HEDGING EFFECTIVENESS OF RUBBER MARKET IN THAILAND

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DECLARATION

We hereby declare that:

(1.) This undergraduate research project is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

(2.) No portion of this research project has been submitted in support of any application for any other degree or qualification of this or any other university, or other institutes of learning.

(3.) Equal contribution has been made by each team member in completing the research project.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
AFET	Agricultural Futures Exchange of Thailand
ARCH	Autoregressive Conditionally Heteroskedasticity
BEKK	Baba-Engle-Kraft-Kroner
CCC	Constant Conditional Correlation
C-COM	Central Japan Commodity Exchange
GARCH	Generalized Autoregressive Conditionally Heteroskedasticity
OHR	Optimal Hedge Ratio
OME	Osaka Mercantile Exchange
OLS	Ordinary Least Squares
PP	Phillips-Perron
RSS3	Grade No.3 of Ribbed Smoked Rubber
SD	Standard Deviation
SICOM	Singapore Commodity Exchange
TOCOM	Tokyo Commodity Exchange
VAR	Vector Autoregression

ABSTRACT

This study evaluates the hedging effectiveness of rubber futures contract in Agricultural Futures Exchange of Thailand (AFET), Singapore Commodity Exchange (SICOM) and Tokyo Commodity Exchange (TOCOM). Using naïve, ordinary least squares (OLS), constant conditional correlation (CCC)-GARCH and Baba-Engle-Kraft-Kroner (BEKK)-GARCH approaches, we observe that GARCH hedge ratios are significantly outperform as compared to the static hedge ratios at all cases. In addition, the conditional correlation model does not always more superior to other unconditional correlation GARCH model, but it remains important for modeling hedging strategies. Furthermore, the empirical results suggest that the omission of basis term will cause lower hedging effectiveness. Meanwhile, the hedging performance is improved when the effect of basis is being examined asymmetrically rather than symmetrically. Thus, it is important to separate the basis effect to be positive and negative effects in determining the best hedging strategy. Lastly, the empirical results show that SICOM has the highest hedging effectiveness among the three futures contracts in Thailand rubber spot market. This implies that local futures contract does not ensure better hedging performance even when it is used to hedge at its home country.

CHAPTER 1: INTRODUCTION

1.0 Overview

In this chapter, we explain the background of spot and futures relationship. It is followed by hedging effectiveness in commodity market, background of rubber market in Thailand and finally rubber futures exchange markets. The problem statement will be explained in the subsequent section. Objectives and significance of study will be discussed at the next section. The outline of this study will be stated in the last section.

1.1 Background of spot-futures relationship

The spot market is a place where all purchases and sales require an underlying commodity to be delivered and paid instantly, while the futures market is a place for contractual instrument (John, 2009). The spot price is the market price of a particular commodity to be delivered immediately but the futures price is the expected price of a particular commodity to be transacted somewhere in the future with its price set at the present moment (Johnson, 1960 and Schrock, 1971).

According to Xiaosu (2011), there are two main functions of the futures markets. Firstly, it is used to hedge the potential risks for market participants. Secondly, it is used as a price discovery mechanism to determine the spot price of underlying assets in the marketplace through demand and supply in the futures market (Liu & Wan, 2011and Silvapulle & Moose, 1999).

1.1.1 Hedging effectiveness in commodity market

The mismatch of demand-supply for commodity has resulted in a negative effect on the agricultural yields and it has subsequently caused commodity prices to become unstable. Due to unstable commodity price, hedging with futures contract is able to reduce the potential losses from the buyer and seller of the commodity. Given a spot position, hedgers usually enter an opposite position in the futures market. This can minimize price risk because gain in a futures contract will offset losses in the spot market. Hedge ratio is the ratio of futures position acquired relative to the spot position to hedge. Optimal hedge ratio (OHR) is defined as the ratio of futures keeping to a spot position that able to minimize the variance portfolio.

Studies of Johnson (1960) and Stein (1961) have attracted the concerns of researchers on risk-minimization approach in hedging cash position with futures. Traditional methods such as naïve and ordinary least squares approaches are employed in past studies. However, the result of these strategies was criticized to be biased due to the existence of cointegration relationship between spot and futures prices (Ghosh, 1993). This is because conventional approaches assume a constant optimal hedge ratio over time. This assumption is not applicable where basis risk varies over time (Myers, 1991).

The development of time variant models is included in the entire literature from here onwards. In order to capture the nature of the return series in time variant and conditional covariance between spot and futures markets, many researchers employed generalized autoregressive conditional heteroscedastic (GARCH) models such as Baba-Engle-Kraft-Kroner (BEKK) and Constant Conditional Correlation (CCC) (Kumar & Lagesh, 2011). In study of Baillie and Myers (1991), they explained the importance of GARCH models in improving the assumption of constant hedge ratio and the estimation of hedge ratios.

1.1.2. Background of rubber market in the world

In 1876, Henry Wickham smuggled out rubber tree seeds from Amazonia to the Botanical Gardens in London. After grafting, resistant varieties of rubber trees were developed and sent to British colonies in Malaysia, Ceylon, and Singapore.

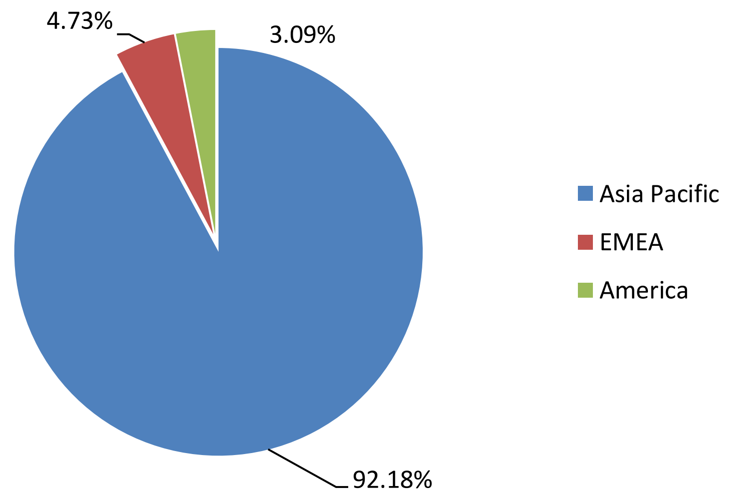
Sir Henry Nicholas Ridley distributed seeds to many planters and came up with a tapping method that did not hurt the trees. He commercialized rubber especially in Malaysia and Singapore region during 1808-1911. The global rubber industry has grown since then.

Table 1.1 World's natural rubber production and consumption for 2013

Natural Rubber Production (tonnes)	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Total**
Asia Pacific	2, 477, 000	2, 461, 000	3, 014, 000	**7, 952, 000**
EMEA	127, 000	121, 000	137, 000	**385, 000**
America	83, 000	90, 000	64, 000	**237, 000**
Total	**2, 687, 000**	**2, 672, 000**	**3, 215, 000**	**8, 574, 000**
Natural Rubber Consumption (tonnes)	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Total**
Asia Pacific	1, 885, 000	2, 085, 000	2, 098, 000	**6, 068, 000**
EMEA (Eu-27)	268, 000	258, 000	278, 000	**804, 000**
EMEA (exclude Eu-27)	102, 000	101, 000	108, 000	**311, 000**
America	409, 000	425, 000	406, 000	**1, 240, 000**
Total	**2, 664, 000**	**2, 869, 000**	**2, 890, 000**	**8, 423, 000**

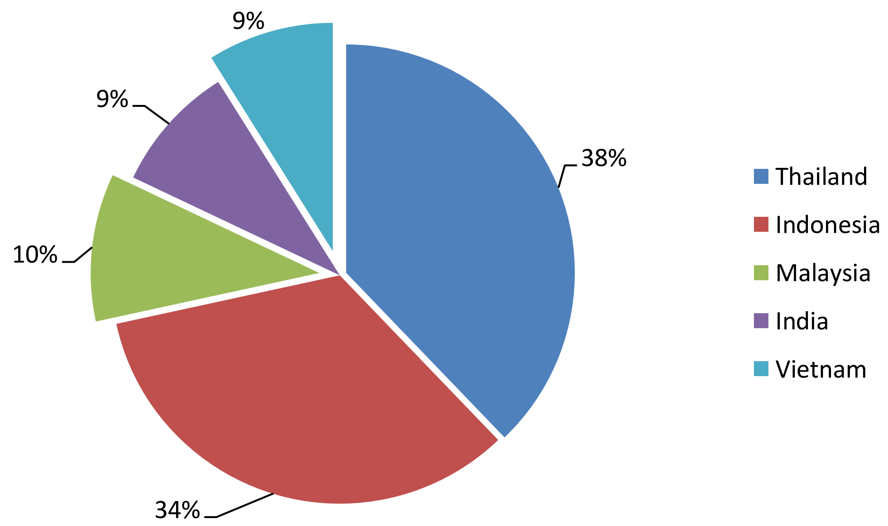
Source: RubberStudy.com (2013).

Figure 1.1: World's natural rubber production 2013



Source: Rubber Study (2013).

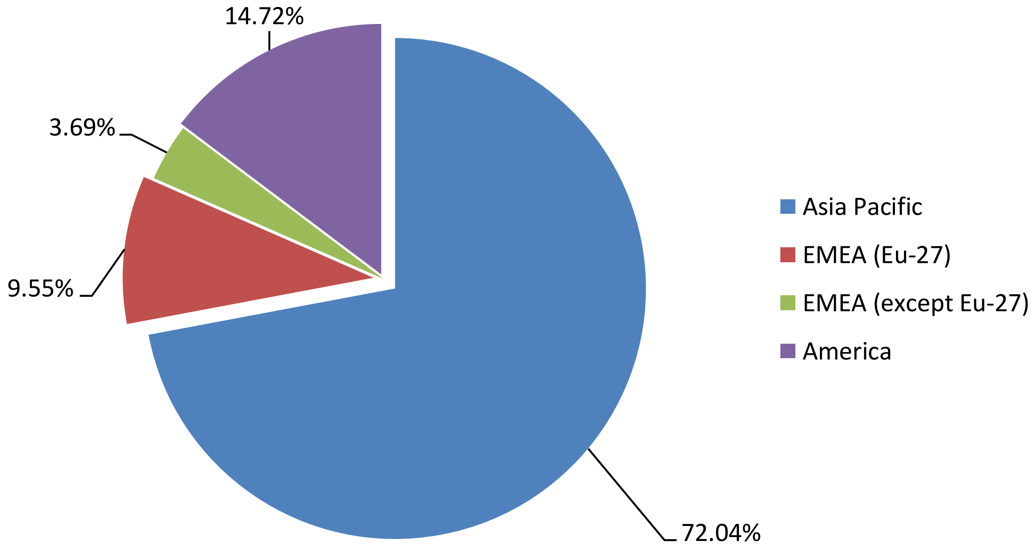
Figure 1.2: The top five rubber producing countries 2011



Source: FAOSTAT data (2013).

Based on Table 1.1, Asia Pacific countries are the largest rubber producers in the world. Referring to Figure 1.1, Asia Pacific has seized over 90 per cent of the world's production throughout 2013 because all rubber producing powerhouses are located in Asia such as Thailand, Indonesia, India, Malaysia and China. As observed from Figure 1.2, Thailand, Indonesia, Malaysia, India, and Vietnam are the top five rubber producing countries (FAOSTAT, 2011). Thailand ranked first in 2011 with a total production of 3,348,897 metric tonnes, while Indonesia follows behind Thailand with a total production of 2,990,200 metric tonnes. Third was Malaysia, falling short of the 1 million tonnes mark with a total production of 926,000 metric tonnes. India and Vietnam had their total productions at 800,000 metric tonnes and 789,635 metric tonnes respectively. These countries have optimum climate, environment and ample space for rubber production. On the other hand, the rubber production of America recorded a 3.09 per cent and Europe, Middle East, and Africa (EMEA) is 4.73 per cent of the world's production.

Figure 1.3: World's natural rubber consumption 2013



Source: Rubber Study (2013).

From Figure 1.3, Asia Pacific also has the biggest consumption of rubber. The countries consume about 72 per cent of total rubber consumption in the world as shown in Figure 1.2. They highly consume imported rubber products. On the other hand, America, European Union and the rest of EMEA consume about 14.72, 9.55 and 3.69 per cent of rubber in the world respectively.

1.1.3. Thailand rubber market

Natural rubber is obtained by processing latex harvested from "Hevea Brasiliensis" rubber trees, also named as Pará rubber tree. It uses to produces milky latex that become the principal source of natural rubber. Most of the rubber products come from rubber tree plantations in Asia including Thailand, Indonesia, Malaysia, and Sri Lanka.

