,6)
Expected Exchange rate	MA(1)
Expected Industrial production index	MA(6)
Expected Interest rate	AR(1)
Expected Money supply (M2)	ARMA(12,12)
Expected Oil price	MA(3)
Expected Producer price index	AR(1)
Expected Rubber producer price index	AR(1)
Expected Trade balance	ARMA (2,1)

These are the entire best ARMA model of expected variables which these variables are independent variables. Therefore, the unexpected variables estimated; the different value between the actual value and the expect value which the expected value is equal to the fitted value from the best ARMA model of macroeconomic variable. So the unexpected variable can be estimated as follows:

$$\begin{aligned} &\mathit{The\ unexpected\ value\ of\ X} \\ &\qquad = \mathit{The\ actual\ value\ of\ X} \\ &\qquad - \mathit{The\ expected\ value\ of\ X} \end{aligned}$$

Table VI The ARMA model and GARCH type model of Energy index return

Variable	ARMA model	GARCH type model
The sector of Energy index return	MA(1)	EGARCH (2,1)

Table VII The effect of macroeconomic variables on the sector of energy index return volatility

Variable	Coefficient	SE	z-Statistic	Probability
r_agr	3.700443	12.47866	0.296542	0.7668
r_cpi	-2.425711	41.23897	-0.058821	0.9531
r_ca	2.25E-06	4.90E-06	0.458588	0.6465
r_ep	6.131209	3.4441	1.780206	0.075
r_ex	7.167959	6.783648	1.056653	0.2907
r_ipi	-69.62531	56.50687	-1.232157	0.2179
r_int	1.308735	1.45932	0.896812	0.3698
r_m2	-55.77656	38.429	-1.451411	0.1467
r_gas95	8.301674	37.42457	0.221824	0.8245
r_ppi	1.961711	3.90013	0.502986	0.615
r_rub_pi	3.012604	70.12922	0.042958	0.9657
r_tb	8.34E-06	5.88E-06	1.419096	0.1559

Notes: r_agr = agriculture producer price index return, r_cpi = consumer price index return, r_ca = current account return, r_tb = trade balance return, r_ex = exchange rate return, r_ipi = industrial production index return, r_int = interest rate return, r_m2 = money supply return, r_gas95 = gasoline 95 return, r_rub_ pi = rubber producer price index return, r_ep = employment return.

Table VIII: The effect of unexpected macroeconomic Variables on the sector of energy index returns volatility

Variable	Coefficient	SE	z-Statistic	Probability
r_agr_u	-1.966541	3.05251	-0.644237	0.5194
r_cpi_u	-22.23667	45.79288	-0.485592	0.6273
r_ca_u	4.95E-06	3.91E-06	1.265818	0.2056
r_ep_u	13.79653	3.543201	3.893803	0.0001*
r_ex_u	8.102959	11.70696	0.692419	0.4888
r_ipi_u	-6.169723	33.70713	-0.183039	0.8548
r_int_u	-11.43533	1.923855	-5.943968	0*
r_m2_u	-3.401105	21.56652	-0.157703	0.8747
r_gas95_u	-29.07821	23.98977	-1.212108	0.2255
r_ppi_u	-3.538238	4.857722	-0.728374	0.4664
r_rub_u	-34.69491	29.72858	-1.167056	0.2432
r_tb_u	-1.55E-05	3.50E-06	-4.426065	0*

Notes: * = 5 % of significant level
r_agr_u = the unexpected agriculture producer price index return,
r_cpi_u = the unexpected consumer price index return,
r_ca_u = the unexpected current account return,
r_tb_u = the unexpected trade balance return,
r_ex_u = the unexpected exchange rate return,
r_ipi_u = the unexpected industrial producton index return,
r_int_u = the unexpected interest rate return,
r_m2_u = the unexpected money supply return,
r_gas95_u = the unexpected gasoline 95 return,
r_ppi_u = the unexpected producer price index return,
r_rub_u = the unexpected rubber producer price index return,
r_ep_u = the unexpected employment return.

5. Discussions and Conclusion

From table VII can indicate that there are not the significant relationship between the macroeconomic variables and the sector of energy index return volatility at 5% level of significance. And from the table VIII there are the significant relationship between the unexpected macroeconomic variables and the sector of energy index return volatility which consists of μ (16) is the coefficient value of unexpected employment, μ (19) is the coefficient value of unexpected interest rate, and μ (24) is the coefficient value of unexpected trade balance which the probability of these unexpected variables are less than 0.05 or 5% level of significance. So it means; these unexpected variables have the effect on the sector of energy index return volatility. From the previous evidences; there are many studies to examine the impact of macroeconomic variables and unexpected macroeconomic variables on the stock returns volatility. Adjasi (2009) found the significant relationship between the macroeconomic variables and the stock market returns volatility in Ghana. Form his empirical result showed that the cocoa price and interest rate had the positive impact on the stock market returns volatility. Gold price, oil price, and money supply had the negative effect on the stock market return fluctuation. And exchange rate didn’t have the significant relationship with stock market return volatility. Tsoukalas (2003) examined the important relationship between the macroeconomic variables and stock returns volatility in Cyprus and he found that money supply, industrial production index, consumer price index, and exchange rate had the impact on the stock returns fluctuation in Cyprus. Mcsweeney and Worthington (2008) detected the significant relationship between the stock price returns volatility and the macroeconomic variables in Australia. From their evidences showed that oil prices, exchange rate, and interest rates had the effect on the industry stock returns fluctuation in Australia. Nguyen (2011) also found many the US macroeconomic factors which affected to the stock market returns volatility in Vietnam. He proved that unemployment, gross domestic product, percentage level housing statistics, industrial production, leading indicators, retail sales, consumer price index, producer price index, current account, trade balance, and the Federal Reserve’s target rate which these macroeconomic variables had the positively significant relationship with the volatility of stock market returns in Vietnam. This research just is the prediction the impact of macroeconomic and their unexpected macroeconomic variables on the sector of energy index return volatility on the period from January, 2005 to January, 2015 which examines only the outside effect but in the truth the volatility of energy index return or any stocks returns don’t depend on the only the outside effect. There are many causes of the fluctuation such as the operation of companies, the quality of product, the strategic plan in the companies, and etc. Since the researcher uses the 5% level (0.05) of significant confident in the hypotheses because it help to certainly prove the impact of macroeconomic and their unexpected macroeconomic variables on the sector of energy index return volatility. But it doesn’t mean; the other factors don’t have the effect on energy index return volatility, some dependent variable has the effect on energy index return volatility that is the employment. It has the positively significant relationship on the fluctuation of energy index return at 10 % level (0.1) of significant confident. This research can indicate the cause of the volatility of energy index return volatility in long term

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Internal Factors Determining the Leverage of Non-financial Companies in Vietnam

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Abstract

Vietnam is a developing country and currently providing huge opportunities for foreign investors who can understand the market. After joining World Trade Organization, Vietnam is following the commitment by gradually opening up the previous restricted industries and sectors. The Vietnam economy is expected to have a boom on new opening up business in 2016 due to the allowance of foreign ownership up to 100% (before was 49% maximum).

The objective of this research is to study the internal factors that will affect leverage of the non-financial companies in Vietnam. According to previous studies, the selected variables used to test the relationship with leverage are dividend payout ratio, profitability, size, liquidity, return on equity, growth, working capital, market to book ratio and total tangible asset. The annual data of 116 non-financial companies with 580 observations was collected from 2010-2014. The relationship between leverage of Vietnam companies with mentioned internal factors will be tested by panel regression analysis with fixed effect model.

The results showed that there are four factors that have significant relationship with leverage, including: return on equity (positive relationship at 1% significant level), company's size (positive relationship at 1% significant level), working capital (negative relationship at 1% significant level), and profitability (negative relationship at 10% significant level). Other factors have no significant effect on the leverage of Vietnam companies. This study enables investors to have deeper understanding about capital structure of companies in Vietnam.