There are two types of sheet rubber in the international market, namely Ribbed Smoked Sheets (RSS) and Air Dried Sheets (ADS). Over 70 per cent of the natural rubber production is processed as RSS. Those of better quality are sort out from fresh field latex through implementing modern processing methods. Rubber latex is processed into ribbed rubber sheets and then sheeted, dried, smoked, and graded visually. After grading, the sheets are packed in 50 kilograms bales with the grades marked on the bales.

Figure 1.4: RSS3 (Grade 3 Ribbed Smoked Sheets)

Source: Thomson Group (2011).

Ribbed Smoked Sheets is sold based on visual assessment of quality. Referring to Table 1.2, it is graded according to the grading characterization and standard defined in the 'The Green Book" of International Rubber Quality and Packing Conferences as RSS1, RSS2, RSS3, RSS4, RSS5 and RSS9 (Thomson Group, 2011).

Table 1.2: Grading of Ribbed Smoked Sheets (RSS)

Grade	Technical Specifications	Areas of Consumptions
RSS1	Dry, clean, strong, sound and evenly smoked. Free from molds, blemishes, specks, rust, blisters, sand, etc. Slight specks might be seen	Tubes
RSS2	Dry, clean, strong, sound and evenly smoked. Free from molds, blemishes, specks, rust, blisters, sand , etc.	Extruded Hoses, Quality Footwear Items, Tires, Tubes, Tread Carcasses
RSS3	Dry, strong and free of blemishes, blisters, sand, dirty packing, etc	Tires and ADV Tires, Extruded Hoses, Footwear
RSS4	Dry, firm and free of blemishes, blisters, sand, etc. to the extent shown in samples	Tires and ADV Tires, Extruded Hoses, Footwear
RSS5	Dry, firm and free of blemishes to the extent shown in samples	Handmade Hoses, Re-treading Materials
RSS9	Dry, clean, strong, sound and evenly smoked. Free from molds, blemishes, specks, rust, blisters, sand, etc.	Aero Tires

Source: Thomson Group (2011).

1.1.4 Rubber futures exchanges markets

The three futures markets, namely Agricultural Futures Exchange Market of Thailand (AFET), Singapore Commodities Exchange Market (SICOM) and Tokyo Commodities Exchange (TOCOM).

Osaka Mercantile Exchange (OME) was merged into the Central Japan Commodity Exchange (C-COM) in 2007[1]. However, C-COM was sustaining huge losses and had to close down in 2011 due to unprofitability and slumping volume[2]. Therefore, we chose Tokyo Commodity Mercantile (TOCOM), Agricultural Futures Exchange of Thailand (AFET), and Singapore Commodity Mercantile (SICOM) because these three futures markets have the largest trading volumes for rubber futures. TOCOM as of November 5, 2013 have 12, 568 contracts of trading volume in its day session[3]. AFET have an average of 2, 382 contracts at the end of November 4, 2013[4]. Meanwhile, SICOM have an average of 1, 300 contracts per day during September 2013[5].

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[1] Merger of Central Japan Commodity Exchange and Osaka Mercentile Exchange. (August 22, 2006). Retrieved on April 1, 2014.

[2] Hur, J., & Song, Y. (June 18, 2010). Central Japan commodity exchange to close in January on declining volume. Retrieved on April 1, 2014.

[3] Global Rubber Market. (n.d.). TOCOM. Retrieved on April 1, 2014.

[4] Historical quote. (November 4, 2013). Retrieved on April 1, 2014.

[5] SGX SICOM rubber contracts achieve record volume & open interest in September 2013. (October 1, 2013). Retrieved on April 1, 2014.

Agricultural Futures Exchange Market of Thailand (AFET)

Computerized continuous trading method is used in AFET market. This method is a system that allows transactions to be executed continuously and simultaneously between long and short parties during business hours, in accordance with the members' orders.

Table 1.3: Contract specification of RSS3 in AFET

Contract duration	7 consecutive months
Currency	Thailand Baht (THB)
Contract Size	5,000 Kilogram or 5 metric tonnes
Daily price fluctuation limit	THB 4.30 / Kg
Delivery method	Either on FOB (Free on Board) at Bangkok or Leam Chabang
Delivery period	Until the last day of each month
Delivery unit	20,000 kg

Source: Agricultural Futures Exchanges Market of Thailand (2014).

Table 1.3 shows the contract specification of RSS3 in AFET exchange market. The daily price fluctuation limit under the contract is THB 4.30 / Kg which effective from May 29, 2013 onward. However, it may be subject to change according to the daily price limit criterion.

Singapore Commodities Exchange Market (SICOM)

Electronic trading system which is E-SICOM is used in SICOM market. E-SICOM's web-based interface enhances the accessing speed for market participants and creates a more efficient marketplace. The contract specification of RSS3 in SICOM exchange market is tabulated in Table 1.4.

Table 1.4: Contract specification of RSS3 in SICOM

Contract duration	12 consecutive months
Currency	United States Dollars (USD)
Contract Size	5,000 Kilogram or 5 metric tonnes
Daily price fluctuation limit	Price moves automatically without any limit after 15 minutes of cooling period
Delivery method	Either on Warehouse Delivery or FOB terms at the port of loading in the country
Delivery period	Earlier than tenth business day of delivery month
Delivery unit	20,000 kg

Source: Singapore Commodity Exchange (2014).

This exchange market is recognized as the discovery center for the world price of natural rubber, which means that they will be the ones who set the pricing standard for the rubber industry as a whole. So, its rubber futures contracts are traded in the United States Dollars (USD) for convenience. Additionally, SICOM's system will be slowed down by 15 minutes if the price changes 10 per cent above or below the previous day's settlement price. After the cooling off period, the contract price will be resumed automatically without any limit.

Tokyo Commodities Exchange (TOCOM)

TOCOM started its rubber futures contract on December 12, 1952. This exchange has changed its trading method of rubber futures from the floor-based “Itayose Trading” to computerized individual auction trading system. This trading system has been effective since the advent of 2005 up till today. Computerized individual auction is basically done by matching each order separately to an exercise price using the principles of individual auction. The contract specification of RSS3 in TOCOM is stated in Table 1.5. For the daily price fluctuation limit, TOCOM’s system will be triggered at the start of clearing period.

Table 1.5: Contract specification of RSS3 in TOCOM

Contract duration	6 consecutive months
Currency	Japanese Yen (¥)
Contract Size	5,000 Kilogram or 5 metric tonnes
Daily price fluctuation limit	Based on the settlement price of previous clearing period
Delivery method	Warehouses located either in Tokyo, Kanagawa, Chiba, Ibaragi or Aichi
Delivery period	until the last day of each month
Delivery unit	5,000 kg

Source: Tokyo Commodities Exchange (2014).

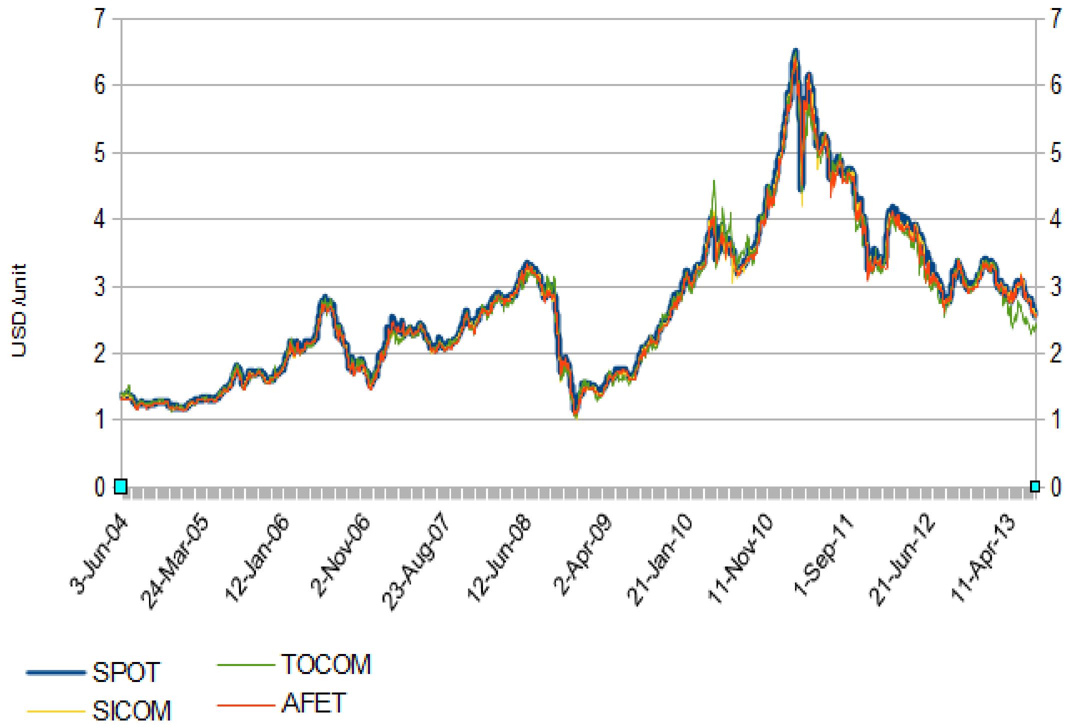
Figure 1.5 shows past performance of rubber spot prices and the three futures prices from May 28, 2004 to December 31, 2013. The rubber spot and futures prices are affected by demand-supply forces in the market. It was experiencing an upward trend since 2004 until it reached a peak early in 2011. Subsequently, the prices fall until 2013.

The price of natural rubber rose from USD 1.37 on May 28, 2004 to USD 3.32 on June 17, 2008. The natural rubber prices started to change direction to show a sharp drop until around USD 1.43 before it continued its' rising trend to the peak. This is largely due to the global financial crisis hit the world during 2008-2009. This crisis badly affected all major economic sectors. At the end of 2008, spot price is achieved at minimum level with USD 1.12. The minimum prices of rubber futures are also close to the spot minimum value, which are USD 1.09, USD 1.02 and USD1.05 for AFET, SICOM and TOCOM correspondingly.

The rubber prices reached a peak on February 21, 2011 at the value of USD 6.5 because its yield is very low during that particular year. It was reported that rubber production in Yunan, China slowed down due to a draught since the year before. Meanwhile, Thailand and Indonesia were drenched in seasonal rains that hindered the tapping process (Global Sources, 2011) and then regressed into a dropping trend with the value of USD 2.54. This reflects the outcome of measures taken to address the rubber yield shortage in 2011.

AFET, SICOM and TOCOM rubber futures prices began at the value of USD 1.35, USD 1.36, and USD 1.42 respectively. The respective peaks are achieved at USD 6.42, USD 6.45 and USD 6.48 for AFET, SICOM and TOCOM correspondingly. At the end of the sample, AFET left off at the value of USD 2.51, while SICOM and TOCOM dropped to USD 2.49 and USD 2.66 respectively.

Figure 1.5: The volatility of spot and futures prices among AFET, SICOM and TOCOM, May 28, 2004-December 31, 2013



Source: Thomson DataStream (2013).

1.2 Problem Statement

In accordance with study of Li and Jefferson (2012), Southeast Asia accounts for 97 per cent of the world's natural rubber supply, extensively from Thailand, Indonesia and Malaysia with 31 per cent, 30 per cent, and 9 per cent respectively. According to Thailand's Agriculture Minister Yukol Limlaemthong (2013), there are about 3.7–3.8 million tonnes of rubber produced annually, yet 3.2 million tonnes was exported.[6]

Meanwhile, China is a major producer in tires and gloves. It remains as the rubber factory of the world as the country converts excessive rubber for its own domestic consumption and exports. Thus, it accounts for about 35 per cent of the global demand for natural rubber that mainly used to produce tires[7].

The increasing and decreasing trend for demand and supply of natural rubber respectively leads to the issue of inequilibrium in natural rubber. Thailand, Indonesia, Malaysia, India, Vietnam, China and Sri Lanka make up the seven top natural rubber producing countries. They faced a production shortage of 5.1 per cent for the year ended September 2009 against the previous year (Punnathara, 2009). This has caused the global industry to look for an alternative for the commodity. On the other hand, Natural rubber is a highly demanded commodity with worldwide consumption rising at an average rate of 5.8 per cent per year since 1990 (Rubber Board, 2005).[8]

There are three reasons for the problem of disparity in demand and supply for natural rubber. Firstly, the falling price of rubber has caused rubber farmers to have protested in the south of Thailand in September 2013, who demand the

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[6] The Government Public Relations Department. (September 2, 2013). Government seeking solutions to the rubber price problem. Retrieved on March 14, 2014.

[7] Global Rubber Market. (September 15, 2013). News: IRSG cuts rubber demand growth outlook. Retrieved on March 9, 2014.