***Keywords*:** Vietnam, Capital structure, Leverage, Panel data, Fixed Effect

1. Introduction

In 1958, Modigliani and Miller contributed their works to the financial world with an important theory on investing. They figured out the importance of capital structure in investor's decision making and firm's value creation. Since then, many other researchers have followed and contributed new works related to this topic. Most of them conducted their researches in developed markets which have attracted many investors. In contrast, only few researchers investigated this topic in developing markets.

Meanwhile, the current situation of the world economy shows that the developing countries are playing more and more important role in the world's economic growth. The United States of America, China and European countries are facing lots difficulties in the economic recovery as well as economic growth. Therefore, developing markets can be considered as a new and potential place for investors and Vietnam is one of the most active markets among developing countries in Southeast Asia. Especially, during this period, Vietnam is one of the fastest growth economies after China. The number of private companies has also increased significantly. In addition, although the world's economy has experienced many crisis lately, Vietnam economy has not been affected seriously. The market is still able to maintain its impressive growth rate. Furthermore, the establishment of ASEAN Economic Community (AEC) along with Trans-Pacific Partnership (TPP) Agreement enables Vietnam to be even more attractive to investors around the world.

However, to be successful, it is essential for investors and firms to understand the characteristics of capital structure in Vietnam market. Thus, this research aims to explore the internal factors determining the leverage of non-financial companies in Vietnam. The results from this research are expected to give deep knowledge and details on the capital structure in Vietnam market. This will further provide insights for managers on making financing decisions and investors on making investing decisions.

This paper examines factors determining the leverage of non-financial companies in Vietnam. Panel data were collected from 116 non-financial companies listed in Vietnam Stock Exchange from 2010 to 2014. The researcher selected variables from different capital structure theories to apply for the first time to Vietnam non-financial companies. The researcher eliminates financial companies due to their special capital structure which depends mostly on debt financing (more than 80%). Moreover, the considerable amount of listed financial companies in Vietnam current stock market may provide bias results for the research.

This paper is organized as follow. In the next session, the literature review on previous studies and theories will be mentioned. Section 3 is about the summary on financial leverage determinants and review of related literature. The hypotheses will be conducted on section 4. Section 5 is statistical treatments of data. Then the research results are shown on section 6. Section 7 is discussions on the results. Final section is conclusion and recommendation.

2. Literature Review

In 1952, Durand firstly contributed capital structure theory to the financial world. This theory suggested that there is no relationship between capital structure and firm value or in different word capital structure is eliminated from factors to evaluate a company. However, Modigliani and Miller (1958) found that previous theory is restricted in the perfect market. In the perfect market, there are no taxes, transaction cost and agency cost. This means a company with high leverage (higher risks) can lead to higher required rate of return. In the real market where taxes are involved, the higher leverage can reduce the cost of capital because interest payment is deducted before taxes making the taxes payment decreased.

Trade-off theory also mentions about the combination of debt-equity and the importance of debt in maximizing firm's value. Jensen (1986) confirmed that companies would decrease their agency costs by using debt effectively. Litzenberger (1973) found that business managers would prefer external financing rather than internal financing due to the tax deductible benefits on the interest payment. Ross (1977) proved that leverage can be a factor in evaluate a company. In conclusion, we can say that companies tend to enjoy tax benefits from using debt. A company can only continue using debt up to a certain point. If they get too much debt, the bankruptcy cost will start to increase. This would make the cost of debt too high.

In contrast, Myers and Majluf (1984) established Pecking Order Theory suggesting that a company would prefer internal funding before obtaining external fund. In this theory, the company firstly using the retain earnings to finance their activities. Once the internal funding is used up, then they would obtain the debt financing. Finally, they only require equity financing once the debt expired. Shyam-Sunder and Myers (1999) again confirms this view. However, Frank and Goyal (2003) argues that the theory can only applied for large firms rather than small firms. Chikolwa (2009) suggest that firms which have a huge ability to obtain debt will tend to avoid issue security and Brennan and Kraus (1987) confirmed that companies with high profit would have low leverage.

Another aspect, Jensen (1986) with the agency cost theory argues that debt can only increase the shareholder's value when it is utilized. Using too much debt financing can bring damage to company. The agency costs happen when the goals of manages and shareholders are not the same.

Shareholders normally consider on the company's profit while managers who are debt-holders concern more about the security of debt. Berger and Bonaccorsi di Patti (2006) found that managers are tending to avoid risks. This can lead to liquidity problems for even bankruptcy.

Based on those theories, many researchers tried to find out the capital structure's determinant. Titman and Wessels (1988) shows the results that firm size, fixed assets, non-debt tax shields, and investment opportunities have positive relationship to the leverage. On the other hand, volatility, advertising expenses, bankruptcy, profitability and the uniqueness have negative relationship with leverage. Basil and Peter (2008) found that profitability, firm size, growth rate, market-to-book ratio, asset structure and liquidity are determinant of capital structure. Gerardo *et al* (2014) suggest that profitability, size, collateral value of assets (CVA) and non-debt tax shields (NDTS) can be used to determine firm's debt level.

However, there are not many researchers did research on the developing market. In previous study, Wiwattanakantang (1999), capital structure determinants in developing countries also follow developed market. After that Chen (2004) also investigated the capital structure's determinants of Chinese companies and found that growth opportunity and tangibility are positively relating to the leverage, but profitability and firms' size have negative relationship with leverage. These finding from China literately contribute to the understanding of other developing countries and emerging economies.

3. Financial Leverage Determinants

Liquidity

The relationship between liquidity and leverage has been discussed for a long time. Myers and Rajan (1998) confirmed a negative relationship between liquidity ratio and leverage ratio. They explained that when a company maintains a high liquidity for a long time, it would be more difficult for company to obtain more debt financing since the lenders can limit the amount of debt to the company.

Moreover, firms with more internal fund available, they tend to use their available source to invest on future project. This also supports a negative relationship between liquidity and leverage. However, Jensen (1986) proposedthat firms with high level of available cash will require more debt financing to prevent using money ineffectively from directors or managers. In addition, Trade - Off Theory suggests that business can use debt instead of available cash to avoid tax payments.

Firm Size

Basil and Peter (2008) found in Jordan that business size has a strong positive relationship with leverage. Company will need more resource to expand its size therefore there would be a positive relationship between size and leverage. Nikolaos *et al* (2014) researched in Greece and confirmed that the larger business will tend to have more debt than the small business. The same result has been found by Gerardo *et al* (2014) with a research in India.

Firm's Growth

Trade-Off Theory suggests it is important for a last growth firm to maintain the level of debt to equity ratio in order to sustain benefits from high growth rate. Nikolaos *et al* (2014) confirm a positive relationship between growth and leverage. Firms with fast growth will enjoy the benefits of high profit but they also need more capital to maintain those profits. Santanu (2013) found out the same results with a research on Indian companies. However, Myers (1977) proposed that high growth firm sending a signal of a risky firm. This would make the firm reluctant to obtain large amount of debt. Therefore it's expected to have a negative relationship between growth and leverage.

Profitability

Trade – Off Theory states that company with high profitability may obtain more debt to prevent from tax reduction. This means there should be a positive relationship between profitability and leverage. However, Pecking Order Theory suggests that firms with high profits may use its own internal resource to financing rather than borrowing. So profitability would have a negative relationship with leverage. Based on previous studies, most of the researches support the Pecking Order Theory like: Titman and Wessels (1988), Raul (2008), Santanu (2013), Nikolaos *et al* (2014).

Working capital

Working capital is an indicator of a firm to show their ability to meet the short-term debt. The firm with high working capital is expected to have a low leverage ratio due to its low level of current debt. On the other hand, when the company acquire from bank to do business, there will be an increase on the current liability of the company which lead to lower working capital. This negative relationship between working capital and leverage has been confirmed by various researches such as: Raul (2008), Eriotis *et al* (2007) and Julia (2014).

Dividend Payout Ratio

Dividend is a part of profit that a company distributes to its shareholders. A company that can maintain dividend payment proves that the company is in good financial condition. Bhaduri (2002) suggests that firms can gain their access to external financing ability if they can maintain their dividend payment to shareholders. That means there would be a positive relationship between dividend and leverage. However, Basil and Peter (2008) showed the result that there is no relationship between dividend and leverage.

Return on Equity

Return on Equity (ROE) is one of indexes showing how wealthy a company is. It reveals how effectively a company using the money from its investors to generate profitability. Albayrak and Akbulut (2008) proved in their research that a higher return on equity will lead to a higher level of debt company would use to increase the profit. This means there is a positive relationship between return on equity and leverage. Uluyol *et al* (2014) with a research on construction industry also found the same result. However, Eriotis *et al* (2002) proved the otherwise with a different result. He proved that there is a negative relationship between return on equity and leverage.

Business Risk

Business risk is identified by the fluctuation or inconsistence of profitability which may have effect on the debt level of a company. When a company has high level of profitability's fluctuation, it shows that the company is experiencing a financial difficult period. Recently, Correa *et al*. (2007) did a research in Brazil and found that companies will have more ability to obtain debt from the banks if they have consistence profitability for a long time. This negative relationship between risk and leverage is also confirmed by Jordon *et al*. (1998). Wiwattanakantang *et al* (1999) found the same result with a research with Thai companies.

Tangible asset

For collateral purposes, tangible asset has more value and offer more security than intangible asset. So, the company with high level of tangible asset will have a higher chance to obtain the debt financing comparing to those with low level of tangible asset. Titman and Wessels (1988) found that there is a positive relationship between tangible asset and leverage. Company with high tangible asset will tend to have more debt since they have more collateralized assets. Bhaduri (2002) also confirm the positive relation with their research.

Growth

Most of investors chose to invest in high growth firms to expect that they will have a higher capital gain comparing to lower growth companies. High growth company sends a positive sign to the investors on the company's future performance. This theory is confirmed on the research of Hovakimian *et al*. (2004). The reason is that investing in those companies with high chance to get a capital gain will help investors prevent double tax payment. In this study, the researcher consider market-to-book ratio (MB) as a proxy of company's growth opportunities.

4. Hypotheses

Based on the literature review on the variables above, following null hypothesis are conducted to test:

H1: There is no significant relationship between liquidity and leverage.

H2: There is no significant relationship between firm size and leverage.

H3: There is no significant relationship between firm's growth and leverage.

H4: There is no significant relationship between profitability and leverage.

H5: There is no significant relationship between working capital and leverage.

H6: There is no significant relationship between dividend payout ratio and leverage.

H7: There is no significant relationship between return on equity and leverage.

H8: There is no significant relationship between business risk and leverage.

H9: There is no significant relationship between tangible asset and leverage.

H10: There is no significant relationship between market to book and leverage.

5. The sample and methodology

In this study, researcher use listed companies in the Vietnam Stock Exchange Market as samples. Data of 250 companies from major sectors of Vietnam Economy was obtained to calculate all variables which are leverage, liquidity, size, growth, profitability, working capital, dividend, return on equity, business risk, tangible asset and market to book ratio. Research collected yearly data from Reuter data base system from 2010 to 2014. All the data was checked on the consistency and continuously. Any company which missed any data will be eliminated from the set. Finally, 116 firms were selected from previous 250 companies.

In this research, all the banks and financial company was excluded because of their special capital structure. Financial institutions are usually operating on highly leverage level. This unique financial characteristic may create a bias result for the study. This was also confirmed by Santanu (2013) with a research on the capital structure determinants of Indian firms.

To investigate the relationship between liquidity, size, growth, profitability, working capital, dividend, return on equity, business risk, tangible asset, market to book ratio and leverage, the researcher using fix effect panel regression analyses as below:

$$LEVit = \beta0 + \beta1DPOit + \beta2ROEit + \beta3BRit + \beta4TANGit + \beta5MBit + \beta6LIQit + \beta7SIZEit + \beta8GROWTHit + \beta9PROFit + \beta10WCit + \Sigma\beta DUMMYi + \Sigma\beta DUMMYt + uit$$

Where:

LEV	Leverage or capital structure was calculated by dividing book value of total debt by the book value of total assets at each financial year end from 2010 to 2014.
DPO	Dividend payout ratio which is the percentage of income that company will distribute to the shareholders during the year. It's calculated by dividing total dividend paid by total income.
ROE	Return on equity which is measure by net income divided to total shareholder's equity.
BR	Risk is calculated by measuring the profitability's variance from 2010 to 2014.
TANG	Tangible asset is portion of fixed assets (including property, plant, equipment and Inventory) over the total asset.

MB	Market to book ratio is calculated by dividing current stock price by book value per share.
LIQ	Liquidity. In this case quick ratio has been used as a proxy for liquidity. It is shown as current assets minus inventories divided by current liabilities.
SIZE	Proxy for size is measured by natural log of total asset.
GROWTH	Percentage change on annual sale is used as proxy for growth.
PROF	Profitability = Earnings before interest rate and tax/Total Assets.
WC	Working capital = current assets – current liability.

Another two variables was added to normal panel regression model are DUMMYi and DUMMYt. This 2 variables was added to model to eliminate the bias result from panel data. This model has been used by many researchers with their research such as; Santanu (2013), Basil and Peter (2008) and Eriotis *et al* (2007) to have more precisely results. DUMMYi is fixed effect dummy variable of company I and DUMMYt is fixed effect dummy variable of year t.

6. Statistical results

As shown in table 1, there is no statistical relationship between DPO and leverage. The same results are found with BR, TANG, MB, LIQ and GROWTH. At 10% significant level, we found a P-value equal to 0.0896 which indicates a negative relationship between PROF and leverage. ROE, SIZE and WC with P-value equal to 0.0000, 0.0000 and 0.0002 are found to have a significant relationship with leverage. Leverage has a negative relationship with WC and positive relationship with ROE and SIZE.

Table 1: Result from Analysis with Fixed Effect Panel Data Regression Model

Variable	Coefficient	Prob.
C	-33.7922	0.0000
DPO	0.002605	0.5379
ROE	0.011825	0.0000**
BR	5.204434	0.2542
TANG	-0.143961	0.6269
MB	-0.082263	0.1468
LIQ	-0.027431	0.2991
SIZE	1.751458	0.0000**
GROWTH	0.001379	0.2672
PROF	-1.97E-10	0.0896*
WC	-2.52E-10	0.0002**

Note: (*) significant at 1% level. (**) significant at 10% level.

7. Discussion of the results

According to the result above, the determinants of leverage of Vietnam firms are following factors.

Profitability

The statistical shows that there is a negative relationship between profitability and leverage of Vietnam Company. This means the Vietnamese companies are tend to use their own profit for financing when they have high profit. The firm with higher profit will have less debt than the one with low profit. This founding is consistence with Pecking - Order Theory. The firms will use their own resource as priority to investment before obtaining any outside debt. There are also many previous research having the same result with is paper such as: Titman and Wessels (1988), Raul (2008) and Nikolaos *et al* (2014).

Size

The research confirmed that there is a signification positive relationship between size and leverage of Vietnamese firms. It indicates that bigger company will need higher debt level. Basil and Peter (2008) also found that company will need more resource to expand its size. The same result has been found by Gerardo *et al* (2014) and Nikolaos *et al* (2014). These two researchers confirmed that the larger businesses will tend to have more debts than the small businesses.

Working capital

As confirmed above, there is a significant negative relationship between working capital and leverage. Company with high working capital is expected to have low leverage ratio due to its low level of current debt. On the other hand, when company borrows debt, its current liability will increase. This leads to the result of lower working capital. Raul (2008), Eriotis *et al* (2007) and Julia (2014) also confirmed the negative relationship between working capital and leverage in their researches.