[8] Rubber Board. (2005). Rubber growers companion. Government of India, Kottayam, Kerala, India. 115.

government to subsidize prices to ease the hardship of rubber planters[9]. Besides, dealers have also refused to buy and stock rubber from farmers as a result of consistency of falling prices. This has forced many rubber farmers to end their rubber plantation, and caused the future supply of rubber to be even scarcer. In addition, rubber production has dropped about 10-20 per cent in beginning of 2013, which was from 300,000-350,000 tonnes per month (Global Rubber Market News, 2014). The anti-government protest has harmed Thailand's 14 southern regions that accounted to around 80 per cent of its output and led to an explosion in the rubber futures prices.

Secondly, the price of natural rubber is regularly linked with oil prices. As oil price is fluctuating over the past few decades, it will also affect the price of natural rubber. Increase in oil price will lead to increase in cost of producing petroleum-based synthetic rubber.[10] Thus, rubber producers will switch demand to natural rubber as a cheaper alternative, which further boosts up the price of natural rubber. Thirdly, substantial increase of rubber inventories by China warehouses in Qingdao has weakened the prices at major rubber futures markets. Huge stockpiles are found to be well above its support levels of 2.5 million tonnes, causing significance dropped of imports to China (Krishnan, 2013).

The mismatch of demand-supply is very serious. Overall, the consumption of natural rubber is predicted to increase from 9.6 million tonnes in 2008 to 13.8 million tonnes in 2018 with a growth of 3.7 per cent per year (Prachaya, 2009). While supply is expected to stagnant at around 8.5-9 million tonnes, the demand-supply mismatch is anticipated to widen up to 4-5 million tonnes during the period of 2014-2015, said by Mr N. Radhakrishnan, former President of the Cochin Rubber Merchants Association. This has contributed to an increase in price and causes the volatility of natural rubber to become more critical.

[9] Global Rubber Market. (January 23, 2014). News: Rubber output in Thailand seen lower as growers join protest. Retrieved on March 9, 2014.

[10] Facts and Details. (n.d.). Rubber, palm oil and the rainforest. Retrieved on March 10, 2014.

1.3 Research Questions

The demand-supply mismatch has caused higher price volatility of natural rubber and thus futures are used to hedge against the price risk. However, due to the existence of basis risk, futures are still unable to eliminate all the price risk. Hence, two research questions are developed in this study:

1. Which hedging strategy provides the highest risk reduction in Thailand rubber spot market?

2. Which futures contract among Agricultural Futures Exchange of Thailand (AFET), Singapore Commodity Exchange Market (SICOM) and Tokyo Exchange Commodity Market (TOCOM) will provides the best hedging effectiveness in trading Thailand rubber?

1.4 Objectives of study

The main objective of this study is to determine the hedging effectiveness of AFET, SICOM and TOCOM futures contracts for rubber across various hedging strategies which consist of time-variant and time-invariant models. In order to achieve our main objective, this study has come up with two specific objectives.

Firstly, we intend to determine which hedging strategy provides the highest variance reduction in the Thailand rubber spot market. This can be done by comparing between time invariant and time variant models as AFET, SICOM and TOCOM futures contracts have different contract specifications.

Secondly, we intend to determine which futures contract can provide the most effective hedge ratio in reducing risk in the Thailand spot market.

1.5. Significance of study

The results of this study are expected to provide contributions to two groups of perspectives. Academia, in terms of hedging strategies while hedgers in terms of which futures contract has the highest hedging effectiveness respectively.

1.5.1 Academia

Past studies on rubber futures are very limited. Most of the researchers focus on hedging effectiveness of commodity market using time varying models, such as Chng; Chang, Khamkaew, McAleer, and Tansuchat; Meng and Liang (2009; 2011; 2013). However, they excluded the effect of basis risk in examining the performance hedging effectiveness. The symmetric and asymmetric effect of basis has been proven as an important variable by recent researcher in studying hedging effectiveness using other commodities. This study will provide advanced methodology in rubber research.

1.5.2 Hedgers

As the owners of rubber in spot market, hedgers wish to enter futures market and short rubber futures contract with the goal of minimizing price risk or unexpected losses. In order to accomplish their goals, their main concern is the performance of futures markets. Therefore, the results of this study provide information to them since our specific objective is to determine which futures contract able to produce the highest effectiveness.

1.6 Outlay of study

The remainder of the study is organized as follows. Chapter 2 discusses the existing literature about hedging effectiveness of commodity futures contract through various strategies. Chapter 3 describes the preliminary analysis of data and methodology used in the study. The subsequent chapter explains and interprets the empirical results for both in-sample and out-of-sample analysis. The final chapter emphasizes on major findings, recommendations, and implications of this study.

CHAPTER 2: LITERATURE REVIEW

In the early stages, Johnson (1960) and Stein (1961) stimulated the field of study of the minimum variance approach in physical commodities. The most classic and simplest time-invariant approach is naïve one-to-one, but Carbonez, Nguyen and Sercu (2011) employed a semi-naïve approach that considered transaction costs in their study on the effectiveness of two futures contracts in hedging agricultural commodities. Despite that, real world traders still prefer the naïve one-to-one approach for its simplicity and low transaction costs. The naïve one-to-one approach provides a hedge ratio of one because it is assumed that each spot contract can be offset by exactly one futures contract. This hedging strategy seems perfect when spot and futures prices are moving in a parallel motion.

However, the assumption of the naïve one-to-one approach is impractical to be applied due to the presence of transaction costs, margin requirements, and liquidity differences, which may cause futures and spot prices to behave differently. Furthermore, the prices of spot and futures may not always move in same direction and ignore the basis risk. By assuming that zero basis risk, this implies that covariance between spot and futures returns equal to the variance of futures returns over time. Thus, the optimal hedge ratio is assumed to be one over time. The variance of hedged portfolio will be identical regardless of spot and futures price movements.

On the other hand, the hedge ratio estimated by Ordinary least squares (OLS) from the simple linear regression can be used to build up the relationship between the spot and futures prices to solve the problem of Naïve approach. This method was first applied in a study by Ederington (1979). The OLS model is simple because it only considers the ability of the hedging strategy to minimize risk by excluding the existing expected return. The OLS approach provides its hedging effectiveness in the form of its R-squared. OLS has been criticized for not considering time-varying distributions, serial correlation, heteroskedasticity and cointegration in financial data. These drawbacks results in an inefficient OLS estimator (Srinivasan, 2011 and Chang, Lai & Chuang, 2010). One of the major problems in using OLS method was first raised by Myers (2000) who criticized the presumed static hedging ratio. This static hedging ratio ignores other conditional information which might help hedgers in making a decision to hedge (Myers & Thompson, 1989).

As the commodity price is frequently fluctuating over different economic conditions, the conditional covariance between spot and futures prices are also changing substantially over time. Cecchetti, Cumby and Figleeski (1988) found that there are substantial fluctuations in the optimal hedge ratio through time when using the autoregressive conditional heteroskedastic (ARCH) model which was modeled by Engle (1982). Then, Bollerslev (1986) introduced generalized ARCH (GARCH) models by overcoming the limitations in ARCH through restriction of non-negativity constraint and the principle of parsimony.

GARCH model has been successful in capturing the heteroskedasticity and the clustering of volatility in financial variables. Choudhry (2004) suggested that a bivariate GARCH model is potentially superior to the static hedge ratio. There are plenty of researches on agricultural futures market using the framework of univariate GARCH specification in the past existing literature, but the framework of multivariate GARCH models are what this field of research lacks. (Chang, Khamhaew, McAleer & Tansuchat, 2011).

The employment of the multivariate GARCH framework in studying hedging performance has led to more relevant empirical research. For instance, Baillie and Myers (1991) who used multivariate GARCH model have documented superior hedging effectiveness in six different commodities, which includes beef, coffee, cotton, gold, and soybean. Their findings indicate that the estimated optimal hedge ratios are restrained to be time varying. It also identifies that GARCH models provide good descriptions for distribution of changes in the commodities' prices. They concluded that GARCH-based hedge ratios provide higher hedging effectiveness than the static hedge ratios for both in-sample and out-of-sample.

However, the curse of dimensionality is often held in GARCH model. The number of parameters increases proportionately to the number of dimensions. Besides that, the positive definiteness assumption of GARCH model is difficult to achieve. In order to solve these problems, Engle and Kroner (1995) proposed Baba-Engle-Kraft-Kroner (BEKK) model which comes under the GARCH family. This model guarantees that there is positive definiteness in the conditional variance and the covariance equation. This model requires only nine parameters in the conditional variance and covariance structure (Kumar & Lagesh, 2011).

In addition, Bollerslev (1990) introduced the Constant Conditional Correlation (CCC) GARCH model. This model differentiates itself with positive semi-definiteness of conditional variance covariance matrix and lesser number of parameters. It assumes constant conditional correlation in the determination of the hedging performance of commodities (Lien, Tse & Tsui, 2002; Kumar & Lagesh, 2011 and Chang et. al., 2010). For instance, Ahmed (2007) employed a time varying hedge ratio using CCC-GARCH in the US Treasury Market and his result shows a clear advantage in minimizing variance of portfolio returns. In the study of Chang et. al. (2010), the BEKK-GARCH model provides higher hedging effectiveness than conventional method for crude oil commodity. The improvement of hedging performance is noticeable when CCC-GARCH was compared against BEKK-GARCH for in-sample but not so for the out-of-sample analysis in the crude oil and gasoline markets.

The spread on the movement of spot and futures prices has been ignored in the earlier studies. This spread is known as a basis. The basis at the expiration of a hedge is risk to hedgers, and is often called as basis risk. The study of basis and its effect in hedging effectiveness is documented in recent literatures. Earlier studies on hedging effectiveness emphasized the importance of incorporating the element of basis into hedging decision making (Working, 1953a, b, 1961), assuming the basis effects are symmetrical. Similarly, Lien (1996) found that hedge ratios and hedging performance may experience extreme changes when cointegration of spot and futures prices is mistakenly omitted from the statistical model. Long-run equilibrium relationship does exist when spot and futures prices are cointegrated, often resulting in higher hedge ratios (Lien, 2004).

The basis effect has been widely emphasized in the models through estimation of the minimum variance hedge ratio (Kroner & Sultan, 1993; Lien, 1996; Lien & Tse, 1999 and Lien, Tse & Tsui, 2002). Recent researches, such as the one by Lau and Bilgin (2013) incorporated the basis effect with structural breaks and spillover effects in examining hedging performance of China aluminum futures market. The findings demonstrate that GARCH model with symmetric basis effect turned out to be the best model for in-sample and out-of-sample analysis.

There are some studies have found that the effect of basis should be asymmetrical instead of symmetrical. Positive and negative basis effect is not indifferent, because different basis signs generate different effects on the risk structures of spot and futures prices. For instance in the early literature, Brooks, Henry and Prsand (2002) estimated variance reduction for FTSE 100 index and FTSE 100 futures. There was an improvement in forecasting accuracy found during the in-sample evaluation but not for out-of-sample evaluation when estimated with asymmetric models in their study.

Lien and Yang (2006) extended the study of asymmetric basis effect to currency market from 1990 to 2004. Their study demonstrates that the effect of positive and negative base lead to an improved dynamic hedging strategy, where higher risk reduction is more evident in asymmetric basis as compared to the symmetric basis. Later on, Lien and Yang (2008) furthered the study of asymmetric basis effect to the commodity market (Chicago Board Of Trade corn, and soybeans contracts, New York Board Of Trade cotton, and coffee contracts, Chicago Merchantile Exchange frozen pork bellies, lean hog contracts, New York Merchantile Exchange heating oil, light sweet crude oil, copper, and silver contracts) during 1980-1999 and found positive basis effect is greater than negative basis effect. The hedging strategy modeled with symmetric basis term will create over-hedged position when basis decrease, and under-hedged position when basis increase. This concludes that treating basis asymmetrically is crucial in determining optimal hedging strategies for the commodity market.

There is one prior literature done on the relationship and volatility spillover between the rubber spot and futures returns (Chang, Khamkaew, McAleer &

Tansuchat, 2011 and Wiyada & Aekkachai, 2010). However, hedging effectiveness in the rubber market has not been studied specifically. Thus, we aim to fill up this literature gap to provide a better understanding regarding risk management tools in framing better hedging strategies and solutions.

Chapter 3: Data and Methodology

3.0 Overview

We explain data description of daily spot and futures prices. In second section, we estimate time invariant and time variant models such as naïve, Ordinary Least Squares (OLS), Baba-Engle-Kraft-Kroner (BEKK)-GARCH and Constant Conditional Correlation (CCC)-GARCH for in-sample and out-of-sample analysis.

3.1 Data description

We use Thailand's RSS3 rubber as the spot market and three futures contracts namely AFET, SICOM and TOCOM in our study. Based on Table 3.1, daily spot price (SP) and futures price (FP) are collected from Thomson DataStream and expressed in United States Dollar (USD).

Table 3.1: Description on Variables

Variable name	Symbol
Spot price	SP
Futures price	FP
Spot return	S
Futures return	F

Source: Thomson DataStream (2014).

The sample period of the data starts from May 28, 2004 to December 31, 2013 consisting of 2503 observations. Our analysis involved in-sample and out-of-sample, which takes 80 per cent of the entire sample period from May 28, 2004 to January 30, 2012 and remaining 20 per cent of period from January 31, 2012. As daily prices are non-stationary, it is transformed into return through natural logarithm thus obtaining stationary return. Specifically, the formula of daily return is stated as follows:

$$S_t = \frac{\ln P_t}{\ln P_{t-1}} \tag{1}$$

This is further confirmed after augmented Dickey-Fuller and Phillips-Perron unit root tests are implemented to check for the existence of a unit root in spot and futures returns series respectively. Both tests are important to avoid spurious regressions when the series are non-stationary. We tabulate the results of ADF and PP tests into Table 3.2. The results show that the null hypothesis of unit root in spot and futures returns is rejected at 1 per cent significance level. This indicates that all returns are stationary, implying that return does not have integrated order.

Table 3.2: Unit root test results for spot and futures returns

Returns	ADF		PP	
	Constant	**Constant with Trend**	**Constant**	**Constant with Trend**
Entire period				
Spot	-25.09*	-25.11*	-38.44*	-38.42*
AFET	-30.84*	-30.85*	-45.52*	-45.44*
SICOM	-30.03*	-30.04*	-44.79*	-44.78*
TOCOM	-49.74*	-49.74*	-49.99*	-49.98*
In-sample				
Spot	-22.06*	-22.05*	-33.77*	-33.77*
AFET	-26.79*	-26.78*	-39.95*	-39.94*
SICOM	-26.45*	-26.44*	-39.19*	-39.18*
TOCOM	-44.32*	-44.31*	-44.55*	-44.54*
Out-of-sample				
Spot	-17.21*	-17.22*	-17.18*	-17.19*
AFET	-22.45*	-22.44*	-22.46*	-22.45*
SICOM	-21.44*	-21.43*	-21.46*	-21.45*
TOCOM	-22.80*	-22.81*	-22.80*	-22.81*

Note: * is denoted as the null hypothesis of a unit root is rejected at 1 per cent significance level.

The descriptive statistics of natural rubber spot and futures returns series are summarized in Table 3.3. The purpose of the summary statistics is to capture the characteristic of spot and futures returns in terms of mean, standard deviation and unconditional distribution.

In Table 3.3, we can observe that daily returns of natural rubber in AFET, SICOM and TOCOM futures are 0.00054, 0.00053, and 0.00051 respectively for in-sample period. These are slightly higher than spot market with mean of 0.000539, except TOCOM market. TOCOM market is comparatively riskier than the other futures markets because of its higher standard deviation of 0.0224 as compared to AFET (0.0167) and SICOM (0.0171). However, it does not compensate with comparable return as it offers the least return against AFET and SICOM. Conversely, AFET market is more favorable among the futures markets because it gives higher daily return with lower standard deviation of 0.0167.

On the other hand, the daily returns of the spot and futures markets for out-of-sample period are obvious than in-sample period because of negative mean values. Furthermore, the futures markets are more volatile than spot market in comparing its standard deviation as shown in Table 3.3. The fluctuation of risk and return of TOCOM is contrast with the result of in-sample analysis. It offers the highest return but also comes with highest risk. This is consistent with general view of riskier asset should compensate with higher return.

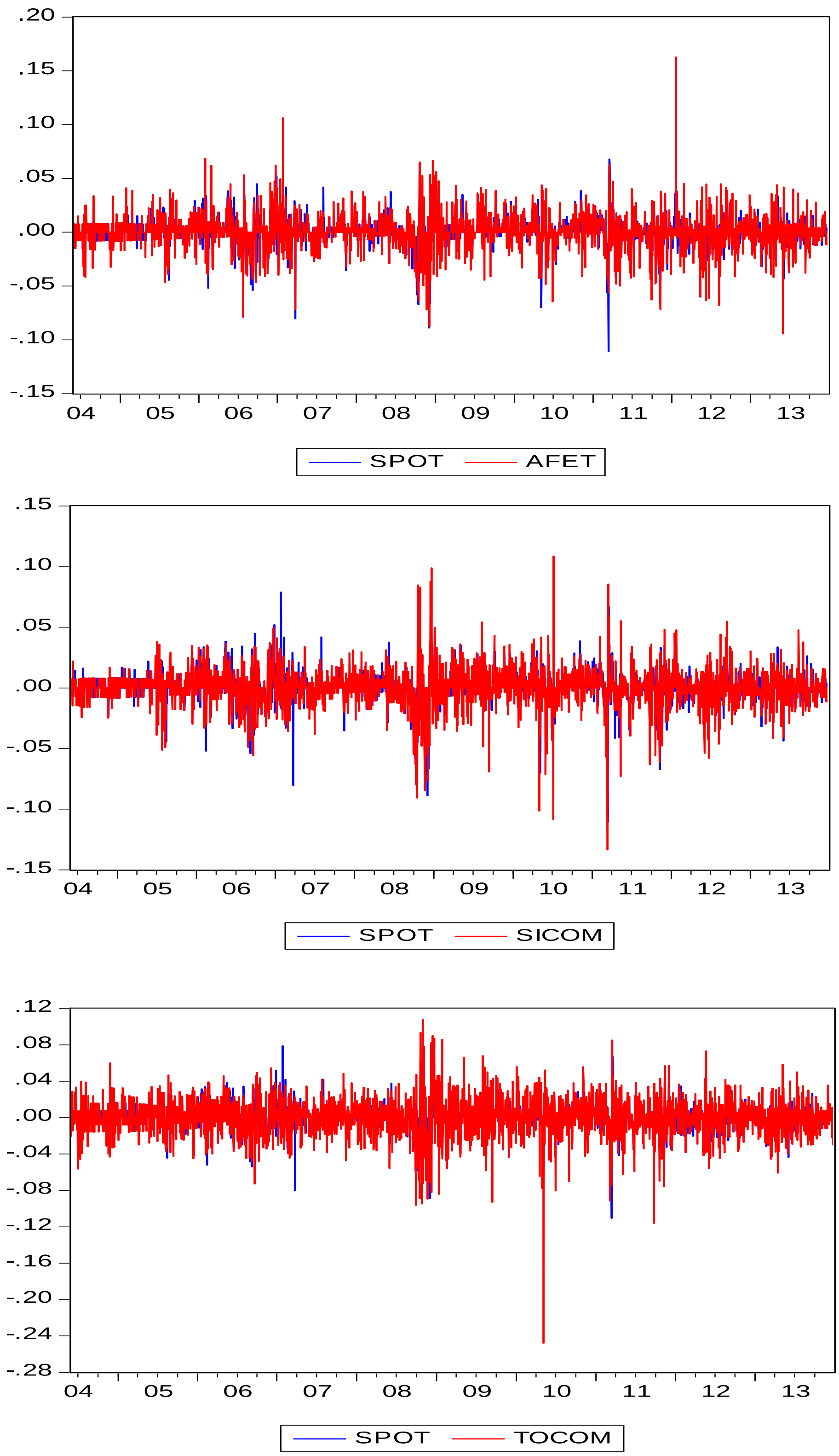
The Jarque-Bera test is employed to check whether return series is normally distributed. As a result, the null hypothesis of normality distribution for return is rejected at 1 per cent significant level. This result indicates that the distributions of these series are not normal. More specifically, we find that all return series have leptokurtic distribution as they have excess kurtosis (more than three) for both in-sample and out-of-sample. Referring to Figure 3.1, the data exhibits clustering volatility and leverage effect. These imply that Autoregressive Conditional Heteroscedasticity (ARCH) effect and General Autoregressive Conditional Heteroscedasticity (GARCH) effect occur in the daily return data.

Table 3.3: Descriptive statistic for spot and futures returns

	Entire sample				In-sample				Out-of-sample			
	Spot	**Futures**			**Spot**	**Futures**			**Spot**	**Futures**		
		AFET	**SICOM**	**TOCOM**		**AFET**	**SICOM**	**TOCOM**		**AFET**	**SICOM**	**TOCOM**
Mean	0.000247	0.000248	0.000242	0.000251	0.000539	0.00054	0.00053	0.00051	-0.00094	-0.00095	-0.000963	-0.000791
SD	0.0123	0.0166	0.0165	0.021	0.0129	0.0167	0.0171	0.0224	0.00937	0.0161	0.0135	0.0172
Skew-ness	-0.9501	0.024	-0.5468	-0.92	-1.0520	0.1809	-0.6133	-1.0268	-0.07135	-0.6911	-0.1217	0.0045
Kurtosis	12.8955	10.47	10.66720	12.36	13.0557	11.1478	10.9525	12.7303	4.43970	7.1401	5.3418	4.1566
Jarque-Bera	10584.61	5822.34	6253.13	9493.25	8799.69	5545.84	5398.27	8245.38	43.6059	396.88	115.48	27.87

Note: SD denotes as standard deviation of particular return. AFET is Agricultural Futures Exchange of Thailand. SICOM is Singapore Commodity Exchange. TOCOM is Tokyo Commodity Exchange.

Figure 3.1: Spot and AFET, SICOM as well as TOCOM futures returns from 2004 to 2013



3.2 Methodology

For this section, we use a four-step approach to obtain our result in order to achieve our research objectives. First, we obtain variance and covariance of spot and futures returns by using various hedging strategies. The hedging strategies will be described in section 3.2.1. Subsequently, we calculate optimal hedging ratio (OHR), variance of portfolio and hedging effectiveness respectively. This will be explained in section 3.2.2- 3.2.4. For the last section, we describe the log likelihood function which is used to identify the estimation of GARCH models through maximum likelihood.

3.2.1 Hedging strategies

We employ ten hedging strategies in this study where two hedging strategies are under time invariant models and the remaining is under time variant models. For time invariant models, we employ naïve one to one hedge ratio and ordinary least squares (OLS) to estimate optimal hedge ratio (OHR) and hedging effectiveness. On the other hand, we also employ Baba-Engle-Kraft-Kroner (BEKK)-GARCH and constant conditional correlation (CCC)-GARCH settings for time variant models. Hence, the hedging strategies are allocated in following section of this chapter.

Time invariant models

Naïve one to one hedge ratio and ordinary least squares are used to estimate optimal hedge ratio and hedging effectiveness. These models are being used due to simple computation. However, the assumptions of these models are ignored time-varying distributions, serial correlation, heteroscedasticity and cointegration in the series.

(i) Naïve one to one hedge ratio

Naïve hedging strategy is a traditional approach to hedge price risk. It implies that an equal amount of futures position is undertaken for given one unit of spot position. By using this model, the optimal hedge ratio is always equal to one. The equation is expressed as follows:

$$S_t = \alpha + \beta F_t + \varepsilon \qquad (2)$$

where,

S	:	Spot return
F	:	Futures return
α	:	Constant term
β	:	Parameter of futures return
ε	:	Disturbance term

(ii) Ordinary least squares (OLS)

Ordinary least squares (OLS) is a simple linear regression of spot return on futures returns. Its equation is expressed as follows:

$$S_t = c + h\,F_t + \varepsilon_t \;\; ; \varepsilon_t \sim \text{i.i.d. N } (0,\sigma^2) \qquad (3)$$

where,

S	:	Spot return
F	:	Futures return
c	:	Constant term
h	:	Optimal hedge ratio
ε	:	Disturbance term which follows independently distributed and identically (i.i.d)

Time variant models

Baba-Engle-Kraft-Kroner (BEKK)-GARCH and constant conditional correlation (CCC)-GARCH are employed to examine whether these models can provide higher optimal hedge ratio and hedging effectiveness than time-invariant models. The hedging strategies of each GARCH setting include model with constant term, model with vector autoregressive term, model with symmetric basis term and model with asymmetric basis term. Thus, each GARCH setting has provided us with three different mean equations and conditional variance-covariance equations.