Return on Equity

It is confirmed that there is a significant positive relationship between return on equity and leverage. This means the companies in Vietnam have a tendency to use more debt financing to invest and earn profit. Albayrak and Akbulut (2008) also found in their research that higher return on equity will lead to higher debt level. Uluyol *et al* (2014) also got the same result in the research in construction industry.

8. Conclusion and Recommendation

The research aims to find out the determinants of the leverage of non-financial companies in Vietnam. Factors used in this study are dividend payout ratio, profitability, size, liquidity, return on equity, growth, working capital, market to book ratio and total tangible asset. All data was obtained from Reuter Database during period from 2010 to 2014.

The result showed that profitability, return on equity, firm's size and working capital are the determinants of leverage of Vietnamese firms. Among those determinants, profitability and working capital have negative relationship with leverage. In contrast, firm's size and return on equity positively relate to the leverage of Vietnam companies. The results were also confirmed by many previous studies.

This research provides details on the determinants of leverage in Vietnamese firms. This would help investors who are looking for opportunities in Vietnam know what information they need to find and review to understand on the capital structure in this market. Managers of Vietnamese firms can also get benefit from this study. This research will help them to know which variables have significant effect on the capital structure so that they can manage and make better financing decisions more effectively in future.

This study only provides overall information on leverage and capital structure in Vietnam market. Therefore, future study may use the same model to conduct research on specific industry in Vietnam.

There are only internal factors were adapted in this research study. Future study can add more external factors to get more details results on the determinants of leverage.

Besides, time frame conducted in this research is only covered from 2010 to 2014. Other research may explore the determinants of leverage in other periods to compare if the results are the same with this study.

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Pension Strategy under Volatility Clustering

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Abstract

The volatility clustering of assets is an important factor to consider in long term investments. Pension schemes are one type of long term investments in which volatility clustering plays a critical role. The aim of this paper is to investigate the effects of volatility clustering in a defined benefit pension scheme. Since pension schemes usually have investment time horizons of forty years, it is critical to guard the wealth of the pension funds especially at the near terminal period and make sure that they are on track to reach the fund target. In this study, the volatility clustering model is restricted to the GARCH family. Three models are thus examined: GARCH, GJR and EGARCH. The model parameters are estimated using a time series of S&P500 returns while the optimal strategy is obtained using dynamic programming. This is followed by comparative static. The most significant static is alpha, which represents volatility clustering. To study the behaviour of an optimal strategy under different models, Monte Carlos simulation was used so as to obtain the average optimal weight for each model. The optimal strategy was back-tested to see which model gives the best outcome. The EGARCH model performed best and provides the best strategy using S&P500 returns. The GJR model has a distribution similar to the GARCH model but the average weight is a bit higher. The EGARCH model's distribution volatility is lower than the other two models. And regarding the behavior of simulated weight, on average, the EGARCH model has a more conservative strategy but is more aggressive at a later period than the GARCH and GJR models.

Keywords**:** Optimal Asset Allocation, dynamic programming, Defined Benefit Pension Scheme, volatility clustering, GARCH Model

Introduction

Volatility has been observed in empirical data that large changes in prices of risky asset tend to come in cluster, and so did the small change. We called this phenomenon volatility clustering. In financial markets, when a new information affects financial markets, it will cause large price movements. The high volatility expects to continue for some periods causing losses in investment. Volatility clustering of risky assets, therefore, is an important factor to consider in long term investment.

Pension scheme are one type of long term investment that volatility clustering will play a crucial role when choosing investment strategies. Pension schemes usually have investment time horizon of forty years. There are two popular types of pension schemes: defined contribution plan and defined benefit plan. In a defined contribution plan, the final target fund depends on the contribution to the fund and the fund's performance. This characteristic is similar to most other funds. But in a defined benefit plan, the final target fund is fixed and depends on the proportion of final salaries of plan participants. The final salary can be predicted, for example, salaries of government officials increase at a constant rate every year. The defined benefit plan shares similar characteristics with other types of funds where the fund's managers target funds 's final gains, for instance, a fund targeting ten percent gain per year. The time horizon of other types of funds may be for a shorter period of time, such as five years or ten years. Time adjustment of portfolio and security prices in other types of funds may use weekly return or bi-weekly return instead of monthly return used in pension funds.

It is critical to guard the wealth of the pension funds especially at the near terminal period and make sure that it is on track to reach the fund target. Otherwise, the fund will take huge losses if the target is not reached by the end of the terminal period. In this research, we will focus on risk management; volatility clustering of risky asset return and its implication on investment strategy in a defined benefit pension fund. Moreover, model extensions that captures specific features of risky-asset returns, such as asymmetric volatility, are explored. Results of this paper should provide more information on investment decision managing a defined benefit pension funds.

It has come to our research question. How does the volatility clustering affect strategies in the pension fund management? And if we choose the different volatility clustering models, how does it affect the optimal strategy?

Concept and Theoretical Background

The dynamic portfolio choice was first introduced by (Merton, 1969) and has been extended to many researches in finding an optimal asset allocation of funds.

The investment strategies of pension schemes have been studied extensively using various models. For instance, (Vigna & Haberman, 2001) have proposed optimal investment strategy with discrete time model. (Ngwira & Gerrard, 2007) utilizes jump-diffusion process in a pension scheme's investment strategy. In both important works of (Vigna & Haberman, 2001) and (Ngwira & Gerrard, 2007), volatility is assumed to be constant through the time horizon. However, there has been evidences of volatility clustering, where periods of high volatilities tend to cluster together and likewise for low volatilities periods. In fact, volatility clustering in financial markets has been studied extensively, i.e. (Lux & Marchesi, 2000) and (Cont, 2007). One model that can express volatility clustering in empirical data is GARCH model.

Volatility clustering in daily returns have long been observed. (Jacobsen & Dannenburg, 2003), however, found evidences on volatility clustering in monthly stock returns of the Europe region using GARCH model. In this paper, we search for optimal asset allocation in pension schemes given volatility clustering in monthly returns of risky assets by using GARCH-family models.

This research focuses on managing a pension fund under volatility clustering. Volatility clustering presents a unique situation for the risk management of pension scheme. In this paper, we restrict volatility clustering model to the GARCH families._ There are other researchers who have worked on related problems. Event-risk, for example, have impacts on financial markets and make a huge loss on security prices which cause individuals and funds to incur a big loss, including Pension fund. (Liu, Longstaff, & Pan, 2003) has studied the effect of jump size in optimal asset allocation.

GARCH Family

In discrete time, the GARCH model was first introduced by (Bollerslev, 1986). It was adapted from the ARCH model proposed by (Engle, 1982). GARCH is often used for modelling stochastic volatility and it has been developed into many extensions. Later, (Ben-Hameur, Breton, & Martinez, 2006) provided a dynamic programming approach in GARCH model setting.

All models considered in this paper are in the GARCH family. Stock return dynamic is the same for every model as following.

$$Y_t = \mu + \sigma_t \varepsilon_t \qquad (1)$$
$$X_t = Y_t - \mu = \sigma_t \varepsilon_t$$
$$\varepsilon_t \sim i.i.d.N(0,1)$$

Where Y_t is a stock return at time t. μ is the mean of return, σ_t is volatility random variable at time t. ε_t is white noise process assumed i.i.d. standard normal distribution. X_t is normal distribution random variable with volatility σ_t.

1. GARCH (1,1) Generalized Autoregressive Conditional Heteroskedasticity, was proposed by (Bollerslev, 1986).

$$\sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \beta_1 X_{t-1}^2 \qquad (2)$$

Where $\alpha_0, \alpha_1, \beta_1$ are coefficients and $\alpha_1 > 0$, $\beta_1 > 0$, $\alpha_1 + \beta_1 < 1$. σ_t^2 is the conditional variance. $\varepsilon_t \sim i.i.d.N(0,1)$. $X_{t-1} = \sigma_{t-1}\varepsilon_{t-1}$, is normal distribution with volatility σ_{t-1}.