(iii) BEKK-GARCH with constant term

BEKK-GARCH was proposed by Engle and Kroner (1995) to capture conditional heteroscedasticity and volatility clustering in the series. BEKK-GARCH with constant term is a model that only includes the intercept of spot and futures returns. Its mean equation and conditional variance-covariance equation are stated as follows:

Mean equation:

$$S_t = \alpha_s + \varepsilon_{st} ; \quad \mid \Omega_{t-1} \sim N(0, H_{St})$$
$$F_t = \alpha_f + \varepsilon_{ft} ; \quad \mid \Omega_{t-1} \sim N(0, H_{Ft}) \tag{4}$$

Conditional variance-covariance equation:

$$H_t = CC' + A\varepsilon_{t-1}\varepsilon'_{t-1}A' + BH_{t-1}B' \tag{5}$$

$$H_t = \begin{bmatrix} H_{SS} & H_{SF} \\ H_{FS} & H_{FF} \end{bmatrix}; \ C = \begin{bmatrix} C_{SS} & C_{SF} \\ 0 & C_{FF} \end{bmatrix}; \ A = \begin{bmatrix} A_{SS} & A_{SF} \\ A_{FS} & A_{FF} \end{bmatrix}; \ B = \begin{bmatrix} B_{SS} & B_{SF} \\ B_{FS} & B_{FF} \end{bmatrix};$$

and $\varepsilon_t = \begin{bmatrix} \varepsilon_{St} \\ \varepsilon_{Ft} \end{bmatrix}$.

$$h_{SS,t} = C_{SS,t} + A_{SS}\varepsilon^2{}_{S,t-1} + B_{SS}h_{SS,t-1}$$
$$h_{FF,t} = C_{FF,t} + A_{FF}\varepsilon^2{}_{F,t-1} + B_{FF}h_{FF,t-1}$$
$$h_{SF,t} = C_{SF,t} + A_{SF}\varepsilon_{S,t-1}\,\varepsilon_{F,t-1} + B_{SF}h_{SS,t-1}\,h_{FF,t-1} \quad (6)$$

where,

S	:	Spot return
F	:	Futures return
α	:	Constant term
ε	:	Disturbance term
Ω_{t-1}	:	Ω_{t-1} is the past information at *t-1*
H_t	:	Conditional covariance matrix at time *t*
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return

(iv) BEKK-GARCH with vector autoregressive term

BEKK-GARCH with vector autoregressive term is an extension of model with intercept by taking lags of spot and futures returns into account in the equations. This model is used to determine whether past information of spot and futures returns will affect hedging performance. The mean equation and conditional variance-covariance equation of the model are stated as follows:

Mean equation:

$$S_t = ß_0 + \sum_{i=1}^{p} \alpha S_{t-1} + \sum_{i=1}^{q} \Theta F_{t-1} + \varepsilon_{SS,t}$$
$$F_t = ß_1 + \sum_{i=1}^{p} ɧ S_{t-1} + \sum_{i=1}^{q} ȣ F_{t-1} + \varepsilon_{FF,t} \quad (7)$$

Conditional variance-covariance equation:

$$h_{SS,t} = C_{SS,t} + A_{SS}\varepsilon^2{}_{S,t-1} + B_{SS}h_{SS,t-1}$$

$$h_{FF,t} = C_{FF,t} + A_{FF}\varepsilon^2{}_{F,t-1} + B_{FF}h_{FF,t-1}$$
$$h_{SF,t} = C_{SF,t} + A_{SF}\varepsilon_{S,t-1}\,\varepsilon_{F,t-1} + B_{SF}h_{SS,t-1}\,h_{FF,t-1} \quad (8)$$

where,

S	:	Spot return
F	:	Futures return
ß	:	Constant term
α, ɧ	:	Parameter for lagged one of spot return
ϴ, ₶	:	Parameter for lagged one of futures return
p	:	Lag numbers of spot return
q	:	Lag numbers of futures return
Ε	:	Disturbance term
H_t	:	Conditional covariance matrix at time *t*
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return

(v) BEKK-GARCH with symmetric effect of basis term

BEKK-GARCH with symmetric basis effect consists of an intercept, lags of spot and futures returns and also basis term. By taking the basis term into equation, we can examine whether spot and futures return has a long run relationship with each other. However, the basis effect is assumed to be symmetrical in this model. Its mean equation and conditional variance-covariance equation are stated as follows:

Mean equation:

$$S_t = ß_1 + \sum_{i=1}^{p} \alpha S_{t-1} + \sum_{i=1}^{q} ϴ F_{t-1} + ɣ_{SS} Z_{t-1} + \varepsilon_{SS,t}$$
$$F_t = ß_1 + \sum_{i=1}^{p} ɧ S_{t-1} + \sum_{i=1}^{q} ₶ F_{t-1} + ɣ_{FF} Z_{t-1} + \varepsilon_{FF,t} \quad (9)$$

<u>Conditional variance-covariance equation</u>:

$$h_{SS,t} = C_{SS,t} + A_{SS}\varepsilon^2{}_{S,t-1} + B_{SS}h_{SS,t-1} + D_{SS}{Z_{t-1}}^2$$
$$h_{FF,t} = C_{FF,t} + A_{FF}\varepsilon^2{}_{F,t-1} + B_{FF}h_{FF,t-1} + D_{FF}{Z_{t-1}}^2$$
$$h_{SF,t} = C_{SF,t} + A_{SF}\varepsilon_{S,t-1}\,\varepsilon_{F,t-1} + B_{SF}h_{SS,t-1}\,h_{FF,t-1} + D_{SF}{Z_{t-1}}^2 \quad (10)$$

where,

S	:	Spot return
F	:	Futures return
ß	:	Constant term
α, ђ	:	Parameter for lagged one of spot return
ϴ, Ꝏ	:	Parameter for lagged one of futures return
p	:	Lag numbers of spot return
q	:	Lag numbers of futures return
ɣ	:	Parameter for lagged one of basis term
Z_{t-1}	:	Lagged one of basis term, obtained by $\ln(p_{S_t,t-1}) - \ln(p_{F_t,t-1})$
ε	:	Disturbance term
H_t	:	Conditional covariance matrix at time *t*
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return
D	:	Parameter for basis squared
${Z_{t-1}}^2$	:	Basis squared (symmetric effect of basis)

(vi) BEKK-GARCH with asymmetric effect of basis term

This model is used to determine whether positive and negative effect of basis will affect the hedging performance. The mean equation of this model is similar to BEKK-GARCH with symmetric basis effect. However, the effect of basis is separated into positive and negative in its conditional variance-covariance equation. The equations are stated as follows:

Mean equation:

$$S_t = ß_1 + \sum_{i=1}^{p} \alpha S_{t-1} + \sum_{i=1}^{q} \Theta F_{t-1} + ɣ_{SS} Z_{t-1} + \varepsilon_{SS,t}$$

$$F_t = ß_1 + \sum_{i=1}^{p} ɧ S_{t-1} + \sum_{i=1}^{q} ȹ F_{t-1} + ɣ_{FF} Z_{t-1} + \varepsilon_{FF,t} \qquad (11)$$

Conditional variance-covariance equation:

$$h_{SS,t} = C_{SS,t} + A_{SS}\varepsilon^2{}_{S,t-1} + B_{SS}h_{SS,t-1} + M_{SS}\max(Z_{t-1},0) + N_{SS}\min(Z_{t-1},0)$$

$$h_{FF,t} = C_{FF,t} + A_{FF}\varepsilon^2{}_{F,t-1} + B_{FF}h_{FF,t-1} + M_{FF}\max(Z_{t-1},0) + N_{FF}\min(Z_{t-1},0)$$

$$h_{SF,t} = C_{SF,t} + A_{SF}\varepsilon_{S,t-1}\,\varepsilon_{F,t-1} + B_{SF}h_{SS,t-1}\,h_{FF,t-1} + M_{SF}\max(Z_{t-1},0) + N_{SF}\min(Z_{t-1},0) \qquad (12)$$

where,

S	:	Spot return
F	:	Futures return
ß	:	Constant term
α, ɧ	:	Parameter for lagged one of spot return
ϴ, ȹ	:	Parameter for lagged one of futures return
p	:	Lag numbers of spot return
q	:	Lag numbers of futures return
ɣ	:	Parameter for lagged one of basis term
Z_{t-1}	:	Lagged one of basis term
Ε	:	Disturbance term
H_t	:	Conditional covariance matrix at time t
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return
M	:	Parameter for positive basis effect

N	:	Parameter for negative basis effect
$\max(Z_{t-1}, 0)$	:	Positive basis effect, where S > F at time t-1
$\min(Z_{t-1}, 0)$	:	Negative basis effect, where F > S at time t-1

(vii) CCC-GARCH with constant term

CCC-GARCH was proposed by Bollerslev (1990). This model takes standardized residuals of spot and futures returns (residuals relative to GARCH conditional standard deviation) into conditional correlation matrix (ρ). However, the conditional correlation is assumed to be constant over time in this model. CCC-GARCH with constant term is a standard model which only includes intercept. Its mean equation and conditional variance-covariance equation are expressed as follows:

Mean equation:

$$S_t = \alpha_s + \varepsilon_{st} \; ; \quad | \, \Omega_{t-1} \sim N(0, H_{St})$$

$$F_t = \alpha_f + \varepsilon_{ft} \; ; \quad | \, \Omega_{t-1} \sim N(0, H_{Ft}) \tag{13}$$

Conditional variance-covariance equation:

$$H_t = D_t R D_t \tag{14}$$

$$H_t = VAR(\varepsilon_{S,t}, \varepsilon_{F,t} \; | \phi_{t-1}) = \begin{bmatrix} h_{SS,t} & h_{SF,t} \\ h_{FS,t} & h_{FF,t} \end{bmatrix} =$$

$$\begin{bmatrix} \sqrt{h_{SS,t}} & 0 \\ 0 & \sqrt{h_{FF,t}} \end{bmatrix} \begin{bmatrix} \rho & 0 \\ 0 & \rho \end{bmatrix} \begin{bmatrix} \sqrt{h_{SS,t}} & 0 \\ 0 & \sqrt{h_{FF,t}} \end{bmatrix}$$

$$h_{SS,t} = \sigma_{SS} + \alpha_{SS} \varepsilon^2{}_{S,t-1} + ß_{SS} h_{SS,t-1}$$

$$h_{FF,t} = \sigma_{FF} + \alpha_{FF} \varepsilon^2{}_{F,t-1} + ß_{FF} h_{FF,t-1}$$

$$h_{SF,t} = \rho \sqrt{h_{SS,t} h_{FF,t}} \text{ , given } \rho = E_{t-1}(\eta_t \eta'_t) = D_t{}^{-1} H_t D_t{}^{-1} \text{ ,}$$

$$\eta_t = \frac{\varepsilon_t}{\sqrt{h_t}} \tag{15}$$

where,

S	:	Spot return
F	:	Futures return
α	:	Constant term
ε	:	Disturbance term
Ω_{t-1}	:	Ω_{t-1} is the past information at *t-1*
H_t	:	Conditional covariance matrix at time *t*
D_t	:	Diagonal $\left\{\sqrt{h_{i,t}}\right\}$
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return
ρ	:	Time invariant correlation matrix of standardized residuals for spot and futures returns

(viii) CCC-GARCH with vector autoregressive term

CCC-GARCH with vector autoregressive term is an extension of the model with intercept. It consists of intercept and lags of spot and futures returns. This model is used to determine whether past information of spot and futures returns will affect hedging performance by taking conditional correlation of spot and futures returns into consideration. The mean equation and conditional variance-covariance of the model are expressed as follows:

<u>Mean equation</u>:

$$S_t = \text{ß}_0 + \sum_{i=1}^{p} \alpha S_{t-1} + \sum_{i=1}^{q} \Theta F_{t-1} + \varepsilon_{SS,t}$$

$$F_t = \text{ß}_1 + \sum_{i=1}^{p} \text{ɧ} S_{t-1} + \sum_{i=1}^{q} \text{ɷ} F_{t-1} + \varepsilon_{FF,t} \qquad (16)$$

<u>Conditional variance-covariance equation</u>:

$$H_t = D_t R D_t \text{ ; } D_t \text{ is the diagonal } \left\{\sqrt{h_{i,t}}\right\} \qquad (17)$$

$$H_t = VAR(\varepsilon_{S,t}, \varepsilon_{F,t} \mid \phi_{t-1}) = \begin{bmatrix} h_{SS,t} & h_{SF,t} \\ h_{FS,t} & h_{FF,t} \end{bmatrix} =$$

$$\begin{bmatrix} \sqrt{h_{SS,t}} & 0 \\ 0 & \sqrt{h_{FF,t}} \end{bmatrix} \begin{bmatrix} \rho & 0 \\ 0 & \rho \end{bmatrix} \begin{bmatrix} \sqrt{h_{SS,t}} & 0 \\ 0 & \sqrt{h_{FF,t}} \end{bmatrix}$$

$$h_{SS,t} = \sigma_{SS} + \alpha_{SS}\varepsilon^2{}_{S,t-1} + ß_{SS}h_{SS,t-1}$$

$$h_{FF,t} = \sigma_{FF} + \alpha_{FF}\varepsilon^2{}_{F,t-1} + ß_{FF}h_{FF,t-1}$$

$$h_{SF,t} = \rho\sqrt{h_{SS,t}h_{FF,t}} \text{ , given } \rho = E_{t-1}(\eta_t \eta'_t) = D_t{}^{-1} H_t D_t{}^{-1} \text{ ,}$$

$$\eta_t = \frac{\varepsilon_t}{\sqrt{h_t}} \qquad (18)$$

where,

S	:	Spot return
F	:	Futures return
ß	:	Constant term
α, ɧ	:	Parameter for lagged one of spot return
ϴ, ȸ	:	Parameter for lagged one of futures return
p	:	Lag numbers of spot return
q	:	Lag numbers of futures return
ε	:	Disturbance term
H_t	:	Conditional covariance matrix at time t
$h_{SS,t}$	:	Conditional variance of spot return
D_t	:	Diagonal $\{\sqrt{h_{i,t}}\}$
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return
ρ	:	Time invariant correlation matrix of standardized residuals for spot and futures returns

(ix) CCC-GARCH with symmetric effect of basis term

CCC-GARCH with symmetric basis effect consists of intercept, lags of spot and futures returns and also basis term. The conditional correlation between spot and futures returns with basis effect is taken into consideration. However, the basis term is assumed to be symmetrical. Its mean equation and conditional variance-covariance equation are stated as follows:

Mean equation:

$$S_t = ß_1 + \sum_{i=1}^{p} \alpha S_{t-1} + \sum_{i=1}^{q} \Theta F_{t-1} + ɣ_{SS} Z_{t-1} + \varepsilon_{SS,t}$$

$$F_t = ß_1 + \sum_{i=1}^{p} ɧ S_{t-1} + \sum_{i=1}^{q} ɷ F_{t-1} + ɣ_{FF} Z_{t-1} + \varepsilon_{FF,t} \quad (19)$$

Conditional variance-covariance equation:

$$h_{SS,t} = \sigma_{SS} + \alpha_{SS} {\varepsilon^2}_{S,t-1} + ß_{SS} h_{SS,t-1} + D_{SS} {Z_{t-1}}^2$$

$$h_{FF,t} = \sigma_{FF} + \alpha_{FF} {\varepsilon^2}_{F,t-1} + ß_{FF} h_{FF,t-1} + D_{FF} {Z_{t-1}}^2$$

$$h_{SF,t} = \rho\sqrt{h_{SS,t} h_{FF,t}} \text{ , given } \rho = E_{t-1}(\eta_t {\eta'}_t) = {D_t}^{-1} H_t {D_t}^{-1} \text{ ,}$$

$$\eta_t = \frac{\varepsilon_t}{\sqrt{h_t}} \quad (20)$$

where,

S	:	Spot return
F	:	Futures return
ß	:	Constant term
α, ɧ	:	Parameter for lagged one of spot return
ϴ, ɷ	:	Parameter for lagged one of futures return
p	:	Lag numbers of spot return
q	:	Lag numbers of futures return
ɣ	:	Parameter for lagged one of basis term
Z_{t-1}	:	Lagged one of basis term, obtained by $\ln(p_{S_t,t-1}) - \ln(p_{F_t,t-1})$
ε	:	Disturbance term
H_t	:	Conditional covariance matrix at time *t*
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return

$h_{SF,t}$	:	Conditional covariance of futures return
D	:	Parameter for basis squared
${Z_{t-1}}^2$	:	Basis squared (symmetric effect of basis)
ρ	:	Time invariant correlation matrix of standardized residuals for spot and futures returns

(x) CCC-GARCH with asymmetric effect of basis term

CCC-GARCH with asymmetric basis effect used to determine whether positive and negative effect of basis will affect the hedging performance. The assumptions of this model do not only include conditional correlation between spot and futures returns, but also include the distinction between positive and negative basis effect in its conditional variance-covariance equation. The mean equation and conditional variance-covariance equation are stated as follows:

Mean equation:

$$S_t = ß_1 + \sum_{i=1}^{p} \alpha S_{t-1} + \sum_{i=1}^{q} \Theta F_{t-1} + \gamma_{SS} Z_{t-1} + \varepsilon_{SS,t}$$

$$F_t = ß_1 + \sum_{i=1}^{p} ɧ S_{t-1} + \sum_{i=1}^{q} \omega F_{t-1} + \gamma_{FF} Z_{t-1} + \varepsilon_{FF,t} \qquad (21)$$

Conditional variance-covariance equation:

$$h_{SS,t} = \sigma_{SS} + \alpha_{SS} {\varepsilon^2}_{S,t-1} + ß_{SS} h_{SS,t-1} + \xi_{SS} \max(Z_{t-1}, 0) + g_{SS} \min(Z_{t-1}, 0)$$

$$h_{FF,t} = \sigma_{FF} + \alpha_{FF} {\varepsilon^2}_{F,t-1} + ß_{FF} h_{FF,t-1} + \xi_{FF} \max(Z_{t-1}, 0) + g_{FF} \min(Z_{t-1}, 0)$$

$$h_{SF,t} = \rho\sqrt{h_{SS,t} h_{FF,t}} \text{ , given } \rho = E_{t-1}(\eta_t {\eta'}_t) = {D_t}^{-1} H_t {D_t}^{-1} ,$$

$$\eta_t = \frac{\varepsilon_t}{\sqrt{h_t}} \qquad (22)$$

where,

S	:	Spot return
F	:	Futures return
ß	:	Constant term
α, ɧ	:	Parameter for lagged one of spot return
ϴ, ꭥ	:	Parameter for lagged one of futures return
p	:	Lag numbers of spot return
q	:	Lag numbers of futures return
ɣ	:	Parameter for lagged one of basis term
Z_{t-1}	:	Lagged one of basis term
E	:	Disturbance term
H_t	:	Conditional covariance matrix at time *t*
$h_{SS,t}$	:	Conditional variance of spot return
$h_{FF,t}$	:	Conditional variance of futures return
$h_{SF,t}$	:	Conditional covariance of futures return
ξ	:	Parameter for positive basis effect
ȣ	:	Parameter for negative basis effect
$\max(Z_{t-1}, 0)$	:	Positive basis effect, where S > F at time t-1
$\min(Z_{t-1}, 0)$	:	Negative basis effect, where F > S at time t-1
ρ	:	Time invariant correlation matrix of standardized residuals for spot and futures returns

3.2.2 Optimal hedge ratio

Optimal hedge ratio is defined as the ratio of futures keeping to a spot position that minimizes the risk of a hedged portfolio. Its formula is written as follows:

$$h = \frac{\sigma_{s,f}}{\sigma_f^2} \tag{23}$$

where,

h	:	Optimal hedge ratio
$\sigma_{s,f}$	:	Covariance between spot and futures return
σ_f^2	:	Variance of futures return

3.2.3 Variance of portfolio

Variance of unhedged position indicates the risk of the contract without any hedging consideration. Whereas, variance of hedge position measures the risk of futures contract after hedged by using various hedging strategies. The formula of variance of unhedged and hedged portfolio is stated as follows:

$$Var_{unhedged} = \sigma_s^2 \tag{24}$$

$$Var_{hedged} = \sigma_s^2 + h^2\sigma_f^2 - 2h * \sigma_{s,f} \tag{25}$$

where,

$Var_{unhedged}$	:	Variance of unhedged portfolio
Var_{hedged}	:	Variance of hedged portfolio
σ_s^2	:	Variance of spot return
h	:	Optimal hedge ratio
σ_f^2	:	Variance of futures return
$\sigma_{s,f}$	:	Covariance between spot and futures return

3.2.4 Hedging effectiveness

Hedging effectiveness is used to determine risk in minimizing hedge ratio. It can be measured by the percentage reduction in variance of hedged portfolio with the variance of unhedged portfolio. Positive value of hedging effectiveness indicates higher variance reduction and vice versa for true through. The formula of hedging effectiveness is stated as follows:

$$HE = \frac{Var_{hedged} - Var_{unhedged}}{Var_{unhedged}} \tag{26}$$

where,

HE	:	Hedging effectiveness
$Var_{unhedged}$	:	Variance of unhedged portfolio
Var_{hedged}	:	Variance of hedged portfolio

3.2.5 Log likelihood

Maximum likelihood is used to generate the estimation of each GARCH setting by assuming the distribution is normal. The log likelihood function for the GARCH model is stated as follows:

$$\mathrm{L_n}(\theta) = -\frac{1}{2n}\sum_{t=1}^{n} \log\det\big(\mathrm{H_t}(\theta)\big) + \mathrm{y_t'}\ \mathrm{H_t^{-1}}\ \mathrm{y_t} = -\frac{1}{n}\sum_{t=1}^{n} \mathrm{l_t}(\theta) \tag{27}$$

where,

θ	:	True parameter vector
n	:	Number of sample observations
H_t	:	Covariance process where the starting values are fixed matrix, drawn from stationary distribution and assumed to be positive definite.

Chapter 4: RESULT INTERPRETATION

4.0 Overview

We present estimation results for Baba-Engle-Kraft-Kroner (BEKK)-GARCH and constant conditional correlation (CCC)-GARCH models, followed by the descriptive statistic of optimal hedge ratio hedging effectiveness of futures rubber markets namely AFET, SICOM and TOCOM for in-sample and out-of-sample analysis. The relationship of optimal hedge ratio and hedging effectiveness of rubber markets will be described in the last section.

4.1 Estimation results for BEKK-GARCH and CCC-GARCH models

Table 4.1 and Table 4.2 show the estimation results of BEKK-GARCH and CCC-GARCH respectively. Additionally, most of the coefficient parameters are significant at 1 per cent level of significance. This implies that all models consist of interactive effect and long run effects in this study.

Table 4.3 shows the Ljung-Box Q-test to check the presence of autocorrelation problem in the model. Q^2 is denoted as Ljung-Box statistics of standardized residual. When higher order of the Ljung-Box statistic is insignificant, it implies the model is homogeneous (Giannopoulos, 1995). The result shows all Q^2 are insignificant at 10 per cent significance level. This indicates our models do not consist of autocorrelation and heteroscedasticity problem. In this case, higher order of the ARCH process is not needed. Therefore, we employ first order of ARCH process in the GARCH models.

Table 4.1: Estimation spot and futures returns for BEKK-GARCH

	AFET				**SICOM**				**TOCOM**			
	Without Basis term		With Basis term		Without Basis term		With Basis term		Without Basis term		With Basis term	
	Intercept	VAR	Symmetric	Asymmetric	Intercept	VAR	Symmetric	Asymmetric	Intercept	VAR	Symmetric	Asymmetric
CC_{SS}	4.33E-06*	2.94E-06*	3.81E-06*	1.78E-06*	4.22E-06*	2.46E-06*	4.61E-06*	1.14E-06	4.13E-06*	3.32E-06*	3.89E-06*	2.92E-06*
	(4.37E-07)	(3.17E-07)	(4.75E-07)	(4.27E-07)	(4.31E-07)	(3.01E-07)	(5.60E-07)	(4.62E-07)	(4.02E-07)	(3.43E-07)	(4.36E-07)	(4.22E-07)
AA_{SS}	0.3197*	0.3163*	0.3395*	0.3261*	0.3334*	0.3360*	0.3221*	0.3312*	0.3421*	0.3602*	0.1313*	0.3697*
	(0.0086)	(0.0096)	(0.0110)	(0.010205)	(0.0078)	(0.0129)	(0.0179)	(0.0163)	(0.0097)	(0.0104)	(0.0087)	(0.0112)
BB_{SS}	0.9332*	0.9369*	0.9011*	0.9073*	0.9318*	0.9296*	0.7964*	0.7950*	0.9287*	0.9226*	0.8146*	0.9022*
	(0.0034)	(0.0034)	(0.0055)	(0.0048)	(0.0034)	(0.0050)	(0.0113)	(0.0116)	(0.0036)	(0.0040)	(0.0107)	(0.0057)
D_{SS}	-		0.0063*	-	-	-	0.0340*	-	-	-	0.0013*	-
			(0.0007)				(0.0031)				(0.0002)	
M_{SS}	-	-	-	0.0002*	-	-	-	0.0009*	-	-	-	7.54E-05*
				(2.99E-05)				(7.86E-05)				(1.73E-05)
N_{SS}	-	-	-	0.0432*	-	-	-	0.0782*	-	-	-	0.0037*
				(0.0070)				(0.0076)				(0.0006)
CC_{FF}	4.44E-06*	5.36E-06*	6.97E-06*	1.67E-06*	2.87E-06*	2.90E-06*	4.59E-06*	1.99E-06*	9.53E-06*	1.10E-05*	1.27E-05*	1.12E-05*
	(5.08E-07)	(6.18E-07)	(7.71E-07)	(6.25E-07)	(4.56E-07)	(4.67E-07)	(4.59E-06)	(6.88E-07)	(1.52E-06)	(1.67E-06)	(1.95E-06)	(1.86E-06)
AA_{FF}	0.1934*	0.2201*	0.2111*	0.1792*	0.2905*	0.308920*	0.3007*	0.2902*	0.2313*	0.2492*	0.0715*	0.236791*
	(0.0059)	(0.0084)	(0.0114)	(0.0115)	(0.0088)	(0.0103)	(0.0125)	(0.0117)	(0.0083)	(0.0106)	(0.0081)	(0.0134)
BB_{FF}	0.9728*	0.9656*	0.9438*	0.9502*	0.9534*	0.9491*	0.9334*	0.9356*	0.9616*	0.9558*	0.8896*	0.9472*
	(0.0011)	(0.0020)	(0.0030)	(0.0026)	(0.0022)	(0.0026)	(0.0036)	(0.0036)	(0.0034)	(0.0040)	(0.0108)	(0.0050)
D_{FF}	-	-	0.0161*	-	-	-	0.0120*	-	-	-	0.0026*	-
			(0.0013)				(0.0020)				(0.0005)	
M_{FF}	-	-	-	0.0007*	-	-	-	0.0004*	-	-	-	0.0001*
				(4.86E-05)				(8.60E-05)				(5.20E-05)
N_{FF}	-	-	-	0.0688*	-	-	-	0.0389*	-	-	-	0.012857*
				(0.0078)				(0.0064)				(0.0014)
CC_{SF}	2.56E-06*	2.28E-06*	2.93E-06*	1.58E-06*	7.18E-07*	7.87E-07*	2.05E-06*	6.54E-07	2.52E-06*	3.05E-06*	2.38E-06*	2.67E-06*
	(3.09E-07)	(2.78E-07)	(4.45E-07)	(4.92E-07)	(2.40E-07)	(1.99E-07)	(5.02E-07)	(5.15E-07)	(3.72E-07)	(4.03E-07)	(4.52E-07)	(6.03E-07)
AA_{SF}	-	0.0696*	0.0716*	0.0584*	-	0.1038*	0.0968*	0.0961*	-	0.0898*	0.0966*	0.0875*
		(8.15E-05)	(1.26E-04)	(1.17E-04)		(1.34E-04)	(2.25E-04)	(1.93E-04)		(1.11E-04)	(1.49E-04)	(1.50E-04)
BB_{SF}	-	0.9047*	0.8505*	0.8622*	-	0.97952*	0.7434*	0.7439*	-	0.8819*	0.8458*	0.8546*
		(7.03E-06)	(1.72E-05)	(1.28E-05)		(1.35E-05)	(4.16E-05)	(4.25E-05)		(1.16E-05)	(3.15E-05)	(2.92E-05)
D_{SF}	-	-	0.0058*	-	-	-	0.0126*	-	-	-	0.0008*	-
			(0.0009)				(0.0020)				(0.0001)	
M_{SF}	-	-	-	0.0002*	-	-	-	0.0003*	-	-	-	5.37E-05
				(3.64E-05)				(6.31E-05)				(2.49E-05)
N_{SF}	-	-	-	0.0156	-	-	-	0.0233*	-	-	-	0.0045*
				(0.0082)				(0.0055)				(0.0007)
L	15046.18	15450.95	15640.08	15654.07	15056.18	15761.93	16037.28	16051.28	14309.71	14729.31	14795.06	14818.13