The GARCH model is used to capture volatility clustering by the term $\alpha_1 X_{t-1}^2$. We will study how this affect optimal investment strategy.

2. GJR (1,1) was proposed by (Glosten, Jagannathan, & Runkle, 1993).

$$\sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \beta_1 X_{t-1}^2 + \omega_1 I_{t-1} X_{t-1}^2 \qquad (3)$$

Where $I_{t-1} = 1 \; if \; X_{t-1} < 0$
and $I_{t-1} = 0 \; if \; X_{t-1} \geq 0$.

Where $\alpha_0, \alpha_1, \beta_1 \; and \; \omega_1$ are coefficient and $\alpha_1 > 0$, $\beta_1 > 0$, $\alpha_1 + \beta_1 < 1$. σ_t^2 is conditional variance. $\varepsilon_t \sim i.i.d.N(0,1)$. $X_{t-1} = \sigma_{t-1}\varepsilon_{t-1}$, is normal distribution with volatility σ_{t-1}.

GJR is another extension from GARCH, that can capture *Asymmetric Volatility*[1]. It is captured by the dummy variable I_t. This will also have effect on investment decision because the volatility depends on whether previous asset return is positive or negative.

3. EGARCH (1,1) Exponential GARCH was proposed by (Nelson, 1991).

$$\log \sigma_t^2 = \alpha_0 + \alpha_1 \log \sigma_{t-1}^2 + \beta_1[|\varepsilon_{t-1}| - E\{|\varepsilon_{t-1}|\}] + \omega(\varepsilon_{t-1}) \qquad (4)$$

Where $\alpha_0, \alpha_1, \beta_1 \; and \; \omega$ are coefficient. σ_t^2 is conditional variance. $\varepsilon_t \sim i.i.d.N(0,1)$. $E[|\varepsilon_{t-1}|] = E[|z_{t-1}|] = \sqrt{\frac{2}{\pi}}$.

EGARCH is extended from GARCH by adding another feature to capture the *Leverage Effect*[2] that some research observes in empirical data by the term $g(\varepsilon_t)$. We think that this model's feature will have an effect on the investment decision.

[1]Asymmetric volatility: phenomenon that volatility is higher in down markets than in up markets.

[2]Leverage Effect: changes in stock prices tend to be negatively correlated with changes in volatility, i.e., volatility is higher after negative returns than after positive returns of the same magnitude.

EGARCH and GJR have an additional feature from GARCH that can capture the sign effects of return: negative residuals induce larger increases in the variance than positive residuals. We called this asymmetric volatility. Consider when a market crashes, stock prices will drop dramatically, causing a significant increase in market volatility. This phenomenon will make asymmetric GARCH models' investment strategies be more cautious about the market crash's situation than a GARCH model. By intuition, due to higher volatility in the asymmetric one, it will lower the weight in risky assets compare to GARCH model in order to reduce the risk. As discussed, we think that EGARCH and GJR will have better investment decisions than GARCH model in the backtest period.

Bellman Equation

Dynamic programming is how you can maximize the utility function. There are decisions to make in every period. In each period there are information that change over time. In defined benefit pension scheme, we only care about wealth at terminal period so we got the dynamic decision problem,

$$J(0, W_0, \sigma_0^2) = \max_{y_i, i=0,..,T-1} \gamma^T V(T, W_T, \sigma_T^2, y_1, \dots, y_{T-1})$$

Where $V(t, W_t, \sigma_t^2, y_1, \dots, y_{T-1})$ is pay off function, $J(0, W_0, \sigma_0^2)$ is utility function at time 0 and $\gamma = e^{-r}$ is discount rate. W_T is wealth at time T. σ_T^2 is variance at time T. y_T is weight invested in risky asset at time T.

In order to solve this problem, Bellman equation is a necessary condition to solve dynamic programming problem.

Bellman's optimality principle (Bellman, 1956): "An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision."

In this research, GARCH (1,1) model is used, so at time T the information that need to use is at time T-1. Solving the Bellman equation, we got

$$J(T-1, W_{T-1}, \sigma_{T-1}^2) = \max_{y_{T-1}} [\gamma E[J(T, W_T, \sigma_T^2) | f_{T-1}]]$$

From the equation above, we got the backward recursion equation

$$J(t-1, W_{t-1}, \sigma_{t-1}^2) = \max_{y_{t-1}} [\gamma E[J(t, W_t, \sigma_t^2) | f_{t-1}]]$$

Overview of Methodology

There are three parts of methodology in this paper.

Analyzing optimal allocation

In this part, the objective is to numerically solve optimal allocation and compare across models. Moreover, study effect of volatility clustering $(\alpha_1, \beta_1, \omega)$ on optimal strategy.

The steps of this section are shown as follow:

1. Estimate parameters of GARCH, GJR and EGARCH models from the same time series, so these three models can be compared to each other.
2. Set up the utility function, wealth dynamic and dynamic programming problem.
3. Solve the optimization problem at period T-1 from the utility function for every pair of state variable.
4. Solve the optimization problem from period T-2 to period 0 by minimize the expectation of utility function in the next period.
5. Analyse the optimal allocation surface of each model.
6. Study the effect of volatility clustering by varying the parameters of GARCH models.

Monte Carlo simulation

In this module, under each model, study probabilistic behavior of allocation and its fund value.

Return and variance of GARCH, GJR and EGARCH are simulated simultaneously for 100,000 paths. The decision rule for optimal allocation are provided by the solution of the dynamic programming. The optimal weight invested in each period, depends on the state variable: current fund value and current variance.

Backtesting strategy

The objective of this part is to evaluate the performance of GARCH family models.

Now that the optimal investment strategy based on each GARCH-type model has found, we are interested to see how each strategy performs in comparison to each other under the realized historical data. The historical returns of S&P500 from year 1956 to 2015. The first 40 years of time series is used to estimate the parameters. The latest 20 years of time series is used for backtesting.

Numerical Method for Solving Bellman Equation

Set up the problem. First, construct wealth dynamic: consist of one risky asset and one risk-free asset.

$$W_t = W_{t-1}(1 + yY_t + (1-y) r_f \Delta t) + c \qquad (5)$$

Where

y is the proportion of the risky asset.

Y_t is risky asset return following GARCH family models.

W_t is wealth at time t.

c is a contribution per period.

r_f is risk-free rate assumed constant.

Now, follow the quadratic utility function setup from Vigna and Haberman (2001). It tends to minimize the difference of target fund and the terminal wealth. Its purpose is to make the fund's wealth as close as the target fund at terminal period.

$$J(T, W_T, \sigma_T^2) = (W_T - F_T)^2 = (W_T - f)^2$$

Where $F_T = f$ is fixed target fund of T periods.

From Bellman equation, we can construct the optimization problem to solve at time $T-1$. As the utility function is quadratic function, the minimization problem is required instead of maximization problem.

$J(T-1, W_{T-1}, \sigma_{T-1}^2 = \min_{y_{T-1}}[\gamma E[J(T, W_T, \sigma_T^2)|f_{T-1}]]$

We can write the equation of $J(t, W_t, \sigma_t^2)$ in general,

$J(t, W_t, \sigma_t^2)$

$= \min_{y_t} E[\gamma(W_T - f)^2 | F_{T-1}]$ when t = T-1

$= \min_{y_t} E[\gamma J(t+1, W_{t+1}, \sigma_{t+1}^2)|F_t]$ when t = 0, …, T-2

Subject to $0 \le y_t \le 1$

At time T-1, consider the term,

$$\min_y E[J(T, W_{i,T}, \sigma_{j,T}^2)|F_{T-1}]$$
$$= \min_y E[(W_{i,T} - f)^2 | F_{T-1}]$$
$$= \min_y E[(W_{i,T-1}(1 + yY_T + (1-y)r_f\Delta t) + c - f)^2 | F_{T-1}]$$

Substitute equation 1 in Y_T.

$$= \min_y E[(W_{i,T-1}(1 + y(\mu + \sigma_T\varepsilon_{1,T}) + (1-y)r_f\Delta t) + c - f)^2 | F_{T-1}] \quad (6)$$

The term σ_T is substituted by model of GARCH family, we firstly start at GARCH (1,1) model by substitute equation 2 in σ_T.

$$= \min_y E[\left(W_{i,T-1}\left(1 + y(\mu + (\alpha_0 + \alpha_1\sigma_{j,T-1}^2\varepsilon_{2,T-1}^2 + \beta_1\sigma_{j,T-1}^2)^{\frac{1}{2}}\varepsilon_{1,T}) + (1-y)r_f\Delta t\right) + c - f\right)^2 | F_{T-1}]$$

To compute the expectation, we need to vary $\varepsilon_t \sim i.i.d. N(0,1)$ both from the equation of Y_t and σ_t. We simplify ε_t by making it vary from -3 to 3 in intervals of 0.05. The sum of total probability is 0.9975. $\varepsilon_t = -3, -2.95, \ldots, 2.95, 3$. Let probability $P[\varepsilon_t] = cdf(\varepsilon_t + 0.025) - cdf(\varepsilon_t - 0.025)$. Then adjust the sum of probability to 1, $P[\varepsilon_t] = P[\varepsilon_t]/\sum P[\varepsilon_t] = P[\varepsilon_t]/0.9975$.

Now, compute the expectation,

$$\min_y E\left[\left(W_{i,T-1}\left(1 + y(\mu + (\alpha_0 + \alpha_1\sigma_{j,T-1}^2\varepsilon_{2,T-1}^2 + \beta_1\sigma_{j,T-1}^2)^{\frac{1}{2}}\varepsilon_{1,T}) + (1-y)r_f\Delta t\right) + c - f\right)^2 | F_{T-1}\right]$$
$$= \min_y \sum_{\varepsilon_{2,T-1}=-3}^{3} \sum_{\varepsilon_{1,T}=-3}^{3} P(\varepsilon_1)P(\varepsilon_2)(\left(W_{i,T-1}\left(1 + y(\mu + (\alpha_0 + \alpha_1\sigma_{j,T-1}^2\varepsilon_{2,T-1}^2 + \beta_1\sigma_{j,T-1}^2)^{\frac{1}{2}}\varepsilon_{1,T}) + (1-y)r_f\Delta t\right) + c - f\right)^2)$$

GJR (1,1) and EGARCH (1,1) setting also follow the same procedure as GARCH, substitute equation 3 for GJR model and equation 4 for EGARCH model in equation 6.

After simplify the equation for specific GARCH family model, we then solve the optimization problem for optimal strategy y_{T-1} and utility function $J(T-1, W_{T-1}, \sigma_{T-1}^2)$ for every pairs of the state variable.

Next, we find the optimal investment strategy from time $T-2$ to 0. After solve the dynamic programming at time -1 , solve it by backward recursion method for the period $t = T-2 \ to \ t = 0$.

given a pair of state variables,$(W_{i,t}, \sigma_{j,t}^2)$, $i, j = 1 \ldots n$. For a given scenario of $(\varepsilon_{1,t}, \varepsilon_{2,t-1})$, we update the state variable to the next period by equation 5 for wealth dynamic $(W_{i,t})$ and equation 2,3 and 4 for GARCH models $(\sigma_{j,t}^2)$. Compare the updated state variable with the grid of state variables at the next period, then interpolate the utility value, $J_{t+1}(t, W_{i,t+1}, \sigma_{j,t+1}^2)$, that already computed at period t+1. Compute it for all scenarios, take expectation and solve the optimization problem for y_t and J_t.

$$J_t(t, W_{i,t}, \sigma_{i,t}^2) \quad i, j = 1 \ldots n$$
$$= \min_{y_t} E[\gamma J_{t+1}(t, W_{i,t+1}, \sigma_{j,t+1}^2)|F_t]$$
$$= \min_{y_t} E[\gamma J_{t+1}(t, W_{i,t}(1 + y_t(\mu + \sigma_t\varepsilon_{1,t}) + (1-y_t)r_f\Delta t) + c, \sigma_{j,t+1}^2)]$$
$$= \min_{y_t} \sum_{\varepsilon_{2,t-1}=-3}^{3} \sum_{\varepsilon_{1,t}=-3}^{3} P(\varepsilon_{1,t-1})P(\varepsilon_{2,t-1})(\gamma J_{t+1}(t, W_{i,t}(1 + y_t(\mu + \sigma_t\varepsilon_{1,t}) + (1-y_t)r_f\Delta t) + c, \sigma_{j,t+1}^2))$$

Substitute equation 2,3 and 4 in $\sigma_{j,t+1}^2$ for GARCH, GJR and EGARCH respectively. $\varepsilon_{2,t}$ is the term ε_t in $\sigma_{j,t+1}^2$'s equation. Solve the optimization problem to get the solution of $y_t \ and \ J_t$, $t = 0, \ldots, T-2$.

Results and Discussion

In reality, although people start working at 20 years old, most people do not start worrying about their wealth at retirement age until they are 40 years old. Therefore, in this paper we choose the investment time window of 20 years, starting from when they start to invest until the retirement at age 60 years old. In long term investment, there is not as much portfolio adjustment as short term investment. The interval between each portfolio adjustment is set at 3 months in this study.

Before solving dynamic programming, the estimated parameter of GARCH family models are need. The model parameters of GARCH, GJR and EGARCH models is estimated using time series data of S&P500 3-month returns from year 1956 to 1995, a total of 40 years or 160 data points. The estimated parameters are shown in Table 1.

Table 1: parameters of GARCH family models, estimated from MLS method.

Model	α_0	α_1	β_1	μ	ω
GARCH	0.0022	0.515	0.124	0.0143	-
GJR	0.00268	0.408	0.021	0.0136	0.2635
EGARCH	-1.4535	0.717	0.293	0.0127	-0.123

Analyzing optimal allocation

After model parameters are estimated, the optimal strategies for GARCH, GJR and EGARCH models are solved for Bellman equation. After solve the problem, the optimal strategies are compared to each other's. And by varying static parameters in GARCH family model: alpha, beta and omega in each model, the optimal strategies are also compared.

To make this pension scheme setting compatible with the models, parameters are set up as followed. The interval between portfolio adjustment is 3 months. From the equation 5, Δt is equal to 1/4. The investment window is 20 years, making total investment periods equal to 80 periods. To simplify the model, no short selling and leverage is allowed ($0 \leq y_t \leq 1, t = 0, \ldots, T-1$). The risk-free rate and discount rate is assumed constant at 1 percent annually. Contribution per period (3 month) is 300.

The optimal allocation and utility function of GARCH, GJR and EGARCH models are shown in Figure 1.1, 1.2 and 1.3 respectively. The utility function at the later period have the lowest point equal to 0 when fund value equal to target fund. Thus the utility value is also positive when fund value goes above target fund, but as risky asset assumed positive expected return. Invest more in risky asset only make the expected fund value more different than target fund, so weight invested in risky asset in the next period is 0.

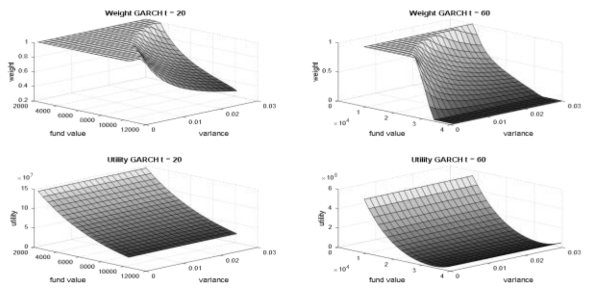


Figure 1.1. The optimal allocation and utility surface of GARCH model in periods 20 and 60.