Note: 1. * indicates statistical significance at 1 per cent level. 2. Number in parentheses represents standard error of parameter. 3. The value of L is log likelihood function calculated in equation (27). 4. BEKK-GARCH with intercept, vector autoregressive (VAR), symmetric and asymmetric basis effect models are estimated by the equations (6), (8), (10) and (12) respectively.

Table 4.2: Estimation spot and futures returns for CCC-GARCH

	AFET				SICOM				TOCOM			
	Without Basis term		With Basis term		Without Basis term		With Basis term		Without Basis term		With Basis term	
	Intercept	VAR	Symmetric	Asymmetric	Intercept	VAR	Symmetric	Asymmetric	Intercept	VAR	Symmetric	Asymmetric
σ_{SS}	5.04E-06*	3.31E-06*	5.23E-06*	1.88E-06*	4.88E-06*	3.42E-06*	4.83E-06*	1.27E-06*	4.90E-06*	3.77E-06*	6.75E-06*	5.48E-06*
	(4.81E-07)	(3.51E-07)	(5.92E-07)	(4.22E-07)	(4.64E-07)	(4.10E-07)	(5.84E-07)	(4.74E-07)	(4.70E-07)	(3.78E-07)	(6.73E-07)	(6.36E-07)
α_{SS}	0.1168*	0.1097*	0.1336*	0.1198*	0.1352*	0.1765*	0.1395*	0.1533*	0.1391*	0.1464*	0.1957*	0.1947*
	(0.0069)	(0.0070)	(0.0090)	(0.0074)	(0.0073)	(0.0111)	(0.0147)	(0.0137)	(0.0078)	(0.0090)	(0.0123)	(0.0120)
β_{SS}	0.8493*	0.8624*	0.7666*	0.8023*	0.8372*	0.7955*	0.5996*	0.5953*	0.8341*	0.8293*	0.7125*	0.7036*
	(0.0078)	(0.0075)	(0.0127)	(0.0099)	(0.0077)	(0.0116)	(0.0190)	(0.0178)	(0.0079)	(0.0089)	(0.0154)	(0.0157)
D_{SS}	-	-	0.0083*	-	-	-	0.0338*	-	-	-	0.0022*	-
			(0.0009)				(0.0032)				(0.0003)	
ξ_{SS}	-	-	-	0.0002*	-	-	-	0.0009*	-	-	-	0.0001*
				(2.94E-05)				(7.86E-05)				(2.55E-05)
ȣ$_{SS}$	-	-	-	0.0565*	-	-	-	0.0824*	-	-	-	0.0069*
				(0.0073)				(0.0079)				(0.0011)
σ_{FF}	4.06E-06*	4.38E-06*	7.53E-06*	1.49E-06*	3.31E-06*	3.52E-06*	4.14E-06*	1.97E-06*	1.20E-05*	1.28E-05*	1.49E-05*	1.35E-05*
	(4.69E-07)	(5.34E-07)	(8.46E-07)	(6.37E-07)	(5.36E-07)	(5.61E-07)	(6.53E-07)	(6.60E-07)	(1.99E-06)	(2.16E-06)	(2.42E-06)	(2.30E-06)
α_{FF}	0.0389*	0.0422*	0.0451*	0.0359*	0.1019*	0.1057*	0.0955*	0.0884*	0.0827*	0.0826*	0.0813*	0.0691*
	(0.0023)	(0.0032)	(0.0054)	(0.0047)	(0.0071)	(0.0074)	(0.0076)	(0.0069)	(0.0079)	(0.0084)	(0.0095)	(0.0096)
β_{FF}	0.9462*	0.9412*	0.8860*	0.8980*	0.8908*	0.8858*	0.8711*	0.8766*	0.8924*	0.8899*	0.8748*	0.8741*
	(0.0019)	(0.0035)	(0.0069)	(0.0056)	(0.0059)	(0.0064)	(0.0072)	(0.0073)	(0.0111)	(0.0118)	(0.0133)	(0.0136)
D_{FF}	-	-	0.0166*	-	-	-	0.0104*	-	-	-	0.0026*	-
			(0.0011)				(0.0020)				(0.0006)	
ξ_{FF}	-	-	-	0.0007*	-	-	-	0.0003*	-	-	-	0.0002*
				(4.63E-05)				(8.11E-05)				(6.38E-05)
ȣ$_{FF}$	-	-	-	0.0807*	-	-	-	0.0369*	-	-	-	0.0151*
				(0.0076)				(0.0063)				(0.0018)
ρ	0.4737*	0.4873*	0.5259*	0.5339*	0.3436*	0.3367*	0.3680*	0.3735*	0.3831*	0.4280*	0.4390*	0.4385*
	(0.0130)	(0.0129)	(0.0117)	(0.0121)	(0.0168)	(0.0167)	(0.0159)	(0.0161)	(0.0142)	(0.0135)	(0.0143)	(0.0149)
L	15069.81	15439.67	15633.98	15640.98	15145.11	15795.19	16044.10	16061.36	14341.21	14714.12	14778.64	14800.32

Note: 1. * indicates statistical significance at 1 per cent level. 2. Number in parentheses represents standard error of parameter. 3. The value of L is the log likelihood function calculated in equation (27). 4. CCC-GARCH with intercept, Vector autoregressive (VAR), symmetric and asymmetric basis effect models estimated by the equations (15), (18), (20) and (22) respectively.

Table 4.3 Ljung-Box Q-test for higher order ARCH effect

Q^2 (23)	AFET		SICOM		TOCOM	
	Spot Equation	Futures Equation	Spot Equation	Futures Equation	Spot Equation	Futures Equation
Intercept BEKK	10.55	7.31	9.98	36.26**	9.50	25.33
VAR BEKK	8.51	8.51	15.85	35.74**	12.69	23.62
Symmetric BEKK	11.69	24.15	29.01	33.07*	12.63	22.45
Asymmetric BEKK	12.55	21.55	26.20	33.48*	12.52	20.45
Intercept CCC	8.47	7.04	8.30	30.38	8.36	23.37
VAR CCC	7.78	9.95	16.76	33.62*	12.5*	22.78
Symmetric CCC	13.76	24.78	29.42	32.22*	6.25	18.35
Asymmetric CCC	12.51	21.39	28.64	31.80	15.03	20.11

Note: 1. $Q^2(23)$ denotes Ljung-Box statistics of standardized residual at 23 orders. 2. ***, ** and * indicates statistical significance at 1, 5 and 10 per cent level respectively. 3. BEKK-GARCH with intercept, vector autoregressive (VAR), symmetric and asymmetric basis effect models are estimated by the equations (6), (8), (10) and (12) respectively. 4. CCC-GARCH with intercept, Vector autoregressive (VAR), symmetric and asymmetric basis effect models estimated by the equations (15), (18), (20) and (22) respectively.

4.2 Descriptive statistic of optimal hedge ratio (OHR)

As observed in Table 4.4, we describe the descriptive statistics of OHR. The mean and standard deviation of OHR are used to compare among three futures markets for in-sample and out-of-sample analysis.

In-sample analysis

AFET has the highest mean and standard deviation of OHR as compared to SICOM and TOCOM. Its range for mean and standard deviation of OHR is 0.3120-0.4460 and 1.72E-14-0.2638 respectively. Based on Table 4.4, the standard deviation of conventional time invariant models is close to zero. Its value is significantly smaller than standard deviation of time varying OHR. The reason is conventional models are unable to capture information efficiently in time varying distribution.

Out-of-sample analysis

As shown in Table 4.4, AFET also attain highest mean and standard deviation of OHR among three futures markets for out-of-sample period with the range of 0.2579-0.3322 and 8.89E-16-0.0495 respectively. This indicates the hedgers in AFET need to acquire higher hedge ratio in order to obtain the optimal hedging performance. Besides, it also indicates that the dispersion from the mean of OHR is the greatest for AFET. While the highest standard deviation of OHR indicates more risk adjustment for the hedge ratio is required in AFET. This is because AFET is the local futures contract which is able to capture information in the Thailand spot market more efficiently than the other two future contracts.

The standard deviation of GARCH models is significantly greater than conventional models in out-of sample period. This implies hedgers can respond directly to latest information to the spot market because GARCH models are able to capture time-varying effect.

Table 4.4: Descriptive statistic of optimal hedge ratio (OHR)

	AFET		SICOM		TOCOM	
	In-sample	Out-of-sample	In-sample	Out-of-sample	In-sample	Out-of-sample
Naïve						
Mean	1	1	1	1	1	1
SD	N/A	N/A	N/A	N/A	N/A	N/A
OLS						
Mean	0.3965	0.2579	0.2834	0.2660	0.2085	0.2698
SD	1.72E-14	8.89E-16	9.77E-15	2.22E-15	1.92E-15	1.17E-15
Intercept BEKK						
Mean	0.3370	0.2998	0.2040	0.3106	0.1840	0.2904
SD	0.1586	0.1305	0.1502	0.1131	0.1227	0.0709
VAR BEKK						
Mean	0.3120	0.3070	0.1730	0.2663	0.192	0.2948
SD	0.1371	0.1041	0.1121	0.0995	0.1070	0.0758
Symmetric BEKK						
Mean	0.4460	0.306	0.3180	0.2687	0.301	0.2955
SD	0.2638	0.1218	0.2315	0.0896	0.2339	0.0878
Asymmetric BEKK						
Mean	0.3250	0.3115	0.1790	0.2676	0.1960	0.2923
SD	0.1201	0.1025	0.0793	0.0780	0.0878	0.0669
Intercept CCC						
Mean	0.3380	0.2796	0.2550	0.2842	0.1950	0.2801
SD	0.0909	0.0495	0.0717	0.0561	0.0674	0.0428
VAR CCC						
Mean	0.3040	0.2826	0.1910	0.2537	0.1940	0.2850
SD	0.0728	0.0486	0.0665	0.0533	0.0694	0.0450
Symmetric CCC						
Mean	0.3300	0.3322	0.1880	0.2703	0.1950	0.29239
SD	0.0725	0.6876	0.0570	0.0670	0.0603	0.0396
Asymmetric CCC						
Mean	0.3320	0.3060	0.1930	0.2666	0.1960	0.2953
SD	0.0809	0.0553	0.0612	0.0627	0.0635	0.0505

Note: SD denotes as standard deviation of OHR. The SD of Naïve hedge is not available (N/A) as the ratio remains unchanged over time. AFET: Agricultural Futures Exchange of Thailand. SICOM: Singapore Commodity Exchange Market. TOCOM: Tokyo Commodity Exchange market.