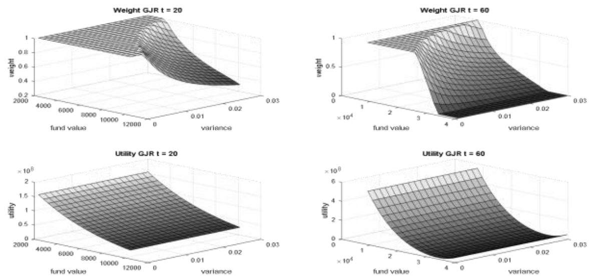


Figure 1.2. The optimal allocation and utility surface of GJR model in periods 20 and 60.

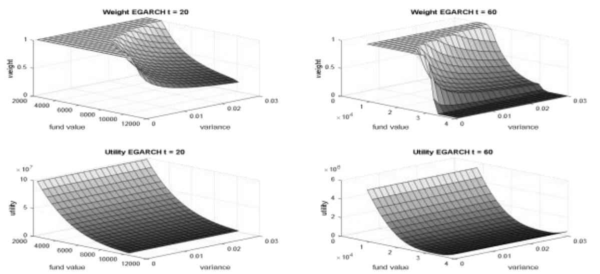


Figure 1.3. The optimal allocation and utility surface of EGARCH model in periods 20 and 60.

Effect of volatility clustering on optimal strategy

This section examines the effect of varying parameter values in GARCH family models on the optimal strategy. There are two important parameters for GARCH family: alpha and beta. The extension models, GJR and EGARCH models, have an additional parameter: omega.

Benchmark values of parameters are still the estimated values from S&P500 returns in the previous section. The same dynamic programming method as in the previous section is applied where, with varying values of the parameter in question while holding the rest of the parameter constant. The optimal strategy surface results are presented as cross section by fixing the state variable, current wealth, and also fix time period invested. The Figures show the plot between variance and optimal weight compare along the varying values of the parameter in GARCH, GJR and EGARCH models.

The first parameter is alpha, represent intertemporal volatility clustering. It is used to adjust how much volatility in the past affects present volatility. The second one is beta represent amplitude of uncertainty in the past period. The last one is omega is used to modify the distribution of volatility model, asymmetric volatility.

Effect of volatility clustering on optimal strategy in GARCH model

The results of varying alpha and beta terms of GARCH model are shown in Figure 2.

Alpha: is used to adjust how much volatility in the past affects present volatility. The larger the alpha, the higher the volatility clustering. In the presence of higher alpha, the optimal strategy put less weight on the risky asset. The level of volatility clustering, alpha, has a significant impact on the optimal weight.

Beta: the higher the beta, the higher the risk of time series is. It is obvious that high beta term makes the risky assets more risk. In result, the higher beta makes the strategy invest more conservative in risky asset.

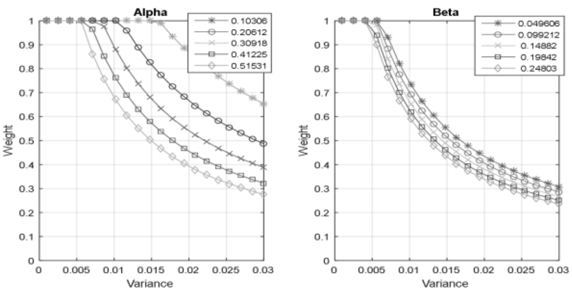


Figure 2. Optimal strategy of GARCH model varying alpha and beta by fixing fund value at period 60.

Effect of volatility clustering on optimal strategy in GJR model

The results of varying alpha, beta and omega terms of GJR model are shown in Figure 3.

Alpha and Beta: GJR is an extension from GARCH model, add the omega term while the rest of the model is as same as GARCH model. Thus the effect of alpha and beta are the same.

Omega: It is an additional term that extends from GARCH model. When uncertainty term is more than zero, this term is equal to zero, and otherwise, positive value. This effect is also known as asymmetric volatility. The higher the omega term, the lower the optimal strategy weight on risky asset.

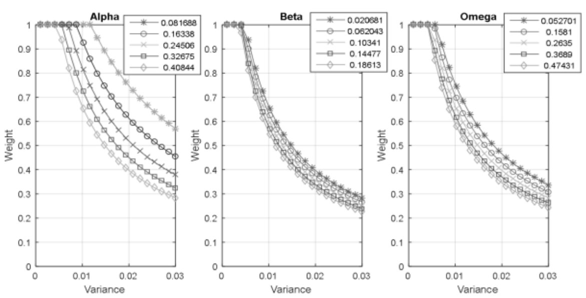


Figure 3. Optimal strategy of GJR model varying alpha, beta and omega by fixing fund value at period 60.

Effect of volatility clustering on optimal strategy in EGARCH model

The results of varying alpha, beta and omega terms of EGARCH model are shown in Figure 4.

Alpha: the effect of alpha term is reverse in the EGARCH models. Due to the characteristic of log function, log(n) is less than 0 when n<1, and the fact that $0 < \sigma < 1$, the term $\alpha_1 \log(\sigma_{t-1}^2)$ is more negative when alpha is higher, resulting in overall lower variance in the current period (σ_t^2). Alpha is a critical parameter in the EGARCH model. Given low alpha, i.e., high variance, the optimal strategy will put very low weight on risky asset. This implies a conservative strategy in the presence of highly risky asset.

Beta: the effect of beta in EGARCH model is the same as in GARCH and GJR models. The higher the beta, the higher the weight of optimal strategy is.

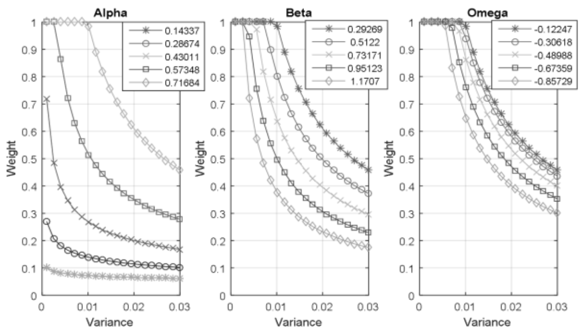


Figure 4. Optimal strategy of EGARCH model varying alpha, beta and omega by fixing fund value at period 60.

Omega: the omega term is a direct variation of uncertainty term. The higher the omega term, the lower the optimal strategy weight on risky asset. This is because the omega term is used to capture the asymmetric effect, i.e. high in negative return causing high volatility. So high omega will make the model put more awareness in risky asset, resulting in lower optimal strategy.

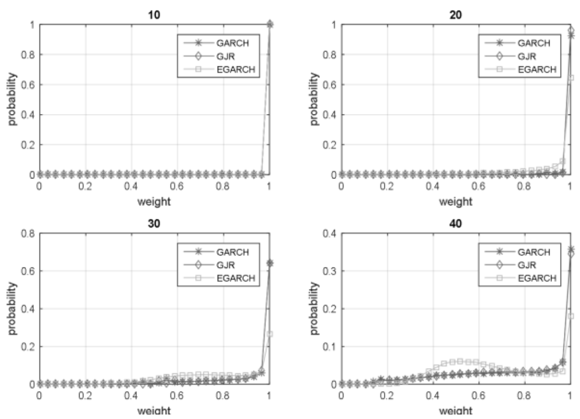
Monte Carlo Simulation

After the optimal strategy for GARCH, GJR and EGARCH is obtained, the distribution of optimal weight in each model is investigated using Monte Carlo simulation. In particular, the average weight put on risky assets of the optimal strategies are compared in each model.

First, return and variance of GARCH, GJR and EGARCH are simulated simultaneously by the estimated parameters provided in Table 1. In simulation, the decision rule from the solution provided by the optimal strategy surface above is used to find the optimal weight to put on risky assets. The optimal weight invested in each period, depends on the state variable: current fund value and variance. Henceforth, the distribution of simulated weight is found from 100,000 paths of each model. The average weight is calculated from optimal weights used in each scenario.

Distribution of simulated weight of GARCH, GJR and EGARCH are shown in Figure 5. At early period, all three models put 100% weight in risky asset like in period 10. After that, the optimal allocation begins to lower the optimal weight to 80%-100% at period 20 for EGARCH model, but it is still high for GARCH and GJR models. The weight is lower as time pass by from early period to later period. At period 50, for GARCH and GJR models, weight 10%-90% in risky asset has about the same probability while EGARCH has the highest probability when weight is about 40% in risky asset. At the terminal period (79), the weight invested have 2 scenarios, the first scenario is invested 100% weight in risky asset because the fund value is still lower than target fund, the highest probability one is EGARCH model follow by GARCH and GJR models respectively. The second one is weight invested less than 100%. The closer the weight to 0%, the closer the difference between fund value and the target fund. It means that if the probability is high at weight close to 0% at the terminal period, it is likely to be that the model will perform well. The simulated models that make the closest value are GARCH, GJR and EGARCH respectively.

Average weight of optimal strategy is shown in Figure 6. The optimal strategies of GARCH and GJR models are very similar (Figure 1), therefore the average weight of GARCH and GJR model are very close. In average, GJR model put more weight in risky asset than GARCH model. In early periods, EGARCH model will put less weight on risky asset than GARCH and GJR model. This implies that assuming EGARCH model result in more conservative strategy than assuming GARCH and GJR models.



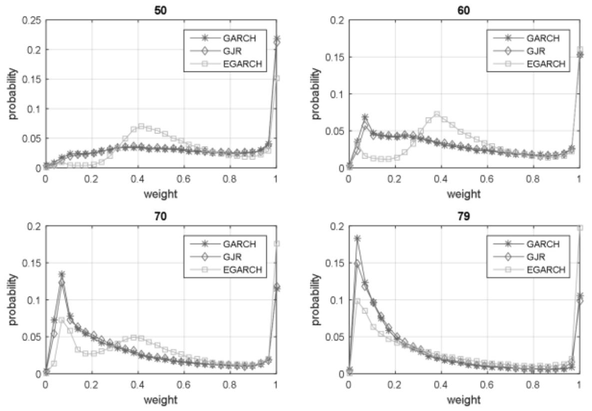


Figure 5. Distribution of simulated weight of GARCH, GJR and EGARCH models at several periods.

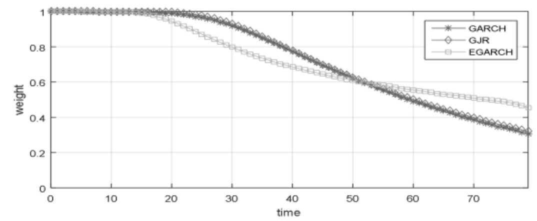


Figure 6. Average weight in risky asset of GARCH, GJR and EGARCH models from simulated of 100,000 paths.

Backtesting strategy

Now that the optimal investment strategy based on each GARCH-type model is calculated, we are interested in seeing how each strategy performs in comparison to each other under the realized historical data.

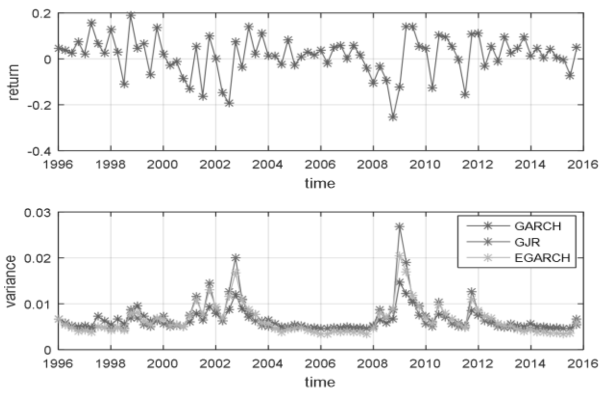
In this section, time series of 60 years of historical return is used. The historical returns of S&P500 from year 1956 to 2015 is collected as a sample. The first 40 years of time series is used to estimate the parameters of GARCH family models. The optimal strategy surface is then calculated given the estimated parameters with the same procedure as in the analyzing optimal allocation section. Afterwards, the latest 20 years of time series is used for backtesting. Fund portfolios are constructed assuming different models given the estimated parameters. Subsequently, the portfolios are adjusted in each period using the calculated optimal strategies above over the last 20 years of the time series. Then, the performance of funds assuming different models are compared.

The result of backtest is shown in Figure 7. In general, the optimal strategy of GARCH and GJR model are similar. However, when the return is deep in the negative territory, the two models will imply quite different variance and hence diverging optimal strategies. When returns are very negative, the variance of GJR model is much higher than GARCH's. For both models, as variance rises, the optimal weight on risky asset lowers. Consequently, GJR optimal strategy will drop the weight on risky asset a lot more than GARCH's optimal strategy, as the variance implied by GJR is a lot higher. For example, at the end of year 2008, return of stock is -25.56% (Figure 7.1). Subsequently, the variance in the next period of GJR increases to 0.0268 while variance of GARCH is only 0.0147 (Figure 7.2), almost half of GJR's. Using current wealth and variance as state variable to interpolate the weight in dynamic programming at the same period, the backtest weight are 0.86 for GARCH's and 0.58 for GJR's (Figure 7.3).

Table 2. Average return per year of backtest fund.

Model	GARCH	GJR	EGARCH
Return	3.76%	3.75%	4.09%

The average return of backtest fund is shown in Table 2. It turns out that the model that give the best outcome is EGARCH model, while GARCH and GJR model give close strategy and result. The most significant impact that make EGARCH give a better performance than the other two models because most of the early period in GARCH and GJR model, the optimal strategy try to put weight in risky asset closely to one ignore what the level of variance is. While EGARCH model use more conservative strategy on volatility of risky asset. For example, (Figure 7.1-7.3) when the return is low along the year 2001-2003 and 2008, this make variance of EGARCH and GJR model hike up closely to each other and higher that GARCH model. But when it comes to optimal strategy, at high variance, EGARCH model put less value in optimal weight, conversely, GJR model still does not took a very good care of high variance as same as GARCH model.



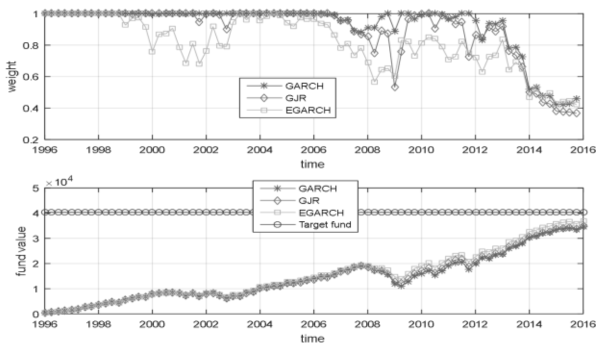


Figure 7.1. 3-month Return of S&P500 between year 1996-2015.
Figure 7.2. Variance of GARCH, GJR and EGARCH model of S&P500 between year 1996-2015.
Figure 7.3. Backtesting weight of S&P500 between year 1996-2015, are calculated from optimal strategy surface in each model.
Figure 7.4. Backtesting fund of S&P500 between year 1996-2015.

Conclusions

This research has investigated the difference of three volatility clustering models: GARCH, GJR and EGARCH model in a defined benefit pension scheme. First, model parameters are estimated using a time series of S&P500 3-month returns. The optimal strategy surface is obtained by solving Bellman equation. Follow by study effect of volatility clustering, the parameter that has the most significant one is alpha.

After that, Monte Carlo simulation is simulated. The results are, GJR model has very similar distribution as GARCH model but the average weight is a bit higher. EGARCH model has low volatile in distribution than other two models. The behaviour of simulated weight, in average, EGARCH model have more conservative strategy but more aggressive at later period than GARCH and GJR model. Lastly, in backtesting strategy, EGARCH provide the best strategy for S&P500.

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