4.3 Hedging effectiveness

Based on Table 4.5 and Table 4.6, we compare the hedging effectiveness of AFET, SICOM and TOCOM within in-sample and out-of-sample period.

In-sample analysis

According to Zanotti, Gabbi and Geranio (2010), the hedging strategy that is able to provide higher hedging effectiveness is the best strategy. In this study, GARCH models obviously show a higher hedging effectiveness than OLS and naïve models. This implies that time variant models outperform time invariant models as they provide higher risk reduction. The best performance of hedging effectiveness is obtained from BEKK-GARCH strategy, while the worse performance is produced by the naïve hedging strategy.

The GARCH models with intercept are underperformed as compared to VAR-GARCH models. This indicates that past information will affect current spot and futures return. Furthermore, VAR-CCC and VAR-BEKK model are compared to investigate whether presence of conditional correlation will influence performance of hedging effectiveness. Referring to Table 4.5, our result shows the performance of hedging effectiveness for CCC-GARCH and BEKK-GARCH models is very close to each other. Although BEKK-GARCH models have higher hedging effectiveness than CCC-GARCH models, this does not imply that CCC-GARCH models are not important in spot and futures returns. This is because CCC-GARCH models play an important role in capturing conditional correlation between spot and futures returns.

We further examine GARCH models with and without basis effect for futures contracts by using BEKK-GARCH and CCC-GARCH models. Our results are consistent with the study of Lien (2004) and Lien and Yang (2007), which show that GARCH models with basis term are able to tolerate more risk reduction than those models without basis. However, this is only applicable to AFET and TOCOM but not

SICOM. Based on our result, VAR-CCC GARCH model in SICOM shows higher risk reduction than BEKK-GARCH with symmetric basis effect with a difference of 7.90 per cent. The difference of hedging effectiveness is small between basis and non-basis effect for SICOM. Majority of the futures contracts have better hedging performance after taking basis effect into account.

We compare GARCH model with symmetric and asymmetric basis effect to investigate the existence of asymmetric effect of positive and negative bases. Overall, GARCH model with asymmetric basis effect attained higher hedging effectiveness, except symmetric effect of basis in CCC-GARCH and BEKK-GARCH model for AFET and symmetric effect of basis BEKK-GARCH model for TOCOM.

An interesting result is found that symmetric effect of basis BEKK-GARCH model for AFET provides higher risk reduction of 56.56 per cent. Referring to Table 4.4, the highest standard deviation of OHR is found for AFET with the highest variance reduction. Greater standard deviation reflects more risk adjustment is made for market information, thus a higher risk reduction is achieved. However, there is insufficient evidence to refute the importance of asymmetric effect of basis in improving hedging performance. The effects of basis term should be distinguished to positive and negative bases on returns rather than treating it symmetrically. Higher hedging performance is achieved when asymmetrical effect of basis is further examined in the out-of-sample analysis. This includes asymmetric effect of basis in CCC-GARCH model to three futures markets, as well as this effect in BEKK-GARCH model for AFET and SICOM.

Out-of-sample analysis

Although the in-sample performance provides an indication of their historical performance, investors are more concerned on future performance. This implies that hedging performance of out-of-sample test shows more reliable measure of hedging effectiveness. The out-of-sample provides better forecasting results because it reflects the information available to the forecasters in practice.

After we compare the conventional approaches with GARCH models, we find that the results are consistent with the in-sample analysis. We take the effect of basis and conditional correlation of spot and futures returns into consideration in order to examine the performance of hedging effectiveness. The result from in-sample analysis does not provide clear indication in determining which model is more superior. Whereas the out-of sample analysis has an obvious result of which hedging strategies has higher hedging effectiveness among three futures market. This explains why imposing asymmetric effect of positive and negative bases into model can provide a better description on dynamic spot and futures returns.

As a summary, SICOM illustrates the optimum hedging performance against AFET and TOCOM. From Table 4.4, SICOM futures contract has the highest standard deviation of OHR using CCC-GARCH model with asymmetric basis effect. CCC-GARCH model with asymmetric effect of basis in SICOM shows the greatest risk reduction of 49.22 per cent. It is slightly greater than the variance reduction of BEKK-GARCH with asymmetric effect of basis with 48.71 per cent. This is consistent with our argument from in-sample analysis that considerable conditional correlation still exist even though the BEKK-GARCH model literally outshines the CCC-GARCH model. As observed from the contract specification of SICOM, it is the discovery center for world prices of natural rubber since it sets the rubber futures price for the industry. Therefore, it trades rubber futures in USD and this allows it to outperform the other two exchange markets.

Besides that, TOCOM performs poorly in variance reduction for both in-sample and out-of sample period, than the other two futures contracts. There is positive relationship between the price of crude oil and the demand of natural rubber. When the crude oil price decreases, producers substitute more synthetic rubber for natural rubber as crude oil is one of the raw materials to produce synthetic rubber. Changes in crude oil prices will affect the demand for synthetic rubber, thus influence the futures prices of natural rubber. Since TOCOM sets the price for tires grade among the main rubber producers in Thailand, Indonesia and Malaysia. The prices of TOCOM natural rubber futures contract exhibit high volatility due to the descending trend in crude oil prices (Commodity Online, 2013).[11] Given the characteristic of setting the price of tires grade causes TOCOM even harder to achieve higher risk reduction as compared to AFET and SICOM.

[11] Commodity Online. (November 6, 2013). TOCOM Rubber near one month low, India Rubber down amid higher imports. Retrieved on March 12, 2014.

Table 4.5: Hedging effectiveness of rubber market in Thailand for in-sample analysis

	AFET		SICOM		TOCOM	
	Variance Portfolio	Hedging Effectiveness (%)	Variance Portfolio	Hedging Effectiveness (%)	Variance Portfolio	Hedging Effectiveness (%)
Unhedged portfolio	0.00017		0.00017		0.00017	
Hedged portfolio						
Naive	0.00022	-34.63	0.00029	-76.40	0.00046	-174.78
OLS	0.00012	26.34	0.00014	14.18	0.00014	13.21
Intercept BEKK	1.21E-04	26.92	1.52E-04	8.39	1.49E-04	10.04
VAR BEKK	8.60E-05	48.19	8.13E-05	51.00	9.87E-05	40.49
Symmetric BEKK	7.21E-05	56.56	7.49E-05	54.88	8.27E-05	50.15
Asymmetric BEKK	8.19E-05	50.64	7.42E-05	55.27	9.10E-05	45.18
Intercept CCC	1.30E-04	21.44	1.56E-04	6.20	1.53E-04	7.66
VAR CCC	9.46E-05	42.97	8.79E-05	47.01	1.05E-04	36.50
Symmetric CCC	8.48E-05	48.93	8.84E-05	46.70	9.81E-05	40.87
Asymmetric CCC	8.53E-05	48.58	7.76E-05	53.23	9.60E-05	42.12

Note: The formula to calculate unhedged portfolio, hedge portfolio and hedging effectiveness are shown in Equation (24), (25) and (26) respectively.

AFET: Agricultural Futures Exchange of Thailand. SICOM: Singapore Commodity Exchange Market. TOCOM: Tokyo Commodity Exchange.

Table 4.6: Hedging effectiveness of rubber market in Thailand for out-of-sample analysis

	AFET		SICOM		TOCOM	
	Variance Portfolio	Hedging Effectiveness (%)	Variance Portfolio	Hedging Effectiveness (%)	Variance Portfolio	Hedging Effectiveness (%)
Unhedged portfolio	8.78E-05		8.78E-05		8.78E-05	
Hedged portfolio						
Naive	0.00021	-142.37	0.00017	-97.51	0.00022	-155.31
OLS	0.00025	-192.66	7.49E-05	14.75	6.63E-05	24.57
Intercept BEKK	6.55E-05	25.47	7.38E-05	16.01	6.55E-05	25.46
VAR BEKK	5.01E-05	42.94	4.55E-05	48.15	5.47E-05	37.78
Symmetric BEKK	4.88E-05	44.44	4.74E-05	46.06	5.31E-05	39.51
Asymmetric BEKK	4.75E-05	45.92	4.51E-05	48.71	5.51E-05	37.29
Intercept CCC	7.02E-05	20.03	7.57E-05	13.80	6.68E-05	23.95
VAR CCC	5.40E-05	38.54	4.79E-05	45.45	5.76E-05	34.39
Symmetric CCC	5.11E-05	41.85	4.67E-05	46.88	5.43E-05	38.24
Asymmetric CCC	4.76E-05	45.78	4.46E-05	49.22	5.38E-05	38.74

Note: The formula to calculate unhedged portfolio, hedge portfolio and hedging effectiveness are shown in Equation (24), (25) and (26) respectively.

AFET: Agricultural Futures Exchange of Thailand. SICOM: Singapore Commodity Exchange Market. TOCOM: Tokyo Commodity Exchange.

CHAPTER 5: CONCLUSION

5.1 Major findings

This study intends to determine the hedging effectiveness of three major rubber futures contracts namely AFET, SICOM and TOCOM using different hedging strategies which consist of time-variant and time-invariant models. We find that conditional correlation model does not always provide better hedging performance than the unconditional model. The BEKK-GARCH model provides higher variance reduction than CCC-GARCH model in all futures contracts. However, the difference of hedging effectiveness for CCC-GARCH and BEKK-GARCH are relatively minimal.

Besides that, our results also show that omission of basis effect tends to produce lower hedging effectiveness. Higher hedging effectiveness is obtained when the basis effect is being treated as symmetrical. Furthermore, if the basis effect is assumed to have an asymmetric effect, the hedging performance improves significantly.

In comparing across different hedging strategies, SICOM provides the highest variance reduction among the three futures contracts. This is because SICOM is traded in international currency whereas AFET and TOCOM are traded in their respective local currency. Thus, the use of international currency enables SICOM to adjust and react quickly to the price changes in the spot market. Moreover, one of the loading ports of SICOM is at Bangkok, Thailand. This makes SICOM hedging contract more favourable and convenient to Thailand rubber hedgers.

5.2 Policy implications

Our findings contribute implications to two groups of perspectives. The BEKK-GARCH slightly outperforms CCC-GARCH. This indicates there is no conclusive result of conditional correlation model is more superior to other unconditional correlation GARCH models. However, conditional correlation is still important to academia when modeling hedging strategies because it able to captures the movement between spot and futures returns.

Moreover, our findings imply that models with basis effect provide higher hedging effectiveness. This indicates that hedgers should consider the long run relationship between spot and futures returns when constructing the hedging strategy. Furthermore, distinguishing the effect of positive and negative basis plays a key role in determining optimal hedge strategies as it can provide higher variance reduction. Hence, users of futures contract should not omit the asymmetric effect in basis when constructing hedging strategies in order to obtain better hedging performance.

Empirical evidences show AFET displaying lower hedging performance against SICOM futures contract. This implies that local futures contract does not ensure better hedging effectiveness. We suggest hedgers to enter into SICOM futures because it is the most favorable contract to hedge Thailand's rubber spot market as this contract provides the highest hedging effectiveness as compared to other major futures. There are two main reasons why the SICOM futures contract is the most feasible to be traded. Firstly, SICOM futures contract is traded in international currency. Secondly, SICOM provides convenience in rubber loading at Singapore and Bangkok.

5.3 Recommendations

This study is able to accomplish the goals of academia and hedgers. Academia concern more on the method used in rubber research while hedgers tends to emphasis on the hedging performance of the three futures markets. SICOM is demonstrated to have the highest hedging effectiveness among three futures contracts. However, SICOM futures contract is not only used to hedge the rubber spot in Thailand, but also other spot markets such as Malaysia, Indonesia, India and Vietnam. Different hedging strategies will result in different hedging performance. We believe that studies on other major rubber producing countries are also essential. Therefore, future researchers can attempt to examine the hedging effectiveness of SICOM using different spot markets and time periods since we only examined on Thailand rubber spot market.

From our findings, we find that basis term is an important variable and needs to be considered in examining hedging performance. Additionally, our findings also show that optimal hedge ratio is higher when asymmetric basis effect is taken into consideration in the dynamic covariance of spot and futures returns. It would be in the interest of future researchers to expand the study on asymmetric effect whether the positive or negative signs of basis effect will have greater impact on hedging effectiveness. The study of different signs of asymmetric effect will continue to be an important issue to investors in obtaining the optimal hedging effectiveness of futures markets.

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